Australian Government
Australian Radiation Protection and Nuclear Safety Agency

SAFETY GUIDE

Use of Radiation in Schools

Part 1: Ionizing Radiation

Part 2: Lasers

RADIATION PROTECTION SERIES No. 18

Radiation Protection Series

The ***Radiation Protection Series*** is published by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) to promote practices which protect human health and the environment from the possible harmful effects of radiation. ARPANSA is assisted in this task by its Radiation Health and Safety Advisory Council, which reviews the publication program for the ***Series*** and endorses documents for publication, and by its Radiation Health Committee, which oversees the preparation of draft documents and recommends publication.

There are four categories of publication in the ***Series***:

Radiation Protection Standards set fundamental requirements for safety. They are regulatory in style and may be referenced by regulatory instruments in State, Territory or Commonwealth jurisdictions. They may contain key procedural requirements regarded as essential for best international practice in radiation protection, and fundamental quantitative requirements, such as exposure limits.

Codes of Practice are also regulatory in style and may be referenced by regulations or conditions of licence. They contain practice-specific requirements that must be satisfied to ensure an acceptable level of safety in dealings involving exposure to radiation. Requirements are expressed in 'must' statements.

Recommendations provide guidance on fundamental principles for radiation protection. They are written in an explanatory and non-regulatory style and describe the basic concepts and objectives of best international practice. Where there are related **Radiation Protection Standards** and **Codes of Practice,** they are based on the fundamental principles in the **Recommendations**.

Safety Guides provide practice-specific guidance on best practice and/or achieving the requirements set out in **Radiation Protection Standards** and **Codes of Practice**. They are non-regulatory in style, but may recommend good practices. Guidance is expressed in 'should' statements, indicating that the measures recommended, or equivalent alternatives, are normally necessary in order to comply with the requirements of the **Radiation Protection Standards** and **Codes of Practice**.

In many cases, for practical convenience, regulatory and guidance documents which are related to each other may be published together. A **Code of Practice** and a corresponding **Safety Guide** may be published within a single set of covers.

All publications in the *Radiation Protection Series* are informed by public comment during drafting, and Radiation Protection Standards and Codes of Practice, which may serve a regulatory function, are subject to a process of regulatory review. Further information on these consultation processes may be obtained by contacting ARPANSA.

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Radiation Protection Series Publication No. 18

June 2012

Part 1 of this publication was approved by the Radiation Health Committee on 18 May 2009, and the Radiation Health and Safety Advisory Council advised the CEO to adopt it on 12 June 2009

Part 2 of this publication was approved by the Radiation Health Committee on 14 March 2012, and the Radiation Health and Safety Advisory Council advised the CEO to adopt it on 20 April 2012

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The mission of ARPANSA is to assure the protection of people and the environment from the harmful effects of radiation.

This Safety Guide supersedes the National Health and Medical Research Council's RHS 19, *Code of practice for the safe use of ionizing radiation in secondary schools (1986)* and RHS 36, *Code of practice on the safe use of lasers in secondary schools (1983)*.

RPS18 – *Safety Guide for Radiation in Schools – Part 1: Ionizing Radiation* was first published on ARPANSA's website in October 2009. Only editorial changes have been made to Part 1 in this new edition and the content remains the same.

Part 1 of this *Safety Guide* is based heavily on the content of a UK document; CLEAPSS guide L93, *Managing Ionising Radiations and Radioactive Materials*, September 2008 Edition. We gratefully acknowledge the kind permission of CLEAPSS to draw on their document.

Published by the Chief Executive Officer of ARPANSA in June 2012.

Foreword

The *Safety Guide for the Use of Radiation in Schools* aims to provide practical advice and guidance on the use of radiation sources in Australian secondary schools and colleges. This *Safety Guide* contains detailed guidelines for using ionizing radiation sources and lasers.

School students will be future users of radiation and therefore school or college is an ideal stage to instil a respect for the safe and proper use of radiation. Teaching about radiation helps people develop a balanced attitude towards the subject, neither blasé nor apprehensive. Providing students with 'hands-on experience' with a variety of radiation sources offers many benefits for the teaching of science and technology.

Part 1 of this *Safety Guide* provides teachers with guidance on how to handle radioactive materials and radiation emitting apparatus and perform demonstrations, and also on when responsible students may be able to conduct practical work using ionizing radiation under supervision. *Part 1* of this *Safety Guide* indicates the basic philosophy behind the current approach to the control of hazards associated with the use of ionizing radiation in such practical work.

Part 2 of this *Safety Guide* deals with the safe use of lasers in teaching applications: from using a 'pointer' for a presentation to carrying out more advanced optics or electronic experiments with senior students. The information contained in *Part 2* of this *Safety Guide* will allow teachers to understand the potential hazards associated with the use of lasers and the classification and labelling scheme for laser products that reflects these potential hazards. Based on this understanding, teachers should be able to develop risk assessments for their intended use of a laser in the classroom.

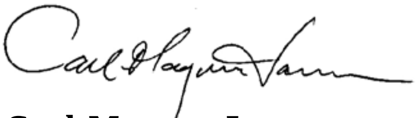
This *Safety Guide* contains information about the most appropriate ionizing radiation sources and lasers to be used in Australian schools and colleges. It outlines how these sources should be stored, handled, used and disposed of. Persons responsible for ionizing radiation sources and lasers in schools should refer to this document and follow its recommendations for best practice. They should also check the relevant State or Territory radiation protection legislation and the school's local rules.

A draft of the *Safety Guide for the Use of Radiation in Schools – Part 1: Ionizing Radiation* was released for public consultation from 7 August 2008 to 3 October 2008. This draft was then revised by the working group to take into account the comments made in the submissions. The Radiation Health Committee approved the final version of *Part 1* of the *Safety Guide* on 19 May 2009 and the Radiation Health and Safety Advisory Council advised me to adopt *Part 1* of the *Safety Guide* at its meeting on 12 June 2009.

A draft of the *Safety Guide for the Use of Radiation in Schools – Part 2: Lasers* was released for public consultation from 22 August 2011 to 30 September 2011. This draft was then revised by the working group to take into account the comments made in the submissions. The Radiation Health

Committee approved the final version of *Part 2* of the *Safety Guide* at its meeting on 14 March 2012 and the Radiation Health and Safety Advisory Council advised me to adopt *Part 2* of the *Safety Guide* at its meeting on 20 April 2012.

An initial electronic publication of *Part 1* of this *Safety Guide* was released on the ARPANSA website in October 2009. A separate working group was then formed to develop the second part on lasers. Both parts are now being published together as a single resource for schools.



Carl-Magnus Larsson
CEO of ARPANSA

5 June 2012

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Note: Terms that are described in the glossary appear in **bold type** on their first occurrence in the text.

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Part 1: Ionizing Radiation

An Overview for Teachers

Ionizing radiation sources can be used in secondary schools and colleges provided local and national rules are followed when they are used.

Safety policy and local rules

Two Australian documents cover the use of **radiation source**s:

- ARPANSA's Radiation Protection Series No. 1, *Recommendations for limiting exposure to ionizing radiation (1995)*, and National Occupational Health and Safety Commission (NOHSC) 2002, *National standard for limiting occupational exposure to ionizing radiation* (**RPS1**) (ARPANSA 2002)
- Radiation Protection Series No. 6, the *National Directory for Radiation Protection* (**NDRP**) (RPS6) (ARPANSA 2004).

Both documents are available on the ARPANSA website at www.arpansa.gov.au.

RPS1 outlines the responsibilities of the employer and of employees. The NDRP provides information on nationally agreed elements of radiation protection regulation.

To comply with the requirements in the above documents, your school will have:

- a responsible person – usually the school principal or the head of your State/Territory Education Department – who is legally responsible for ensuring that all requirements are met and that best practice is followed
- a radiation supervisor – the person generally responsible for the safe storage, use, monitoring and disposal of radiation sources
- developed a set of local rules for the use of radiation sources, which need to be followed. These rules will include where the radiation sources are stored, where they can be used, who can use them and where the use log is kept. Model local rules are included in Annex 4 of this document.

What radiation sources can be used?

All **radioactive source**s used in secondary schools or colleges should be sealed as this will reduce the likelihood of **contamination**. Students in years 11 and 12 are able to use **sealed radioactive source**s in supervised practical work. Radioactive sources should only be used for demonstrations for students in year 10 and below.

The NDRP contains information about radiation sources that are exempt from all regulatory requirements. An example of some **radioactive material**s and apparatus that are exempt from regulation and are therefore suitable for use in Australian secondary schools and colleges include:

- sets of very low activity radioactive sources of americium-241, strontium-90 and cobalt-60; and
- **electron** tubes with a maximum operating voltage of no greater than 5 kV.

Exempt radioactive sources do not need to be treated as radioactive for disposal and can therefore go out with general garbage when they are no longer needed.

The NDRP contains information about other higher activity radioactive sources that are still exempt from some regulatory requirements. These are also recommended for use in schools. Because these radioactive sources have activities above the exemption level, you need to treat them as radioactive when you want to dispose of them. You need to consult with your radiation regulatory authority (see page 97) about disposal.

Your school may wish to use radiation sources that are not exempt or are not listed in the NDRP. You will need to consult with your radiation regulatory authority to find out what their requirements are for the use of such sources.

Australian Guidelines

This document contains detailed guidelines for using ionizing radiation sources in Australian secondary schools and colleges. These guidelines are a good basis for storing and handling these sources wherever your school is in Australia. You should however check your State or Territory radiation protection **legislation** and your school's local rules.

Part 1 Overview

Table 1 provides an overview of the sections included in Part 1 of the Safety Guide.

Table 1: Overview of Sections

Section 1 – Introduction	
Introduction	Basic information on radiation sources and why this document was written
Scope	What this part of the document applies to
Purpose	What this part of the document will be used for
Australian radiation regulations	Laws, rules and authorities controlling people using ionizing radiation
Section 2 – Ionizing Radiation	
Basics	Why use radiation in secondary schools including the benefits of using sources of ionizing radiation at school/college
Sources For Schools/College	Lists the recommended types of radiation materials that can be used at school/college
Sources	Sources of ionizing radiation (both man-made and found in the environment)

Section 3 – Safe Handling of Radiation Sources	
Handling Radiation at School	How to safely handle different types of radiation sources used in the secondary school setting
Section 4 – Administrative Procedures	
Radiation Supervisor	What, who and why there should be a radiation supervisor and how they should be selected
Acquiring Purchasing	What to do when you buy a radiation source
Person Permitted to Handle	Person who are or should be allowed to handle radiation
Monitoring and Testing	When, how and how often radiation sources should be tested or monitored to ensure they are safe
Record Keeping	How, when and what records should be kept about radiation usage and storage.
Storage	What containers and in what areas radiation sources should be stored
Disposal	What and how to dispose of radiation sources
Transport	Requirements for transporting radiation sources
Section 5 – Incidents	
Spills	What to do and how to clean up after a spill
Misplacing/ Losing Sources	What to do and who to contact if a radiation source is misplaced or lost

1. Introduction

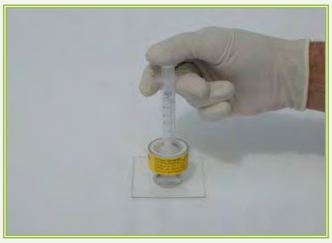
Use of real radiation sources in schools, as opposed to computer simulations, should not be difficult. This guide aims to provide practical advice and guidance so that all secondary schools and colleges can have the confidence to promote safe usage of radioactive sources and electron tubes in the classroom. Figure 1 shows pictures of some of the ionizing radiation sources typically used in schools.

Figure 1: Some ionizing radiation sources used in Australian schools

Alpha sources in perspex blocks

Disc source – strontium-90

Elution of caesium-137/ barium-137m mini-generator



Disc source – caesium-137

Disk sources in storage box

Cup source and storage box

Teltron tube – Maltese cross

Caesium-137/barium-137m mini-generator

Thoron generator being lifted out of storage tin

Hands-on experience with real radiation sources gives benefits from a science learning perspective. As with any other potentially hazardous material or chemical or electrical appliance, we need to follow some rules so that the radiation sources are used safely and appropriately.

This part of the Safety Guide contains information about the most appropriate ionizing radiation sources to be used in schools and colleges. It outlines how these sources should be stored, handled, used and disposed of. Persons responsible for ionizing radiation sources in schools should refer to this document and follow its recommendations for best practice.

1.1 Scope

This part of the Safety Guide covers all sources of ionizing radiation used in Australian secondary schools and colleges including that resulting from the radioactive decay of radioisotopes and that produced electronically.

It should be noted that:

- higher activity radioactive sources, and
- electronic devices that produce higher energy and/or higher intensity ionizing radiation

are likely to require an authorisation issued by the relevant regulatory authority and could consequently be subject to the provision of another Radiation Protection Standard, Code of Practice or Safety Guide. It is expected however, that the general guidance herein should also be able to be applied to these radiation sources in order that they can be used in a safe manner.

Part 1 of this Safety Guide does not apply to sources of **non-ionizing radiation**.

1.2 Purpose

This part of the Safety Guide provides practical advice on how justification, optimisation and dose limitation can be applied, in order to ensure the safe use of ionizing radiation sources. It also provides practical advice and guidance on procedures that, if followed, will:

- reduce the likelihood of **exposure** to ionizing radiation to staff and students
- ensure the safety of all persons where sources of ionizing radiation are used for teaching purposes in schools.

The NDRP has adopted dose limits, for occupational exposure and exposure of members of the public, proposed by the International Commission on Radiological Protection (ICRP) and published in Australia in RPS1 (ARPANSA 2002). In the school situation, there is no reason for any person to receive doses in excess of the dose limits for members of the public and most people should receive very much less than these. The dose limits are for whole body exposure, lens of the eye, skin and hands and feet.

Good planning and use of risk assessments can achieve the aims of justification and optimisation. Thus, only useful experiments/ demonstrations should be carried out. Experiments should be carefully planned to minimise the handling of radiation sources and to avoid unnecessary repetition of experiments/demonstrations.

Unnecessary exposure to radioactive materials in storage can be avoided by ensuring that these sources are securely stored, in suitably shielded containers, away from frequently occupied areas.

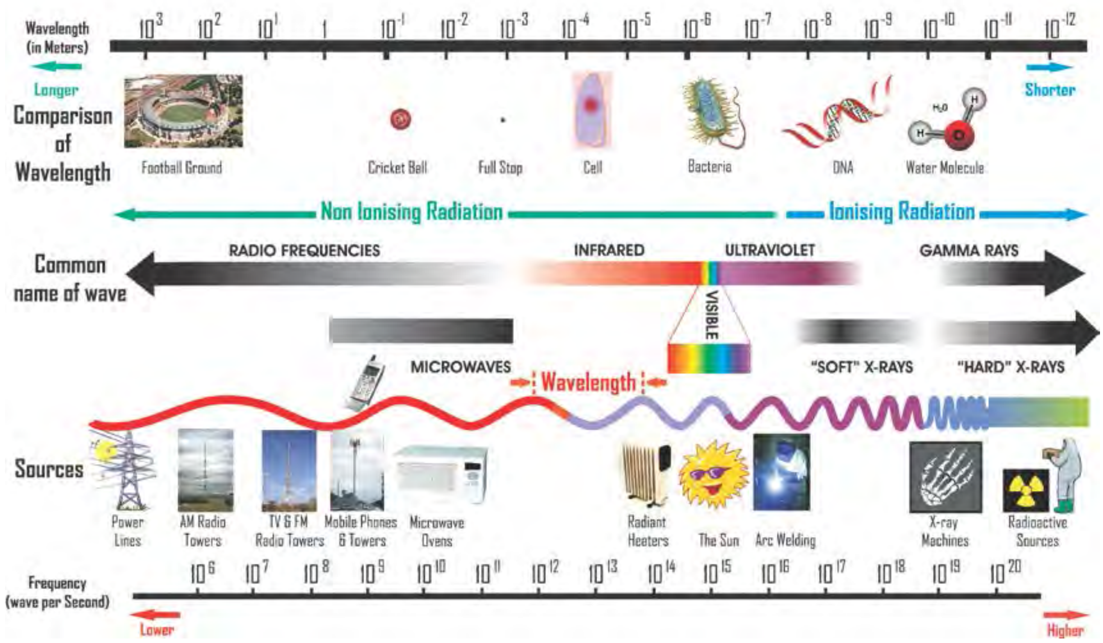
Exposures to ionizing radiation from some radiation sources can be so low that is not necessary to regulate some or all uses of these sources. Such sources may then be exempted from regulation. The NDRP specifies criteria for deciding when sources should be exempted from aspects of regulation and provides lists of radioactive materials and apparatus that all jurisdictions have agreed to exempt. Information on relevant exempt sources is provided in this document.

1.3 Radiation and its Properties

Radiation is part of our everyday life and comes in many different forms – as heat, **light**, as radio waves, etc. We are all exposed to background radiation of varying levels, depending on where we live and what activities we undertake.

Radiation is often described in terms of the **electromagnetic spectrum** and is divided into two types – ionizing and non-ionizing, as illustrated in Figure 2.

Figure 2: The electromagnetic spectrum.



We can sense many forms of non-ionizing radiation, particularly through sight, sound and sensations of heat. However, we cannot detect ionizing radiations by our senses. This can contribute to an irrational degree of fear of ionizing radiation or to us ignoring its presence.

Non-ionizing radiation

Non-ionizing radiation is found at the long **wavelength** end of the spectrum and may have enough energy to excite molecules and **atoms** causing them to vibrate faster. This is very obvious in a microwave oven where the radiation causes water molecules to vibrate faster creating heat.

Non-ionizing radiation ranges from extremely low frequency radiation, shown on the far left of the electromagnetic spectrum above through the radiofrequency, microwave, and visible portions of the spectrum into the ultraviolet range.

Extremely low-frequency radiation has very long wavelengths (in the order of a thousand kilometres or more) and frequencies in the range of 100 Hz or less. Radiofrequencies have wavelengths of between 1 and 100 metres and frequencies in the range of 1 to 100 MHz. Microwaves that we use to heat food have wavelengths that are about 10 cm long and frequencies of about 2 GHz.

Ionizing radiation

Ionizing radiation has more energy than non-ionizing radiation; enough to cause chemical changes by breaking chemical bonds. This effect can cause damage to living tissue.

Shorter wavelength **ultraviolet radiation** begins to have enough energy to break chemical bonds. **X-ray** and **gamma radiation** have very high frequencies (in the range of 10^{20} Hz) and very short wavelengths (around 10^{-12} metre). Radiation in this range has extremely high energy. It has enough energy to strip electrons from an atom or, in the case of very high-energy radiation, break up the nucleus of the atom.

The process in which an electron is given enough energy to break away from an atom is called **ionization**. This process results in the formation of two charged particles or ions: the molecule with a net positive charge, and the free electron with a negative charge.

Each ionization releases energy which is absorbed by material surrounding the ionized atom. Compared to other types of radiation that may also be absorbed, such as heat, ionizing radiation deposits a large amount of energy into a small area. In fact, the energy from one ionization is more than enough energy to disrupt the chemical bond between two carbon atoms. All ionizing radiation is capable, directly or indirectly, of removing electrons from most molecules.

There are three main kinds of ionizing radiation:

- **alpha particles**, which include two protons and two neutrons
- **beta particles**, which are essentially electrons
- gamma rays and X-rays, which are pure energy (photons).

Alpha particles and beta particles are not part of the electromagnetic spectrum; they are energetic particles as opposed to pure energy bundles (photons).

Ionizing radiation can come from radioactive materials, such as uranium and thorium, which occur naturally, or can be produced in electronic devices, such as X-ray units.

1.4 Regulation and Control of Radiation in Australia

We are exposed to ionizing radiation at all times and it can be used for many beneficial purposes. However, exposure to ionizing radiation can also be harmful. Therefore, all Australian States and Territories and the Commonwealth regulate the use of ionizing radiation through legislation. A list of the contact details for each jurisdiction can be found on page 97.

Uniformity of radiation protection regulation throughout Australia is important. The Radiation Health Committee has developed a radiation protection framework and this has been published in the NDRP (ARPANSA 2004). All jurisdictions have agreed to adopt the framework.

The NDRP contains some information and requirements relevant for schools and the jurisdictions may adopt these by various means. Thus, you should contact your radiation regulatory authority to find out the relevant requirements in your jurisdiction. For example, you may need to notify the regulatory authority, or possibly to have a licence to use ionizing radiation sources in schools and colleges.

The NDRP incorporates the philosophy of radiological protection recommended by the ICRP in its publication 60 (ICRP 1991). Radiological protection concerns itself with exposures to ionizing radiation above natural background and assumes that any such exposure presents a risk, with the level of risk being proportional to the dose.

The three key processes of radiological protection are:

- *Justification*
  showing that the benefits outweigh the detriment that the radiation might cause.
- *Optimisation*
  keeping all exposures as low as reasonably practicable/achievable.
- *Dose limitation*
  keeping the total relevant dose for workers and for the public below specified limits. These apply to the potential for accidental exposures as well as predictable normal exposures.

2. Ionizing Radiation

2.1 Reasons to use Ionizing Radiation Sources in Secondary Schools and Colleges

Ionizing radiation is used widely in medicine, food processing, archaeological investigations, fire protection, electricity generation and numerous industrial processes. Radioactive materials are essential tools in many areas of scientific research and development. Amongst the school and college students are some of the future users of ionizing radiation, for these industrial, medical or scientific purposes. School or college is an ideal stage to instil a respect for the safe and proper use of radiation.

Teaching about ionizing radiations also helps students to develop a balanced attitude towards the subject, neither blasé nor apprehensive. For many students, their study of ionizing radiations at school or college may be their only opportunity to achieve this.

The school curriculum for science includes the study of atoms and radioactivity, so everyone who teaches science to this level should know how to handle radioactive materials and radiation emitting apparatus and perform demonstrations. This part of the Safety Guide provides guidance on this and on when responsible students may be able to conduct practical work using ionizing radiation under supervision.

Practical work in this subject provides a unique opportunity to undertake meaningful investigations at the atomic level. This part of the Safety Guide for schools indicates the basic philosophy behind the current approach to the control of hazards associated with the use of ionizing radiation in such practical work.

2.2 Choice of Safe Ionizing Radiation Sources for Secondary Schools and Colleges

Careful choice of radiation sources and good control measures ensure that the use of radiation sources in secondary schools and colleges is safe. By following various aspects of legislation and guidance, such as contained in this document, you will ensure that the radiation exposure of students is only ever at trivial levels.

Radiation exposure can arise from two mechanisms: external or internal exposure. Annex 1 discusses these further. Briefly, external irradiation can arise from the exposure to X-rays (from some radiation apparatus) or to radiations from sealed or **unsealed radioactive source**s external to the body. Internal irradiation results from the entry of radioactive materials into the body, often by breathing in a radioactive gas or eating or transferring radioactive material into the mouth. Organs that have absorbed such materials and, in most cases, other nearby organs are exposed to radiation. Annex 2 gives relevant properties of some radioactive materials found in schools.

In education, we try to design activities with ionizing radiation to achieve the learning objectives while keeping the exposures of students and staff as low as reasonably achievable.

Exposures from the use of radiation in teaching in schools can be compared with other, common radiation exposures indicated in Table 2.

Table 2: Typical Exposures to Ionizing Radiation

Source of Exposure	Exposure
Natural radiation (terrestrial and airborne)	1.5 mSv per year
Natural radiation (cosmic radiation at sea level e.g. Australian capital cities)	0.3 mSv per year
Natural radiation (cosmic radiation at 2 240 m (e.g. Mexico City))	0.9 mSv per year
Natural radiation (cosmic radiation at 3 900 m (e.g. La Paz, Bolivia))	2.0 mSv per year
Cosmic radiation from a seven hour aeroplane flight	0.05 mSv
Chest X-ray	0.02 mSv
Cosmic radiation exposure of domestic airline pilot	2-6 mSv per year

Background radiation occurs everywhere and in Australia, we each receive an annual whole body dose that is typically about 2 millisievert (mSv). Medical radiation in Australia (X-rays and radioactive materials used in diagnosis), results in an average dose per person of about 1.2 mSv per year. By comparison, the dose received by the hand (not the whole body) during a standard school demonstration will be no more than 0.01 mSv (see the risk assessments in Annex 3).

Consequently, a teacher could carry out hundreds of demonstrations in a year before acquiring a dose equal to a typical background level. Doses to students observing demonstrations will be far lower.

Sealed radioactive sources

The NDRP provides broad guidance for sealed radioactive sources that are suitable for use in schools. The activities of the specified sealed radioactive sources are listed in column 2 of Table 3.

Table 3: Sealed radioactive sources for use in schools and colleges

Radionuclide	Max activity of sealed radioactive sources in NDRP for use in schools (kBq)	Exempt activity in NDRP (kBq)
Cobalt-60	200	100
Strontium-90	80	10
Caesium-137	200	10
Polonium-210	–	10
Radium-226	20	10
Americium-241	40	10

The NDRP exempts the end user from the requirements of registration and of licensing to possess or use sealed radioactive sources with the activities specified in column 2 above when such sources are used for teaching. All jurisdictions will adopt the provisions of the NDRP in due course but you should check the current requirements in your jurisdiction with your radiation regulatory authority.

Radioactive sources with the activities specified in column 3 are exempt from all regulatory requirements and may be dealt with in general as though they were not radioactive. Radioactive sources with up to these activities may be suitable for many experiments and should be the first choice for sources to be used in schools. Use of exempt activities also allows other radionuclides to be considered, for example polonium-210 with activity less than 10 kBq may be an alternative to an americium-241 source for demonstration of the properties of alpha particles.

The NDRP also specifies some consumer products, including ionization smoke detectors and luminous watches, which are exempt from the requirements of registration and of licensing the end user to possess or use.

The data in Annex 2 for each radionuclide shows that, although these radioactive sources are approved for use in schools, the dose rates can be high near to the sources. We can, however, easily protect ourselves from exposure to a radiation source by:

- reducing the time of exposure
- increasing the distance from the source
- increasing the shielding between ourselves and the source.

Your school or college may have, or may be considering the purchase of, sealed radioactive sources other than those listed in Table 3 or exempt radioactive sources. These other sources are not recommended for use in schools or colleges and you should discuss their future with your radiation regulatory authority. The risk assessments in Annex 3 may be useful for these discussions.

Unsealed radioactive materials

Other radioactive sources that may be found in schools include:

- small quantities, possibly up to 100 g, of uranium compounds as chemicals
- protactinium generators for **half-life** experiments
- radon-220 (thoron) generators for half-life experiments
- mini-generators using caesium-137 for half-life experiments
- low-level radioactive artefacts such as protected luminous dials, cloud chamber sources and spinthariscopes
- radioactive rocks.

These sources are all 'unsealed' radioactive sources and therefore require greater care in their use.

Mini-generators

Unsealed radioactive materials can be useful in the form of 'mini-generators', which are used to produce short half-life radioactive materials. A risk assessment, however, may show that unsealed radioactive materials are not suitable for use at your school or college. The following information may assist you in making this decision.

One currently available mini-generator uses caesium-137/barium-137m with an activity of 370 kBq. As this is an unsealed radioactive source, with activity higher than that specified in the NDRP for a sealed radioactive source, you should contact your radiation regulatory authority if you wish to use such a mini-generator.

In this type of mini-generator, the caesium-137 is held on an **ion** exchange column. (An ion exchange column is made by filling a glass cylinder with an exchange resin, which is usually in the form of tiny plastic beads.) The caesium, which has a long half-life of 30 years, decays continuously to form a short-lived barium isotope. A few drops of a solution, called an eluent, are passed through the column to wash away only the barium ions, leaving the caesium ions on the column. The solution coming from the generator is collected in a suitable container and placed under a radiation detector and the count rate is measured over time.

Therefore, this experiment involves dealing with small volumes of unsealed radioactive material and you should follow the protocols in Section 3.2.

When we are working with unsealed radioactive materials, we should also consider the chemical risks associated with the materials. For some materials, e.g. those containing thorium or uranium, the chemical risks may dominate the radiation risks. Some historical mini-generators, such as the protactinium or radon-220 (thoron) generators, contain such materials. The protactinium generator contains uranyl nitrate, hydrochloric acid and an organic solvent. The radon-220 generator contains thorium hydroxide. Neither is recommended for continued use in schools or colleges.

Radioactive rocks may also be used in schools. The NDRP exempts a geological sample that contains radioactive material from the requirements of registration, and of licensing the end user to possess or use, if:

- it emits radiation at a level not more than 5 microsieverts an hour, measured at a distance of 10 cm from its surface
- it is being used as a sample in teaching or for display as a geological specimen.

Such rocks are best kept in a box with a clear lid so that their radioactive properties may be demonstrated without the need to handle them.

Other considerations when choosing radioactive sources

Even though a risk assessment may indicate that all of the sealed radioactive sources in column 2 of Table 3 above are suitable for use in your school or college, there are other considerations, including the issue of disposal of radioactive sources. Disposal of radioactive materials is discussed in Section 4.7.

Another option for radioactive sources to be used in schools is to ensure that the activities of these sources are less than the exempt activities for the radionuclides concerned. These activities are listed in column 3 of Table 3. Then, there are no regulatory requirements (but still some good practice requirements as indicated in this part of the Safety Guide) and such sources can be disposed of with normal garbage.

Sets of three sealed radioactive sources – americium-241, strontium-90 and cobalt-60 – are available in which the individual sources have exempt activities. These sets provide a useful source of alpha, beta and gamma radiation.

Individual exempt radioactive sources are also exempt from transport requirements for radioactive materials. Transport of radioactive materials is discussed in Section 4.8.

Age of radioactive sources

Radioactive sources in schools tend to be used for only a few days per year. Therefore, if they are well looked after, they can last for many years without deteriorating physically. As long as a radioactive source is not damaged, passes its regular testing for contamination (see Annex 5) and still has sufficient radiation output to be useful, then there is no reason to stop using it.

Nevertheless, short half-life radioactive sources, particularly those that decay rapidly to below the exempt activity, have some advantages. They are not likely to cause any problems if placed in a cupboard and forgotten about (and this has happened in the past when proper administrative processes were not in place) and are able to be disposed of at minimal cost, with ordinary garbage, when they are no longer required.

Radioactive sources with shorter half-lives should generally be chosen over those with longer half-lives as long as they will fulfil the required purpose.

Apparatus that may generate by-product X-rays

Any apparatus in which high-speed electrons strike a **target** in a (partial) vacuum may produce X-rays. These conditions typically exist in evacuated tubes where the accelerating voltages are in the range of 10 kV or more. Crookes tubes (see Figure 3) and other cold cathode discharge tubes are potential sources of X-rays in the classroom. (Spectrum tubes used to observe spectra of elements and compounds are not a source of X-rays if the tubes are in good condition because the enclosed gases prevent electrons from achieving high enough energies).

The radiation dose from X-rays is dependent on:

- operating factors of the X-ray tube (kV (peak) and mA)
- filtration of the X-rays by-material in the beam
- amount of scattering of the primary beam that has taken place
- protective barriers between the tube and the body
- distance between the tube and the body
- duration of irradiation.

Figure 3: Crookes Tube

For some such devices, the X-rays are of such low level or energy that they are readily absorbed in the tube casing and these devices therefore pose no hazard.

Thus, the NDRP states that a radiation generator or electronic tube, of a type approved by the radiation regulatory authority, is exempted from the notification, registration or licensing requirements specified, provided that:

- in normal operating conditions it does not cause an ambient dose equivalent rate or a directional dose equivalent rate, as appropriate, exceeding 1 μSv/h at a distance of 0.1 m from any accessible surface of the apparatus, or
- the maximum energy of the radiation produced is no greater than 5 keV.

In addition, the following apparatus are exempt from notification, registration and licensing requirements:

- television receivers
- visual display units
- cold cathode gas discharge tubes
- electron microscopes.

You should contact your radiation regulatory authority if your school or college has any apparatus that could generate by-product X-radiation other than those discussed above.

3. Safe Handling of Radiation Sources

Although the radiation sources recommended for use in schools are such that the potential for harm is very low, you should treat them as potentially hazardous and take advantage of the opportunity to train students in dealing with hazardous items.

Exposure to ionizing radiation sources can minimised by using the three principles of radiation protection:

- Time – keep the time you stay next to a radiation source to the minimum necessary in order to reduce the total exposure.
- Distance – keep the distance from the source to the maximum practicable as the further away you are from a source, the lower your exposure. The inverse square law applies to physically small radiation sources and describes the relationship between distance and doserate. The inverse square law means that if you double the distance from a source, the doserate will be ¼ of the original; triple the distance and the doserate becomes ⅑ of the original etc.
- Shielding – the thicker the appropriate barrier between you and the source, the less you get exposed.

3.1 Sealed Radioactive Sources

Sealed radioactive sources should never be picked up with fingers, but always with tongs or tweezers.

3.2 Unsealed Radioactive Sources

Because of the possibility of spillage leading to contamination, extra care is required in the use of unsealed radioactive materials. Thus, specific laboratory facilities and work procedures should be provided for the use of unsealed radioactive materials.

Laboratory facilities

The desired standards for facilities where work with unsealed radioactive materials takes place are listed. Even though the sources used in schools are well below levels requiring such facilities, you should apply the standard as far as is practicable because of its educational value. This means that you should:

- designate an area for work with unsealed radioactive sources and indicate it clearly by signs or barriers
- use an area where the floors and furniture surfaces are smooth, impermeable, and easy to clean
- reserve laboratory ware for experiments with radioactive material and positively identify it as such, e.g. by colour coding with durable paint
- conduct experiments on metal or plastic trays lined with absorbent disposable materials

- place local shielding around the container of the unsealed radioactive material, where necessary to reduce radiation levels to 10 μSv/h at 5 cm from the surface of the shielding
- have sufficient washbasins for students and staff, and an adequate supply of disposable towels. The basins should not be used for washing laboratory ware
- provide a waste bin with a disposable waterproof liner for contaminated laboratory ware and disposable towels. The bin should be labelled with the recognised radiation symbol
- dispose of the liner and contents with normal garbage because of the low levels of activity involved. You should not label this as radioactive waste.

Laboratory work procedures

- Personnel with hand wounds should not work with unsealed radioactive sources.
- Do not permit eating or the application of cosmetics.
- Students should wear disposable gloves and be taught how to avoid contaminating objects in the laboratory, and how to remove the gloves without contaminating themselves.
- You should prohibit pipetting by mouth; mechanical devices are essential.
- Avoid actions or procedures that increase the chances of spilling or splashing radioactive materials.
- You should regularly clean the glassware, equipment, and surfaces liable to contamination.

3.3 X-RAY SOURCES

To minimise possible X-ray exposure, three rules should be observed by teachers and students:

- minimise the voltages used to operate vacuum tubes (X-rays are only produced when the tube is electrically energised)
- maximise the distance between the tube and the observers
- minimise the time during which the tube is operated. If you suspect any tube or apparatus of emitting X-rays, then you should check it for high levels of radiation.

4. Administrative Procedures

The administrative requirements for the use of radiation sources in schools should be no different from those for other potentially hazardous items, such as those used in chemistry. Thus, all existing occupational health and safety requirements will also apply to radiation sources. If the school has an occupational health and safety committee, radiation sources should therefore be covered in its scope.

The administrative procedures provided in this document recommend that you:

- appoint a suitable 'radiation supervisor'
- develop and follow local rules for the use of radiation sources
- carry out an appropriate risk assessment for each activity involving work with ionizing radiation.

These administrative procedures have been based on the responsibilities in the NDRP. Legislation, both for radiation protection and occupational health and safety, governs work with radioactive materials and ionizing radiations (other than exempted radiation sources) and all persons need to work to this legislation.

The Principal/Education Department has the legal responsibility to ensure safe management of radiation sources. If the person who is legally responsible is unclear about any aspect of his or her work, he or she should contact their radiation regulatory authority for advice. The name and contact details for the radiation regulatory authority should appear in the local rules and in the science department's Occupational Health and Safety Policy.

4.1 Appointment of a Radiation Supervisor

Someone, whatever his or her title, should have responsibility for the safe storage, use and monitoring of radiation sources. For this reason, we strongly recommend that each science department has a named radiation supervisor.

This radiation supervisor will have management functions and would probably be a member of the science teaching staff, e.g. the Head of Science or Head of Physics. A laboratory manager may assist the radiation supervisor with the day-to-day tasks. The radiation supervisor may not have any formal training or qualifications in addition to those needed to be able to teach science.

The Principal/Education Department should ensure that the radiation supervisor is competent and is fully aware of his or her role. The radiation supervisor should understand the basic principles of radiation protection and the relevant requirements of the local radiation protection legislation. Attendance on a radiation protection course specifically designed for school-level work is highly recommended.

The radiation supervisor should:

- be directly involved with work using ionizing radiations
- be able to carry out a risk assessment of all uses of radiation sources and for storage of these sources
- ensure that all such work is carried out in accordance with the local rules
- be able to exercise supervision, though need not be present all the time
- ensure that regular monitoring is carried out on radioactive sources and their containers
- ensure that items of equipment that might produce by-product X-rays are identified and appropriate radiation protection measures for these devices are instituted
- ensure that high voltage electronic tubes are checked for the possible emission of extraneous X-rays
- ensure that all records required are accurate and kept up to date
- know what to do in an emergency.

The radiation supervisor should be fully aware of the hazards, risk assessments and control measures associated with each radiation source in his or her care. The immediate responsibility for handling radiation sources and the supervision of practical work may often be delegated to other members of staff, e.g. the laboratory manager or other science teachers. Therefore, the radiation supervisor should be satisfied that all persons involved are informed and trained to a level which enables them to carry out procedures safely.

After radiation sources have been used, the radiation supervisor should be confident that they have all been replaced in the store and that the use log (see Section 4.5 and Annex 4) has been completed. They also need to ensure that the checks specified in Section 4.4 are carried out.

All schools and colleges need standard operating procedures (i.e. written information and instructions) for their work with radioactive materials.

To comply with RPS1 (ARPANSA 2002), the Principal/Education Department would be responsible for agreeing local rules with the radiation supervisor. Model local rules are printed in Annex 4. All staff handling or working with ionizing radiations should be familiar with, and have easy access to, the local rules. Students in years 11 and 12[1], who are allowed to carry out supervised investigations with sealed radioactive sources, should also be given access to the appropriate sections of the local rules.

[1] Not all students in year 11 or 12 will have reached the age of 16. RPS1 (ARPANSA 2002) states that no person under the age of 16 is to be employed under conditions where they are directly involved in work with radiation. When this is applied to the school situation, it means that, if students are under the age of 16 then the teacher should do all experimental work with radiation as demonstrations. However, given the low risk due to use of the sources recommended here, teachers should be able to judge whether year 11 or 12 students are sufficiently mature to use the radiation sources responsibly.

Occasionally, a radiation protection expert, e.g. a radiation regulatory authority, may visit a school and carry out demonstrations of the properties of ionizing radiation. Any such person should also follow the local rules.

4.2 ACQUIRING RADIATION SOURCES

You should select radiation sources, including sealed radioactive sources, radio-chemicals and radiation apparatus, on the basis recommended in this document (see Section 2.1) and obtain these from recognised educational suppliers. You may also acquire some consumer products, such as ionization type smoke detectors, some gas mantles and some luminous products but only after a risk assessment shows that the intended use is acceptable.

Purchase of unsuitable radiation sources may result in very expensive disposal costs and/or long-term storage of useless radiation sources, which is highly undesirable.

You should not accept unsolicited gifts, such as gifts of historical items.

If there is any uncertainty about the suitability of a radiation source, contact your radiation regulatory authority before you purchase or accept it.

When you purchase a new radiation source, the radiation supervisor should keep copies of all relevant paperwork (e.g. order, delivery note, invoice, instructions and safety datasheets).

These documents are extremely useful, for example, when disposal becomes necessary in the future.

4.3 PERSONS WHO MAY BE PERMITTED TO HANDLE RADIATION SOURCES

Only appropriately qualified and trained staff should handle radiation sources. Visiting radiation protection experts may, on approval from the Principal/Education Department, handle radiation sources for the purpose of demonstration of properties of radiation to students. However, the handling of radiation sources by students is restricted.

Teacher qualifications

Teachers appointed to permanent positions on the science staff should have the qualifications required to handle radiation sources. Trainees, some temporary staff, or those for whom science is a secondary subject, may not be suitably qualified. If they are to handle radiation sources, they should be supervised by a teacher who is qualified, until the radiation supervisor considers that they have gained sufficient knowledge and experience.

Support-staff qualifications

Technical support staff have various levels of qualifications and experience. The radiation supervisor should decide what functions (if any) they can reasonably be given. It is important that technicians are confident and competent, if they are to deal with radiation sources.

In some establishments, technicians never handle radiation sources; teachers always collect and return these sources from the store. In other schools, technicians transfer radiation sources to laboratories, carry out annual monitoring and prepare half-life investigations.

Staff training

The radiation supervisor should ensure that all those who work with ionizing radiations and radioactive materials follow the local rules. To achieve this, the radiation supervisor should check that each member of staff (teaching or non-teaching), who works with ionizing radiations, is competent and follows correct procedures. The radiation supervisor should provide appropriate instruction, as a matter of course, in the following areas:

- security and storage arrangements
- record keeping
- safe handling of each type of radiation source
- correct use of associated equipment, particularly that used for monitoring purposes
- action to take if a radioactive source is dropped or a spill occurs
- when to seek help and advice from the radiation supervisor.

Training is particularly important for newly qualified or newly recruited staff. Do not assume prior knowledge. Equipment often differs considerably from school to school.

Students in Year 10 and under

Class work with radioactive sources for students in year 10 and under is restricted to teacher demonstrations. Students should be kept at least 2 metres away from these sources during demonstrations. However, closer inspection of devices containing low-level radioactive sources (e.g. small cloud chambers, spinthariscopes, smoke alarms, radioactive watch dials) is acceptable, provided the source is fully enclosed. Contamination of the fingers should be avoided, particularly with radioactive rocks, which should be kept in suitable transparent containers. Local rules should require that all radioactive sources, whatever their activity, are never left unattended by the teacher in charge.

Students in Years 11 and 12

Students in years 11 and 12 may handle sealed radioactive sources in order to carry out standard investigations of the properties of ionizing radiations. The teacher in charge should be satisfied that the students are sufficiently responsible, have received appropriate instruction and have seen and understood the appropriate sections of the local rules. The teacher should closely supervise all work. The sources should be inspected for signs of damage as soon as they are returned to the teacher. The procedure for doing this is explained in Annex 5. Local rules should require that all radioactive sources, whatever their activity, are never left unattended by the teacher in charge.

New and expectant mothers (staff or students)

It is always important for an expectant mother to let her employer know as soon as she is aware that she is pregnant, so that the employer may advise her of any special precautions or changes to working procedures.

Provided the local rules are followed (see Annex 4), nobody handling radioactive materials in schools will receive an additional dose anywhere near the limits laid down by radiation protection legislation for members of the public. A new or expectant mother may continue to carry out normal procedures with sealed radioactive sources. However, if an expectant mother is still seriously concerned over the risk to her unborn child, it would be advisable to ask another person to carry out the work on her behalf. Unnecessary stress is likely to be far more harmful than the radiation.

In order to eliminate the already very low risk of contamination, it is recommended that new and expectant mothers do not carry out wipe tests (see Annex 5), contamination checks or work with unsealed radioactive sources (e.g. dealing with spills of radioactive materials, preparing protactinium or radon-220 (thoron) generators, disposing of radio-chemicals etc).

4.4 Radiation Monitoring and Testing of Radioactive Sources

In order to carry out meaningful experiments, every establishment that keeps radioactive sources needs to possess an appropriate radiation detector to detect ionizing radiations. In schools and colleges, this may be a G-M tube connected to a suitable measuring instrument. The low count rates involved in wipe tests and contamination testing mean that the measuring instrument should be able to count discrete pulses from the G-M tube. This type of instrument is known as a scaler.

When you are wipe testing a radioactive source or carrying out a contamination check, you should keep all other radioactive sources at least 2 m away so that they do not affect the radiation detector.

Very occasionally, you may find that you need to carry out more-sensitive checks for contamination or dose. In these cases, you may require more sophisticated monitoring equipment and should contact your radiation regulatory authority for advice.

4.5 Record Keeping

History of the radiation sources/radiation source records

An inventory of all radiation sources should be kept and, for each source, should include:

- a copy of the purchase order/invoice/receipt
- an individual record for each radioactive source, i.e. the radioactive source history including, where possible, the:

- unique name or reference number
- radionuclide or chemical name
- original activity
- delivery date, supplier and manufacturer
- results of inspections and wipe tests on the source (see Annex 5);

• an individual record for each radiation apparatus, including where possible, the:
  - unique name or reference number
  - delivery date, supplier and manufacturer.

If you no longer have the source, the history should include details of its disposal and written confirmation from the organisation accepting responsibility for it (including the name and address).

Use log

The whereabouts of all radiation sources should be checked at 'appropriate intervals'. In most schools, sources are used over a period of a few days, and then not for another year. Provided the use log is always completed correctly, the store is always locked and the key kept securely, a year would be an appropriate interval between formal checks. However, if there are doubts or, unusually, the sources are subject to frequent use and/or by several members of staff, then more frequent checking, e.g. monthly, may be necessary. A formal check should be carried out immediately if any changes are made to the storage location or in the event of break-in, theft or school trespass. Whenever a check is made for the presence of the sources, the containers will need to be removed from the store and opened. This constitutes a 'use' of the sources and should therefore be recorded as an entry in the use log. Inspections, wipe tests and contamination checks are explained in Annex 5.

4.6 STORAGE OF RADIOACTIVE SOURCES

You should keep all radioactive sources in suitable containers when not in use. These should be locked in a secure store when a member of staff is not supervising them.

Radioactive source containers

Best practice is to keep each radioactive source in a suitable container. This is normally the container in which the source was supplied. It allows the source to be identified easily and carried safely. For example, the cup source is kept in a lead pot inside a wooden box. Labelling on each container should uniquely identify the radioactive source(s) inside and include a trefoil warning sign with the wording 'radioactive materials'. An example of a suitable radiation warning sign is given in Figure 4. Australian Standard AS 1319-1994 (Standards Australia 1994) contains further detail about requirements for such signs.

Figure 4: Example of a suitable radiation warning sign

Specific guidance on appropriate containers for the radioactive sources commonly found in schools and colleges is provided in the risk assessments for sources in Annex 3.

Location of the store

The store should be indoors, where security is better, access is easier and corrosion damage to sources is minimised. It should not be in the same room as highly flammable material. This is to save fire fighters having to worry about radioactive sources and flammables at the same time. The store will normally be in a prep room or laboratory, which is easily accessible from the area(s) where the radioactive sources will be used.

Should your school have several (e.g. more than 10) radium sources, then the store should be in a well ventilated area to prevent any build up of radon.

Any container enclosing a gamma source will allow some radiation through. For this reason the radioactive materials store should be at least 2 m (ignoring walls) from a place where anyone spends extended periods of time, usually interpreted as more than half the week. In a prep room, this means well away from the technician's desk and the washing-up sink. If the store is in a teaching laboratory, with different students present throughout the day, it should be at least 1 m from areas where students sit and at least 2 m away from the usual teacher position. Calculate distances in a straight line, ignoring walls.

Construction of the store

The minimum recommended requirement for a radioactive materials store is a strong, steel container (such as a tool box) that should be recognisable after a fire or other such major incident. A lead container or lead-lined wooden container alone is insufficient protection in a fire. The steel container should be kept in a fixed, locked cupboard or drawer, making sure there is no access via an adjacent cupboard or drawer.

Alternately, a lockable, steel cupboard is often used. This should be fixed in place securely. Educational suppliers may offer a cupboard specifically designed for the purpose.

Stock containers of radio-chemicals may be placed on a small tray within the store, in order to minimise problems in the unlikely event of a spill.

You should keep nothing other than radioactive materials in the store, which means that:

- you only open the store when sources are required
- every item kept in the store is radioactive, avoiding any possible confusion
- in the unlikely event of a spill or leak, decontamination is much easier.

Labelling the store

You should mark the outside of the cupboard or drawer (and the separate metal tin, if used) with a warning sign. This should be of the standard triangular warning type, with a black trefoil pictogram on a yellow background with black edging. Text is optional, but serves as a useful reminder for users unfamiliar with the symbol (see Figure 4).

The local fire warden may request that an additional sign be placed on the door of the room in which the radioactive sources are stored.

It is however, important to review risks carefully before labelling room doors.

Security

The key to the store should be unique and kept securely. Ideally, staff should fetch radioactive sources from the store for immediate use and return. Whenever radioactive sources are outside the locked store, best practice is to ensure that a member of staff supervises them. Where temporary storage is required just before or after a lesson (e.g. where a laboratory is far from the normal store), sources, in their containers, may be locked for short periods in another cupboard or drawer. They should always be returned to the normal store as soon as possible.

4.7 DISPOSING OF RADIATION SOURCES

You can dispose of a radioactive source with an activity below the exemption level specified in the NDRP (as reproduced in column 3 of Table 3 in this document) without regard to its radioactive properties. There may however, be requirements for its chemical properties. If you are disposing of a source that has decayed to an activity below the exemption level for regulatory control, you should permanently remove or obscure all markings relating to its previous radioactive status.

You should contact your radiation regulatory authority if you wish to dispose of a radioactive source with an activity above the exempt level.

You should also contact your radiation regulatory authority if you wish to dispose of any other type of radiation source, such as an X-ray unit or a Crookes tube.

4.8 Transport of Radioactive Sources

The transportation by road of school radioactive sources is rarely necessary and should be reduced to a minimum. If radioactive sources are often used in laboratories on different sites, it is far better to have a separate store and sources at each location.

If radioactive material has to be transported, the driver of the vehicle should be a member of the science staff who is familiar with handling the sources. This person should be responsible for the safety and security of the sources throughout, ensuring that they are stored properly when they reach their destination.

The *Code of Practice for the Safe Transport of Radioactive Material* (ARPANSA 2008a) covers the transport of all radioactive materials in Australia. When packed correctly, following the procedures below, a source recommended in this document for use in schools becomes an 'Excepted Package' under the Code. If there is any uncertainty about the transport of radioactive material, consult your radiation regulatory authority for advice. Radioactive materials should never be transferred to other establishments without the permission of the two radiation supervisors responsible.

Requirements for an Excepted Package

The *Code of Practice for the Safe Transport of Radioactive Material* (ARPANSA 2008a) has three main requirements for a package containing radioactive materials to be classed as an excepted package.

- The activity of the radioactive material will be less than specified activities, depending on the radioisotope. The activity requirements are met for all sources recommended for use in schools in this document.
- The dose rate at 10 cm from any point on the external surface of the unpackaged item will not be greater than 0.1 mSv/h. This requirement will be met for all sources recommended for use in schools in this document.
- The dose rate at any point on the external surface of the package will not be greater than 5 μSv/h. All sources recommended for use in schools in this document will also meet this requirement if the guidance in this Section is followed.

Packaging for an Excepted Package

The Code requires the package to retain its contents under conditions likely to be found in routine transport.

You should therefore pack a cup source in its normal container at the centre of a substantial cardboard or metal box (approximately 300 mm cube) using any lightweight packaging material.

You should wrap a uranium or thorium compound in an appropriate container inside a strong plastic bag; tie this and then securely pack it in a substantial cardboard or metal box.

You should restrict transportation of radioactive material in solution to a 30 ml protactinium generator. Keep this upright and surrounded by a mineral absorbent (e.g. vermiculite or perhaps cat litter) in a sturdy, watertight outer container, wrapped in a strong plastic bag. Tie this and securely pack it in a substantial cardboard or metal box.

Load all packages securely, as far as possible from the occupants, and out of sight, in the boot of the vehicle. Lock the vehicle whenever it is left unattended.

Labelling of an Excepted Package

The *Code of Practice for the Safe Transport of Radioactive Material* (ARPANSA 2008a) requires that each item inside the package bears the marking 'RADIOACTIVE'. The package itself will also need to bear the marking 'RADIOACTIVE' on an internal surface so that, when the box is opened, a warning of the presence of radioactive material is visible. The external surface of the package will also need to be labelled with the appropriate UN number, either UN 2910 (which is for 'radioactive material, excepted package – limited quantity of material' and is appropriate for unsealed radioactive sources) or UN 2911 (which is for 'radioactive material, excepted package – Instruments or Articles' and is appropriate for sealed radioactive sources). No external signs are required on the vehicle.

Documentation

You do not require a dangerous goods declaration for transport of an excepted package. Standard transport documents should contain the names and addresses of the sender and recipient and the relevant UN number.

Further guidance on the transport of radioactive materials may be found in the *Safety Guide for the Safe Transport of Radioactive Material* (ARPANSA 2008b).

5. Incidents

5.1 Spills and Decontamination

Work with radioactive sources recommended in this document would rarely give rise to a radioactive spill, i.e. an incident in which a radioactive material contaminates the working area. However, if *any* source is dropped, *including* the cup source, the surface on to which it fell should be checked for radioactive contamination (even if no spill is visible).

You would be wise to make provision for dealing quickly, safely and efficiently with any spills that may occur. This provision should form part of the risk assessment for the whole activity; see Annex 3 for model risk assessments specific to most types of sources.

All members of staff using sources should be familiar with the procedures described below. RPS1 (ARPANSA 2002) requires that all incidents or accidents, for example a spill involving radioactive material, are reported to the radiation regulatory authority without delay. This will usually be the radiation supervisor initially. If the radiation supervisor is available, it may be appropriate for him or her to oversee the cleanup process. In extremely rare circumstances, where a spill is large or widespread, you should take containment measures (see below), restrict access and contact the regulatory authority immediately.

5.2 Avoiding Spills

You should design normal working practices to:

- avoid a spill in the first place
- limit the volume of material to be used
- limit the extent of any spill
- make it easier to clear up if a spill does occur.

Work practices based on the recommendations in Annex 4 will fulfil this need for unsealed radioactive materials.

For example, it is most important that you carefully inspect the protactinium generator and the radon-220 (thoron) generator for deterioration or damage before and after use. Both should always be used in a tray.

5.3 Anticipating a Spill

All science departments should have chemical spill kits readily available.

In addition to the items in the normal chemical spill kit, the following items should be available:

- disposable gloves
- a pack of soft paper towels or tissues
- a pack of filter papers

- a disposable dust mask (where powders, e.g. thorium compounds are present)
- a working radiation detector.

5.4 ACTION TO BE TAKEN FOLLOWING A SPILL

Personal protection

Where unsealed radioactive materials are used, the teacher or demonstrator should wear a lab coat and disposable gloves. Also, if the materials contain fine powders (such a thorium compounds), a disposable dust mask should also be worn. Use of a protactinium generator containing hydrochloric acid will also require the wearing of eye protection (goggles).

Thorough personal washing is, of course, vital after dealing with any spill. This should be carried out at a sink in the area where the spill occurred, to avoid any possibility of spreading contamination to other areas. If there is any possibility that a lab coat, or other item of clothing, has been contaminated, you should wash it separately from other items before normal laundering. Seal significantly contaminated items in strong plastic bags and consult the radiation regulatory authority.

Containment

The most important and immediate action after a spill is to stop the radioactive material (and any other hazardous material) from spreading any further. The action taken will depend on the type of spill. The following actions are recommended:

- *Small amounts of crystalline materials* (such as uranyl nitrate): brush this carefully on to filter paper using a tissue and return it to an appropriate container.
- *Spilt liquids*: cover these with a mineral absorbent (or tissues for very small quantities).
- *Spilt powders* (e.g. thorium compounds): cover them and the area surrounding them with damp tissues or paper towels and keep air disturbance to a minimum.

Containment will be much easier if the spill has occurred into a tray. Label any area that may be contaminated and could pose a hazard to others and restrict access, if appropriate.

Cleaning up and disposal

Once a spill has been contained, it should be cleaned up as soon as possible. Students should not be present while this takes place. In the extremely unlikely event of a larger or widespread spill (particularly if a fine powder, such as a thorium compound, is involved), it would be wise to close windows, lock the room and consult the radiation regulatory authority, so that the situation can be assessed before proceeding. For example, it may be necessary to use more sensitive contamination-monitoring instruments than are normally available in the school.

However, in most circumstances, the spill will be small. The area should initially be cleaned with soft paper towels or tissues (held by forceps or tongs) moistened with water or a very dilute detergent solution. The cleaning process should always commence from the outer extent of the spill and proceed towards the centre.

You should place used paper, gloves, dust masks and small amounts of mineral absorbent, whether or not likely to be contaminated, in a strong plastic bag and dispose of these in a bin that will be emptied directly by a waste contractor.

You should scoop larger quantities of mineral absorbent into a bucket and wash in water. If the mineral absorbent contained acid, add sodium carbonate. If it contained pentyl ethanoate (amyl acetate) solvent, add detergent. Pour the resulting liquid down an appropriate sink with copious amounts of water.

Checking for contamination

After a spill has occurred and has been cleaned up, you will need to check the affected area for contamination. Contamination may not be visible, so a check will need to be made for radioactivity. You should very slowly scan the radiation detector over the area, keeping the end window within 5 mm of the affected surface without touching it. You should investigate any regions of apparently increased count rate over background in more detail. The radiation detector could be supported close to the surface, using a clamp and stand (resting the base on an uncontaminated surface). If a 2 minute reading of the activity of a suspect area reveals a count of more than 1.5 times background, more cleaning will be required using tissues and a detergent solution. If contamination persists, or the radiation supervisor has any doubt about the success of the clean up, you should protect the area, restrict access and put appropriate warning notices in place. Contact the radiation regulatory authority for advice.

5.5 CHECKING A SOURCE AFTER A SPILL

After a radioactive source is dropped or spilt, you should thoroughly inspect and then wipe test the source if you suspect damage. The procedure is similar to that given in Section 4.4 and Annex 5.

5.6 LOSS OF A RADIATION SOURCE

If all movements of radiation sources are recorded accurately in the use log, the chance of such a source being lost is very small. However, if a radiation source is not where it should be, the radiation supervisor should check that it has not been:

- returned to the wrong store
- left inside the piece of equipment within which it was last used
- temporarily removed to another area, or
- placed with waste for disposal.

RPS1 (ARPANSA 2002) requires that all incidents or accidents involving radiation sources, such as a situation where a radiation source cannot be found, be reported to the radiation regulatory authority. In the first instance, this will usually be the Principal. If you suspect that someone has removed the source unlawfully from the premises, the Principal, in consultation with the radiation regulatory authority, will need to inform the police.

Managers and staff in schools and colleges should take all possible steps to ensure that loss of a radiation source cannot happen.

Annex 1

Internal and External Radiation Exposure

There are two possible modes of radiation exposure: external or internal exposure. The degree of hazard associated with the two basic modes of irradiation can be quite different for a given radioactive material.

A1.1 External Radiation Exposure

External irradiation results from the exposure to X-rays or to radiations from sealed or unsealed radioactive sources external to the body.

The radiation dose from X-rays depends on the factors listed in Section 2.2.

The radiation dose from radioactive materials external to the body depends on the radionuclide and on:

- the type of radiation emitted by the radioactive materials – that is, alpha particles, beta particles, gamma radiation or combinations of these, and the energy of the radiation emitted
- the activity of the radioactive material
- the distance between the source and the body
- the protective barrier between the source and the body
- the duration of exposure to the radiation.

A1.2 Internal Radiation Exposure

Internal irradiation results from the entry of radioactive materials into the body, with the resultant exposure of organs, which have absorbed such materials and, in most cases, the exposure of other nearby organs. The amount of radioactive material taken into the body depends on a variety of factors including:

- the activity of the radioactive materials being handled
- its physical state (e.g. liquid, gas, powder, aerosol, solid)
- its concentration and chemical form
- methods of handling and precautions taken
- personal hygiene
- the duration of handling
- site of entry into body (e.g. skin, wound, mouth, nose, etc.).

The radiation dose resulting from the entry of a particular amount of radioactive material into the body depends upon:

- the type of radioactive material
- the type and energy of the radiation it emits
- its solubility, physical and chemical form, and effective half-life
- the biological behaviour (or characteristics) of the radioactive material (e.g. some elements are selectively absorbed by certain organs of the body, such as iodine by the thyroid, and radium and strontium by bone).

The annual limit on intake (ALI) gives the activity of a radionuclide, which if ingested or inhaled, will result in a (lifetime) dose of 20 mSv to the individual. Thus, radionuclides with a low ALI are more hazardous than those with a high ALI.

The handling of an unsealed radioactive material may pose a much greater problem than the handling of a sealed radioactive material of the same activity. This is illustrated by the luminous wrist watch. Many people wear such watches, which contain small quantities of radioactive materials (sometimes radium in older watches) in the luminous paint on the dial and hands. As a result such people may be subject to external irradiation, but the dose received by the skin is a very small fraction of the annual limit. However, if the quantity of radium found in the older watches were to be incorporated in the internal body organ which will retain it throughout the person's lifetime (i.e. in the bone), it would deliver approximately the annual dose limit to that organ.

A1.3 SHIELDING

Generally, the radiation levels in approved school experiments involving X-rays or radioactive materials are so low that no special shielding is required. However, it is important when using sources of radiation in schools to demonstrate the role of shielding as part of safe working practices.

Radioactive materials generally emit alpha or beta particles or gamma rays or combinations of these, while X-ray units generate electromagnetic waves similar to gamma rays, but usually of lower frequency (and longer wavelength). The amount and type of shielding needed depends upon the penetrating power of the particular form of radiation. The denser the shielding material the better shield it will be. Alpha particles, being charged and relatively heavy atomic particles, are easily stopped while gamma rays, usually being very short waves, are far more penetrating and hard to stop. To sum up:

Alpha particles	–	Stopped by sheet of paper or surface layers of skin.
Beta particles	–	Stopped by a few millimetres of aluminium or 1-2 centimetres of plastic.
Gamma rays	–	Almost completely stopped by about 1 metre of concrete or about 5 centimetres of lead. Most will pass through the human body.
X-rays (medical)	–	Almost completely stopped by 2-3 millimetres of lead, or about 10-15 centimetres of concrete. Will pass through the body with some absorption depending on the density of organs in the beam (e.g. skin, bones etc.).

Annex 2

Properties of Some Radiation Sources

A2.1 Properties of Some Radioactive Materials

Radionuclide	Cobalt-60	Strontium-90/ Yttrium-90		Americium-241
Half-life (years)	5.26	29.1	2.7 d	432
Main ionizing radiations	γ (β)	β		α (γ)
Energies of main ionizing radiations	1173/1333 keV γ 318 keV β	0.546 MeV	2.284 MeV	59.5 keV gamma (max) 5.48 MeV alpha (max)
Gamma factor (mSv/h/MBq @1m)	3.703×10^{-4}	-	-	8.497×10^{-5}
ALI – ingestion (MBq)	5.9	0.714	7.4	0.1
ALI – inhalation (MBq)	0.69	0.133	13.3	5.12×10^{-4}
Exempt activity (Bq)	10^5	* 10^4	10^5	10^4
Exempt concentration (Bq/g)	10	* 100	1000	1

Radionuclide	Radium-226	Thorium-232	Caesium-137	Polonium-210
Half-life (years)	1602	1.4×10^{10}	30	138 d
Main ionizing radiations	α, β, γ	γ (α) (excluding progeny) α, β, γ (including progeny)	γ (β)	α
Energies of main ionizing radiations	Ra: 186 keV γ Bi: 609, 1120, 1764 keV γ	4.01 MeV α; ~ 60 keV γ; 130 keV γ (excluding progeny) α to 9 MeV; β to 2.3 MeV; γ to 2.6 MeV (including progeny)	662 keV	5.3 MeV (alpha)
Gamma factor (mSv/h/MBq @1m)	3.1×10^{-5} (including progeny)	1.85×10^{-5} (exclusive of progeny)	1.032×10^{-4} (including progeny)	1.424×10^{-9}
ALI – ingestion (MBq)	7.14×10^{-2}	0.2 (oxides and hydroxides) (excluding progeny)	1.538	8.3×10^{-2}
ALI – inhalation (MBq)	1.25×10^{-3}	9×10^{-4} (oxides and hydroxides) (excluding progeny)	4.17	6.7×10^{-3}
Exempt activity (Bq)	* 10^4	* 10^3	* 10^4	10^4
Exempt concentration (Bq/g)	* 10	* 1	* 10	10

* assumes that the isotope is in equilibrium with its progeny

The gamma factor gives the radiation dose level at 1 m from a point source that has an activity of 1 MBq. You can use the gamma factor to estimate the dose rate at various distances from your sources. You need to be far enough away for the sources to be 'point' sources – more than two times the diameter of the active part of the source is a rough guide.

The ALI (annual limit on intake) gives a useful indication of the hazard from an unsealed radioactive material. The ALI is the activity of the radioactive material, which if inhaled or ingested, will give a dose of 20 mSv (the occupational dose limit for one year). The smaller the ALI, the greater the hazard. Thus, americium-241 is more hazardous if breathed in (the relevant ALI is 512 Bq) than ingested (this ALI is 100 000 Bq).

A2.2 Rules of Thumb

Range of beta particles in air ~ 3.7 metres per MeV

Range of beta particles in matter, R ~ $E_{max}/2$, where R is the range in g/cm^2 (range in cm times the density in g/cm^3) and E_{max} is in MeV.

Dose rate to skin at 30 cm from a beta point source (neglecting self and air absorption) is ~ 0.12 mSv/h per MBq for many beta emitters.

Range of alpha particles in air:

For alpha particle energies of $E < 4$ MeV, $R \approx 0.56\ E$

For alpha particle energies of $4 < E < 8$ MeV, $R \approx 1.24\ E - 2.62$

Where R = range in cm of air at 1 atm and 15^{o}C, and

E = energy in MeV.

A2.3 Skin Penetration

Alpha particles require at least 7.5 MeV to penetrate the protective layer of the skin.

Beta particles require at least 70 keV to penetrate the protective layer of the skin.

The data in A3.1, A3.2 and A3.3 above are taken from:

Handbook of Health Physics and Radiological Health, 3rd edition (Shleien et al. 1998)

Radionuclide and radiation protection data handbook, Radiation Protection Dosimetry, vol. 98, no. 1, pp. 1-168 (Delacroix et al. 2002)

ICRP Publication 68 'Dose coefficients for intakes of radionuclides by workers' (ICRP 1995)

A2.4 Production and Absorption of X-rays

When electrons, such as those produced in teltron tubes or a Crookes tube, hit the walls of the glass tube they may be stopped. These electrons give off (bremsstrahlung) radiation as they decelerate. This radiation is low energy X-rays, the maximum energy being the same as the maximum energy that the electrons had. This is the kV applied to the tube i.e. a 5 kV tube will have electrons with a maximum energy of 5 keV. X-rays produced would then have a maximum energy of 5 keV. Such

X-rays are often described as being 'soft' because of the ease with which they are absorbed in matter. While this characteristic enables soft X-rays to be readily shielded, it also makes them particularly hazardous since they are highly absorbed even by soft tissue. For example, 5 keV X-rays will be almost completely absorbed in about 0.5 mm of glass or about 3 mm of soft tissue.

Table 4 gives the linear attenuation coefficients[2] of X-rays in soft tissue and in glass. This information should assist you when you are carrying out a risk assessment of electron tubes, for example.

Table 4: Linear Attenuation Coefficients

X-ray energy (keV)	Linear attenuation coefficient in soft tissue (cm^{-1})	Linear attenuation coefficient in borosilicate (Pyrex) glass (cm^{-1})
5	44	275
10	5.3	36.7
20	0.6	4.45
30	0.17	1.27

You can use the linear attenuation coefficient in the equation:

$$I = I_0 e^{-\mu t}$$

Where I is the intensity of X-rays emerging from the barrier
I_0 is the intensity of the X-rays impinging on a barrier of thickness t (cm)
μ is the linear attenuation coefficient of the barrier material (cm^{-1}).

This will give you a rough estimate of the effectiveness of the barrier in absorbing X-rays.

[2] Data derived from 'Tables of X-ray mass attenuation coefficients and mass energy-absorption coefficients' J.H. Hubbell and S.M. Seltzer available at http://physics.nist.gov/PhysRefData/XrayMassCoef/cover.html

Annex 3

Model Risk Assessments for Radioactive Sources

A3.1 The need for Risk Assessments

This document recommends that no work be carried out using radioactive sources in schools or colleges unless a risk assessment shows that it is acceptable. The radiation supervisor should ensure that members of staff, who use radioactive sources, are familiar with the hazards and control measures associated with each.

A3.2 Use of Model Risk Assessments

The following sheets provide model risk assessments for the most common radioactive sources used in schools and colleges. Your State or Territory occupational health and safety legislation requires you to identify workplace hazards. The information in these model risk assessments may assist you in this process. Where advice or assistance is required from the relevant occupational health and safety regulator, you should contact your Workplace Safety Authority. Details are available at the Heads of Workplace Safety Authorities website (www.hwsa.org.au/about_us/about_us-associated_internet_sites.aspx).

As with all model risk assessments, you should consider adaptation to cover the special circumstances of your particular establishment, class or teacher. For example, if the management is not sufficiently effective to ensure that appropriate control measures will be followed, it may be unsafe to store or use a particular source (this applies particularly to radon-220 generators). Similarly, if there are serious behaviour problems in a particular class, use of *any* radioactive sources may be inappropriate.

If your school stores or uses other radioactive sources, we advise that you produce similar risk assessments. The radiation regulatory authority and the radiation supervisor should both agree on these assessments.

A3.3 Notes on these Model Risk Assessments

Radioactive sources rarely emit only one type of ionizing radiation. The most significant radiations are given for each source. Those given in parenthesis may need to be taken into account when planning investigations about the properties of the different radiations.

Several references are made to 'large forceps' as a handling tool for radioactive sources. Suitable forceps are 300 mm extra-long, stainless steel forceps. You could also use plastic forceps or tongs, provided that they are sufficiently strong and easy to decontaminate.

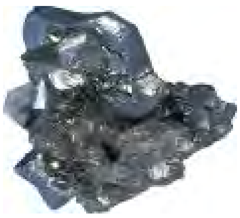
You should inspect and wipe test sources regularly; see Annex 5.

A3.4 List of Model Risk Assessments

1. Radioactive rock
2. Smoke alarm
3. Luminous dial and spinthariscope

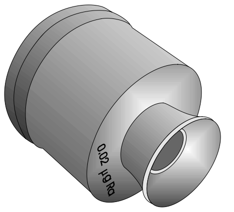
4. Becquerel plate and scintillation plate
5. Diffusion cloud-chamber source
6. Expansion cloud-chamber source
7. Perspex slide source
8. Cup source
9. Protactinium generator
10. Radon-220 (thoron generator (not permitted by some Principals/Education Departments)).

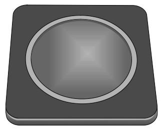
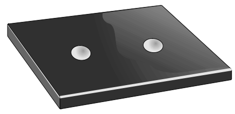
1 Radioactive rock

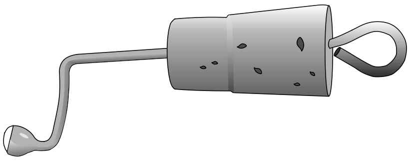
Description	 Typical radioactive minerals offered by educational suppliers are allanite, autunite, davidite, monazite, phosphuranylite, pitchblende and torbenite. These usually contain thorium or uranium minerals. The geography or geology department may also keep rocks of this type and the radiation supervisor may wish to ensure that the control measures described here are applied as in the science area.
Use	To demonstrate that natural rocks contain radioactive minerals. A rock should be regarded as radioactive if the count rate at the surface is more than 50% above the background count.
Supplier	Supplied, for example, by Philip Harris or Griffin & George as a set. Sometimes collected in the field by enthusiastic students, geology or physics teachers.
Original activity	Typically from 0.18 kBq g^{-1} to 5 kBq g^{-1}.
Radionuclide	Thorium and/or uranium.
Main ionizing radiations	α, β, γ in any combination.
Half-life	Typically millions of years.
Hazard	External irradiation of the body, including possibly more-sensitive organs such as the eyes. Internal irradiation of the body arising from rock fragments which have entered by inhalation, absorption through the skin, ingestion or through wounds.
Risk assessment	Provided the control measures given below are applied, the risk to health from small rock samples of this type is minimal. However, where large, and/or particularly active specimens are kept, the radiation supervisor should be consulted for advice.
Control measures	**Always follow the local rules for the use of radioactive sources.** Radioactive rocks should be treated in the same way as other radioactive sources.
During use	The lid of the container may be removed for inspection or checking the rock with a radiation monitor. The rock should not be touched with the hands.
Inspection	Annually or after use by students. A rock should be checked for damage and any chips or fragments disposed of. Forceps or disposable gloves should be used to handle rocks. Care should be taken to avoid chipping the rock with forceps. Handling time with gloves should be kept short.
Wipe test of source	Not required.
Contamination check of container	Annually or if damage to the rock is suspected. The container should be cleaned if necessary.
Storage and labelling	Radioactive rocks are best stored in sturdy, transparent, plastic or glass containers with secure lids, labelled with a radioactive warning sign and kept in the radioactive materials store or a locked drawer or cupboard. If rocks are to be displayed, they should always be kept in a locked cabinet and the count rate on the outside surface of the glass should be similar to the background level. Rocks of high activity should not be displayed.
Spills	A lab coat and disposable gloves should be worn. Should a radioactive rock be dropped, the area on to which it fell should always be checked for contamination and decontaminated if necessary.
Disposal	Small quantities of radioactive rocks may be disposed of in a strong plastic bag, tied and put in the refuse.

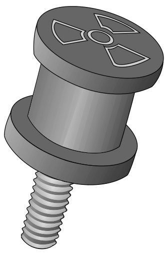
2	Smoke alarm	
Description		Most domestic smoke alarms use an ionization chamber smoke detector. This is a small metal chamber containing a radioactive source. If smoke enters the chamber, the level of ionization reduces, decreasing the flow of electric current in a circuit and triggering a siren.
Use	To show that most domestic smoke alarms contain a radioactive source. To explain the widespread agreement that the very low radiological risk and the substantial benefits in terms of life-saving, make it well worth installing such devices in the home.	
Supplier	Hardware stores.	
Original activity	Typically 37 kBq (1 µCi).	
Radionuclide	Americium-241.	
Main ionizing radiations	α, γ.	
Half-life	432 years.	
Hazard	External irradiation of the body, including possibly more-sensitive organs such as the eyes. Internal irradiation of the body arising from materials which have entered by inhalation, by absorption through the skin, by ingestion or through wounds.	
Risk assessment	Provided the control measures given below are applied, the risk to health from a source of this type is minimal. Note: such control measures are **not** required for smoke alarms used in the home, which are extremely unlikely to suffer damage in the normal position on the ceiling. Climbing a step ladder to reach the alarm is likely to present a far greater risk to health and safety than the radioactive material.	
Control measures During use	**Always follow the local rules for the use of radioactive sources.** The plastic cover of the smoke alarm may be opened for observation, to detect ionizing radiation and to insert the battery. Under no circumstances should the metal ionization chamber be opened. The test button or smoke can be used to trigger the alarm.	
Inspection	Annually and after use by students. Check that the ionization chamber is undamaged.	
Wipe test of source	Annually or if damage is suspected. The accessible surfaces of the ionization chamber should be tested.	
Contamination check of container	Not required unless leakage is suspected.	
Storage and labelling	A smoke alarm should be put in a strong, self-sealing, plastic bag (to avoid any contamination from other sources), labelled with a radioactive warning sign and kept in the radioactive materials store.	
Spills	A lab coat and disposable gloves should be worn. If a smoke alarm is dropped, it is most unlikely that any radioactive spill will occur. Should damage occur, the fragments should be swept into a strong plastic bag, which is tied and put in the refuse, the area checked for contamination and decontaminated if necessary.	
Disposal	A single smoke detector may be securely wrapped in a strong plastic bag and put in the refuse.	

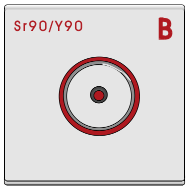
3 Luminous dial and spinthariscope

Description	  Radium-based paint was in regular use in the first half of the 20th century to make various objects self-luminous in the dark. In a spinthariscope, scintillations are produced on a fluorescent screen by the action of particles from a radioactive source.
Use	To demonstrate that old watches, clocks and instruments with self-luminous dials use radioactive materials to make a fluorescent substance (usually zinc sulfide) glow. A spinthariscope demonstrates the particulate nature of ionizing radiation. The user normally needs to spend 10 minutes or more in the dark before observation begins.
Supplier	Luminous dials were often ‘donated’ by generous physics staff. Spinthariscopes were usually supplied by Philip Harris.
Original activity	Luminous dials: normally weak. Spinthariscope: typically 0.74 kBq (0.02 μCi).
Radionuclide	Usually radium-226.
Main ionizing radiations	α, β, γ.
Half-life	1602 years.
Hazard	External irradiation of the body, including possibly more-sensitive organs such as the eyes. Internal irradiation of the body arising from flakes of self-luminous paint which have entered by inhalation, absorption through the skin, ingestion or through wounds.
Risk assessment	Provided the control measures given below are applied, the risk to health from a source of this type is minimal. However, the radium-luminised paint in some older items can become brittle with age. This may flake and release fine particles. These older items should be checked very carefully for contamination. Instrument dials with luminous markings, produced before the regulations of the early 1960’s, may have activities of over 370 kBq and may be poorly protected. They should not be kept. In cases of uncertainty, the radiation supervisor should be consulted.
Control measures Physical design	**Always follow the local rules for the use of radioactive sources.** It is important that all radioactive dials kept are securely encased, effectively making them sealed radioactive sources. Most luminous watches provide satisfactory protection. An old alarm clock usually has holes through which the controls pass and sometimes a loose-fitting face; these should be sealed with an epoxy resin (such as Araldite). An unprotected face from an old instrument or clock should be kept in a sealed, transparent, plastic container. The source inside a spinthariscope is very well encased.
During use	No attempt should be made to operate any old instruments containing radioactive dials (such as by blowing into pressure-operated altimeters). Demonstrations should be limited to using a radiation detector to demonstrate that the device is radioactive and opportunities given to view items in the dark.
Inspection	Annually and after use by students. A check should be made that the visible luminous paint is not crumbling, the glass is intact and that the luminous paint is completely enclosed.
Wipe test of source	Annually or if damage is suspected. The complete outer casing should be tested.
Contamination check of container	Not required unless leakage is suspected.
Storage and labelling	A fully-encased dial or spinthariscope should be kept in a strong, self-sealing, plastic bag, labelled with a radioactive warning sign and kept in the radioactive materials store.
Spills	A lab coat, toxic dust mask and disposable gloves should be worn. If a luminous source is dropped, it is unlikely that any radioactive spill will result. Should damage occur, the fragments should be swept into a strong plastic bag, which is tied and put in the refuse, the area checked for contamination and decontaminated if necessary.
Disposal	Local requirements should be checked with your radiation regulatory authority.

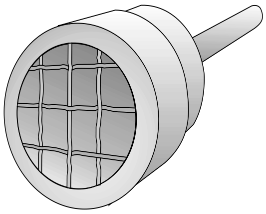
4	Becquerel plate and scintillation plate	
Description	A radioactive material lies in a recess in a plastic plate, normally protected by a transparent cover.	
	 **Becquerel plate**	 **Scintillation plate**
Typical dimensions (mm)	Length 38, width 38, thickness 4.	Length 50, width 25, thickness 4.
Use	Used to produce blackening (fogging) of photographic plates, simulating Henri Becquerel's accidental discovery of radioactivity.	Allows scintillations, produced by a radioactive material in a phosphor, to be observed with a magnifier.
Radionuclide	Uranium oxide paint.	Various radioactive phosphors.
Supplier	These sources have not been available for many years. Most were originally supplied by Griffin & George and Philip Harris.	
Original activity	Weak.	
Main ionizing radiations	α, β, γ.	
Half-life	Various, but long.	
Hazard	External irradiation of the body, including possibly more-sensitive organs such as the eyes. Internal irradiation of the body arising from materials which have entered by inhalation, by absorption through the skin, by ingestion or through wounds.	
Risk assessment	Provided the control measures given below are applied, the risk to health from a source of this type is minimal.	
Control measures	**Always follow the local rules for the use of radioactive sources.**	
During use	These sources should be handled by the edges.	
Inspection	Annually and after use by students. This type of source should be checked for crumbling of the active material and any damage to the plate or its cover.	
Wipe test of source	Annually or if damage is suspected. The outer surfaces of the plate should be tested.	
Contamination check of container	Not required unless leakage is suspected.	
Storage and labelling	For successful use, scintillation plates should be kept in the dark to avoid fluorescence caused by ambient light. They can be kept in any sturdy container, labelled with a radioactive warning sign and kept in the radioactive materials store.	
Spills	A lab coat and disposable gloves should be worn. If a source is dropped, the area on to which it fell should always be checked for contamination and decontaminated if necessary.	
Disposal	To comply with the NDRP, disposal of this type of source can only be via an authorised route. The radiation regulatory authority should be consulted.	

5	Diffusion cloud-chamber source
Description	 This source is part of a diffusion cloud chamber. It is a sample of radium-based luminous paint in a small metal cup attached to a stiff wire, which is mounted in a cork.
Typical dimensions (mm)	Length 70, height 25, diameter of cup 5.
Use	Observation of tracks produced by ionization due to alpha particles.
Supplier	Supplied by Griffin & George as part of a diffusion cloud chamber.
Original activity	Typically 0.74 kBq (20 nCi).
Radionuclide	Radium-226.
Main ionizing radiations	α, β, γ.
Half-life	1602 years
Hazard	External irradiation of the body, including possibly more-sensitive organs such as the eyes. Internal irradiation of the body arising from materials which have entered by inhalation, by absorption through the skin, by ingestion or through wounds.
Risk assessment	Provided the control measures given below are applied, the risk to health from a source of this type is minimal.
Control measures During use	**Always follow the local rules for the use of radioactive sources.** The radioactive end of the source should not be touched. The source should be kept in the cloud chamber.
Inspection	Annually and after use by students. The sources should be checked for damage but kept well away from the eyes. A mirror is useful for closer inspection. The radium-based paint should not be crumbling or cracked.
Wipe test of source	Annually or if damage is suspected. The outer surfaces should be tested, taking great care not to damage the active sample.
Contamination check of container	Not required, unless leakage is suspected. The amount of radium in this source is so small that contamination due to radon will be insignificant.
Storage and labelling	The source should be removed from the cloud chamber by gently pulling out the cork and the wire mounting. Handling should be by the wire loop or the cork; the radioactive end should not be touched. Several sources may be kept together in a closed, plastic, glass or metal container, labelled with a radioactive warning sign and kept in the radioactive materials store.
Spills	A lab coat and disposable gloves should be worn. If a cloud chamber source is dropped, the area on to which it fell should always be checked for contamination and decontaminated if necessary.
Disposal	To comply with the NDRP, disposal of this type of source can only be via an authorised route. The radiation regulatory authority should be consulted.

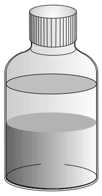
6	Expansion cloud-chamber source	
Description		This source is part of an expansion cloud chamber. It consists of a radium source encapsulated in silver foil held together by a brass assembly, which screws into the chamber.
Typical dimensions (mm)	Diameter 7, height 8, (excluding threaded shaft).	
Use	Observation of tracks produced by ionization due to alpha particles.	
Supplier	Supplied by Philip Harris as part of an expansion cloud-chamber apparatus.	
Original activity	Typically 37 kBq (1 μCi).	
Radionuclide	Radium-226.	
Main ionizing radiations	α, β, γ.	
Half-life	1602 years.	
Hazard	External irradiation of the body, including possibly more-sensitive organs such as the eyes. Internal irradiation of the body arising from materials which have entered by inhalation, by absorption through the skin, by ingestion or through wounds.	
Risk assessment	Provided the control measures given below are applied, the risk to health from a source of this type is minimal.	
Control measures	**Always follow the local rules for the use of radioactive sources.**	
During use	This source should be kept in its cloud chamber. It should not be touched.	
Inspection	Annually and after use by students. The source (left in the cloud chamber) should be checked for damage, keeping at least 20 cm from the eyes.	
Wipe test of source	Annually or if damage is suspected. The outer surfaces should be tested.	
Contamination check of container	Due to the very small amounts of radon gas emitted from radium sources, the inside of the cloud chamber should be checked annually and decontaminated if necessary. This is also required if leakage is suspected.	
Storage and labelling	**It is usually best not to try to remove the source from this type of cloud chamber**, because the process can be difficult and may damage the source. Therefore, the whole chamber should be labelled with a radioactive warning sign and stored in a labelled, locked cupboard, preferably near to the main radioactive materials store. It is normally best not to keep the whole cloud chamber in the main radioactive materials store, because it would be difficult to clean if contaminated by other sources. It may also be too large to fit in the main store.	
Spills	A lab coat and disposable gloves should be worn. If a cloud chamber source is dropped, the area on to which it fell should always be checked for contamination and decontaminated if necessary.	
Disposal	To comply with the NDRP, disposal of this type of source can only be via an authorised route. The radiation regulatory authority should be consulted.	

7	Perspex slide source					
Description				The active substance or foil source is sealed into a perspex slide with epoxy resin. Strontium-90, americium-241 and radium-226 sources have small holes in the perspex and the source is protected with a thin layer of gold.		
Typical dimensions (mm)	Length 50; width 50; thickness 3.5.					
Use	Investigation of basic properties of ionizing radiations.					
Supplier	These sources have not been available for many years. The supplier was Labgear Ltd (no longer in business). The sealed radionuclide was processed and mounted by Nycomed Amersham.					
Radionuclide	**Cobalt-60**	**Strontium-90/ Yttrium-90**		**Americium-241**	**Radium-226**	**Thorium-232**
Main ionizing radiations	γ (β)	β		α (γ)	α, β, γ	β (α)
Original activity kBq (µCi)	37 (1)	37 (1)	185 (5)	3.7 (0.1)	185 (5)	37 (1)
Half-life (years)	5.26	28.1	28.1	432	1602	1.4×10^{10}
Hazard	External irradiation of the body, including possibly more-sensitive organs such as the eyes. Internal irradiation of the body arising from materials which have entered by inhalation, by absorption through the skin, by ingestion or through wounds.					
Risk assessment	Provided the control measures given below are applied, the risk to health from a source of this type is minimal.					
Control measures During use	**Always follow the local rules for the use of radioactive sources.** This type of source should be held near the edge and the source kept at least 10 cm from the hand; large forceps are ideal. Only one source should be used at a time. Between investigations, the source should be returned to its container.					
Inspection	Annually and after use by students. The slide should be checked for any signs of damage. The most active surface should be viewed indirectly, using a plane mirror on the bench. Never point this surface towards the eye. The resin seal and any visible foils should be intact. A record should be kept of any blemishes, particularly to the foil surface.					
Wipe test of source	Annually or if damage is suspected. The outer surface should be tested, taking care not to damage the seals over the active material.					
Contamination check of container	Not required unless leakage is suspected. However, due to the very small amounts of radon gas emitted from radium sources, an annual check should be made on the containers of these sources, which should be cleaned if necessary.					
Storage and labelling	The sources may be kept together in a small plastic 35 mm slide box. The radium source should be wrapped in aluminium foil to contain any contamination from small quantities of radon gas. A 50 mm square, lead absorber should be placed at each end of the 'stack' of sources. The slide box should be labelled with a radioactive warning sign and kept in the radioactive materials store.					
Spills	A lab coat and disposable gloves should be worn. If a source is dropped, the area on to which it fell should always be checked for contamination and decontaminated if necessary.					
Disposal	To comply with the NDRP, disposal of this type of source can only be via an authorised route. The radiation regulatory authority should be consulted.					

8 Cup source

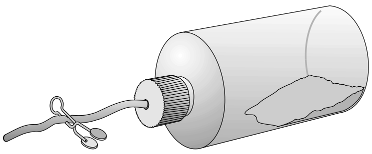
Description		The radioactive material is enclosed in a metal foil and secured at the base of a metal cup by a circlip. Wire mesh covers the open end of the cup. A stem is used for handling and mounting. Details of the radionuclide and original activity are usually stamped on the back of the cup, next to the stem. A serial number may be engraved there too. Cup sources are supplied in a small lead pot with a lead lid inside a suitably-labelled, hardwood, storage container.			
Typical dimensions (mm)	Length 22, diameter 13, stem diameter 4.				
Use	Investigation of basic properties of ionizing radiations.				
Supplier	Usually Griffin & George or Philip Harris, with radionuclide manufactured by Nycomed Amersham. Panax also supplied this type of source in its kits.				
Original activity	3.7 kBq (0.1 μCi) to 370 kBq (10 μCi), depending on type. Most commonly 185 kBq (5 μCi).				
Radionuclide	**Cobalt-60**	**Strontium-90**	**Americium-241**	**Plutonium-239**	**Radium-226**
Main ionizing radiations	γ (β)	β	α (γ)	α	α, β, γ
Half-life (years)	5.26	28.1	432	2.44×10^4	1602
Colour code (if present)	Green	Yellow	Brown	Blue	Red
Hazard	External irradiation of the body, including possibly more-sensitive organs such as the eyes. Internal irradiation of the body arising from materials which have entered by inhalation, by absorption through the skin, by ingestion or through wounds.				
Risk assessment	Provided the control measures given below are applied, the risk to health from a source of this type is minimal.				
Control measures	**Always follow the local rules for the use of radioactive sources.**				
During use	This type of source should be held by the stem and kept at least 10 cm from the hand; large forceps are ideal. Only one source should be used at a time. Between investigations, the source should be returned to its container.				
Inspection	Annually and after use by students. The whole source should be checked for signs of damage. View the most active foil surface using a plane mirror on the bench. Never point the foil surface towards the eye. A record should be kept of any blemishes, particularly to the foil surface.				
Wipe test of source	Annually or if damage is suspected. The outer surface should be tested.				
Contamination check of container	Not required unless leakage is suspected. However, due to the very small amounts of radon gas emitted from radium sources, an annual check should be made on the containers of these sources, which should be cleaned if necessary.				
Storage and labelling	The source should be stored in its lead-lined container, labelled with a radioactive warning sign and kept in the radioactive materials store.				
Spills	A lab coat and disposable gloves should be worn. If a source is dropped, the area on to which it fell should always be checked for contamination and decontaminated if necessary.				
Disposal	To comply with the NDRP, disposal of this type of source can only be via an authorised route. The radiation regulatory authority should be consulted.				

9 Protactinium generator

Description	 This is a sealed, thin-walled polypropylene or Teflon bottle containing an aqueous solution of acidified uranyl(VI) nitrate beneath an equal volume of organic solvent. The protactinium generator can be treated as a sealed source, provided the cap is not removed. Home-made generators may need to be replaced annually, since the organic solvent can soften the plastic bottle or damage the seal in the cap. Commercially made generators have proved to be very long-lasting, most remaining in good condition for well over 10 years.		
Use	When the bottle is shaken, only protactinium passes into the top organic liquid layer. Its decay can then be investigated by placing a radiation detector very close to the organic layer.		
Supplier	Ready-made by Philip Harris, but has not been available for some years. Many schools make their own, but special procedures need to be followed.		
Original activity	Philip Harris version: 44.5 kBq (1.2 µCi). Home-made (30 ml) version 10 kBq (0.37 µCi)		
Radionuclide	**Uranium-238**	**Thorium-234**	**Protactinium-234**
Main ionizing radiations	α	β	β
Half-life	4.5×10^9 years	24 days	72 seconds
Hazard	Concentrated hydrochloric acid is CORROSIVE; Pentyl ethanoate (amyl acetate) is FLAMMABLE; Uranyl(VI) nitrate is VERY TOXIC and RADIOACTIVE. Internal irradiation of the body arising from materials which have entered by inhalation, by absorption through the skin, by ingestion or through wounds.		
Risk assessment	The activity is less than a quarter of that of a typical school cup source. The greatest risk is from contamination if the bottle leaks or the cap is removed. Provided the control measures given below are applied, the risk to health from a source of this type is minimal.		
Control measures	**Always follow the local rules for the use of radioactive sources.**		
During use	**The bottle is not to be opened in normal use.** It should be used in or over a tray (ideally enamel) to contain the solution in the unlikely event of a spill. The bottle may be held in the hand, but for no longer than necessary. When required, shaking should be gentle and take place over the tray. Between investigations, the bottle should be returned to its protective, outer plastic container.		
Inspection	Annually as well as **before and after any use.** Checks should be made for signs of damage or deterioration. If the cap is accessible, a check should ensure that it is tight. (Harris generators have a seal over the cap.)		
Wipe test of source	Annually or if damage is suspected. The outer surfaces of the bottle and its cap should be tested. **Do not open the bottle**.		
Contamination check of container	Annually or if leakage is suspected. Clean if necessary. Contamination means that the bottle may be leaking and further investigation is required.		
Storage and labelling	The bottle should be labelled on the lower half, indicating that it is a radioactive protactinium generator. A label on a cover or a strip of adhesive tape over the cap should state that it is not to be removed. The bottle should be kept upright in a plastic container with tight-fitting lid. This should be labelled with warning signs and full details of the contents and hazards. It should be kept in the radioactive materials store.		
Spills	A lab coat, eye protection and disposable plastic gloves should be worn. A spill should be contained with a mineral absorbent and scooped into a bucket with sodium carbonate and water. Detergent should be added and the resulting liquid poured down a toilet to reach a foul-water drain. Solids should be rinsed and the empty bottle thoroughly washed out. Solids and bottle should be transferred to a strong plastic bag, which is tied and put in the refuse. The surface where the spill occurred should always be checked for contamination and decontaminated if necessary.		
Disposal:	Lab coat, goggles and disposable plastic gloves should be worn. *Home-made generators*: The bottle should be emptied into half a bucket of water and detergent and then poured down an appropriate sink, e.g. in a science laboratory. Then run another 20 litres or so of water into the sink so that a very dilute solution reaches the sewer. The empty bottle should be thoroughly washed out, transferred to a strong plastic bag, tied and put in the refuse. *Commercially-made (sealed) generators*: the radiation regulatory authority should be consulted.		

10 Radon-220 (thoron) generator

(Some Principals/Education Departments do not permit its use)



Description: Originally called a thoron generator, but more correctly termed a radon-220 gas generator. A polythene squeeze bottle containing about 20 g of a thorium compound (usually thorium hydroxide powder). In order to let radon gas out, but keep the powder in, two discs of chamois leather are fitted in the cap to act as a filter. A Mohr clip on a single rubber tube prevents gas escaping when the generator is not in use. Older generators had alternative, unsatisfactory filters and more complex pipework, which should be disposed of carefully and replaced.

Use	When the bottle is squeezed, radon gas travels along the tube into a port on a separate, closed, ionization chamber, where the short half-life of the gas can be determined. Any unused port on the chamber will need to be made gas tight, eg, by fitting a small party balloon over the port and tying it tightly. Unsealed systems should not be used.					
Supplier	The original generators were supplied ready-made by Panax, Griffin and Harris. They have been unavailable to purchase for many years. Some schools have prepared their own generators using polythene wash bottles.					
Original activity	Typically 64 kBq (1.7 μCi).					
Radionuclides	**Thorium-232**	**Radium-228**	**Actinium-228**	**Thorium-228**	**Radium-224**	**Radon-220**
Main radiations	α	β	β	α	α	α
Half-life	1.4×10^{10} years	6.7 years	1.1 hours	1.9 years	3.6 days	52 seconds
Hazard	Thorium compounds are VERY TOXIC and RADIOACTIVE. Internal irradiation of the body arising from materials which have entered by inhalation, by absorption through the skin, by ingestion or through wounds.					
Risk assessment	The activity is usually less than half that of a typical school cup source. Radon gas should not escape if the apparatus is used carefully but, if it did, the concentration in the air would be extremely low. The greatest risk is from inhalation of thorium dust, which is an alpha-emitter. **Extreme care is to be taken if the bottle splits or if top needs to be removed.** *In normal use, provided the control measures given below are applied, risks to health should be very low*. However, stored or used incorrectly, a radon generator can present a greater risk than other sources commonly used in schools. **Some Principals/Education Departments do not permit its use and this needs to be respected.** Science department managers and Principals/Education Departments need to satisfy themselves that staff are fully aware of the hazards and that the control measures given below are in place. If this is not the case, and cannot be addressed, the source should be disposed of. Some radiation supervisors believe that the protactinium generator presents a safer alternative method for half-life investigations.					
Control measures	**Always follow the local rules for the use of radioactive sources.**					
During use	**The bottle is not to be opened.** It should be used in a tray to catch the thorium compound in the unlikely event of a spill. The bottle should not be held for longer than necessary and the clip only removed when the tube is connected to a closed container. An extremely small volume of radon gas is required, so the bottle should only be squeezed very gently two or three times. After use, the generator should be left connected to the closed container for at least an hour to ensure that the radioactive gas has decayed. **It is necessary to wait for 4 or 5 days after use before opening the ionization chamber, to allow the minute amounts of deposited solid progeny to decay.**					
Inspection	Annually as well as **before and after any use.** If the bottle, filter or tubing show any sign of deterioration or damage, that component should be replaced immediately. If the bottle needs to be opened, special precautions, as for spills and disposal below, will need to be followed. The inspection should include the *inside* of the ionization chamber and tubing (where visible), to ensure that the filter keeps the powder in the bottle.					

10	**Radon-220 (thoron) generator** (Some Principals/Education Departments do not permit its use)
Wipe test of source	Annually or if damage is suspected. **Do not open the bottle**. The outer surfaces and the cap should be wipe tested. The inside of the ionization chamber should be contamination checked.
Contamination check	The plastic storage bag should be checked annually and replaced if necessary. Contamination means that the bottle may be leaking and further investigation is required.
Storage and labelling	The squeeze bottle should have a small label indicating that it is a radioactive radon generator. Another label close to the cap should make it clear that the top is not to be removed. The bottle should be kept in a strong, self-sealing, plastic bag This should be fully labelled and kept in the radioactive materials store.
Spills	The following action is recommended: These are to be treated as a major incident. Lab coat, toxic dust mask and disposable plastic gloves will need to be worn and the spill and surrounding area covered **immediately** with damp tissues or paper towels and air disturbance avoided. Once the spill is covered, the room should be evacuated and the radiation supervisor consulted. If the spill is small, or within a tray, it should be possible to clear it up and to decontaminate very carefully. If the spill is larger or more widespread, windows should be closed, the room locked and the radiation regulatory authority consulted. Decontamination may require professional expertise and more-sensitive contamination monitoring instruments.
Disposal	The radiation regulatory authority should be consulted.

Annex 4

Model Local Rules

INTRODUCTION TO LOCAL RULES

Local rules are written to ensure that radiation doses and risks of contamination are minimised. Following them, in addition to normal laboratory rules and procedures, should ensure safe preparation and procedures for teaching about radioactivity. A set of model rules that can be adapted to meet local needs follows.

Model Local Rules for the Use of Radioactive Sources

Name of school	
Name of responsible person	
Name and contact details of radiation supervisor	
Location of secure store for radioactive materials	
Laboratories/rooms where radioactive sources are used	

If you have any uncertainties about these rules or what you have been asked to do, please clarify the position with your radiation supervisor before you begin work.

1. Local rules for science department staff

1.1 Only a member of the staff who has satisfied the radiation supervisor that he or she is competent can carry out or closely supervise all activities involving sources of ionizing radiation. This member of staff will be responsible for ensuring that sources are never left unattended during these activities. In addition to these local rules, the radiation supervisor will ensure that appropriate written instructions and training are provided for all those who handle radioactive materials.

1.2 The security of all radioactive materials is vital. In the event of a source being lost, an immediate search will need to be carried out and the radiation supervisor informed at once. If the source cannot be found, the radiation supervisor will inform the Principal/Education Department who will agree the next course of action. This should involve consulting with the radiation regulatory authority.

1.3 Before work begins with any radioactive source, the member of staff in charge will need to familiarise themself with the correct procedure for its safe use. This includes the procedures required in the event of a source being dropped or spilt, i.e. containment, clearing up and contamination testing. A working radiation detector and an appropriate spills kit are to be available during all activities.

1.4 In the event of any incident resulting in contamination, it is essential that the member of staff in charge informs the radiation supervisor as soon as possible. The radiation supervisor will then need to be satisfied that decontamination has been successfully completed. If appropriate, the radiation supervisor may implement any further control measures to avoid spreading contamination. The radiation supervisor will consult the radiation regulatory authority if there is any uncertainty.

1.5 The member of staff in charge needs to complete the use log whenever a radioactive source is removed from, or returned to, the secure store. **This person, who signs the use log, has to check that the sources are actually present in their containers.** The record should include the approximate mass of any radiochemical that is used up.

1.6 Once a source has been removed from its secure store, no member of staff should ever leave it unattended unless temporary, secure storage has been arranged. The member of staff should return sources to the normal secure store as soon as possible after use.

1.7 When carrying sources (even in their containers), the handling time should be minimised. A clear, uncluttered route to the destination, without students milling around, is essential. Where the journey is likely to take more than a couple of minutes, place the source in an additional container (e.g. a plastic bucket) to keep it away from the body.

1.8 Whenever students carry out work with radioactive sources, the member of staff in charge should always provide full training and, where appropriate, written instructions. Close supervision by a member of staff is essential at all times.

1.9 In high schools, where most students will be under the age of 16, most work with radioactive sources will be performed by teacher demonstration only. Students are not to be permitted to use radioactive sources other than those in:

- small cloud chambers (with the source remaining inside the chamber)
- watches with luminous dials (or equally-sealed instruments)
- radioactive geological specimens (kept in suitable containers).

1.10 Responsible students, in years 11 and 12, may use other sealed radioactive sources in addition to those listed in paragraph 1.9 above. As well as the requirements of paragraph 1.8 above, each student will require a copy of Section 2 and/or Section 3, as appropriate, of these local rules.

1.11 A member of staff is to check sources immediately after use by students. Any suspected damage will need to be reported to the radiation supervisor who will decide if further action or monitoring is required. The source record will include any unusual incident involving that source.

2. Local rules for the use of sealed radioactive sources (staff and supervised students in years 11 and 12)

2.1 Carry each source in its storage container and keep it there until it is required. Do not handle the container for longer than necessary.

2.2 Use only one source at a time in any one investigation.

2.3 Handle the source with a tool (e.g. metal or plastic tweezers or tongs), which keeps the fingers at least 10 cm away.

2.4 Keep the source well away from the eyes.

2.5 Complete the investigation in the shortest time possible, consistent with good results.

2.6 Return the source to its normal container immediately after completing the investigation.

2.7 The member of staff in charge is to check all sources for signs of damage on return.

2.8 Immediately report any event in which a source is dropped or may have been damaged to the member of staff in charge.

2.9 Always wash hands thoroughly immediately after working with any radioactive source.

3. Local rules for the use of unsealed radioactive sources for half-life investigations (staff and supervised students in years 11 and 12)

i.e. use of protactinium and radon-220 (thoron) generators[3].

3.1 Keep protactinium generators upright in a sturdy, plastic container with a secure lid.

3.2 Keep radon-220 generators in a sturdy, sealable, plastic bag.

3.3 Before use, visually check the generator bottle for any sign of damage.

3.4 During use, place the generator bottle on a tray in order to contain the contents in the unlikely event of a spill.

3.5 Under no circumstance are you to remove the top of a generator.

3.6 An appropriate spills kit needs to be readily available and if a spill occurs, it will need to be reported immediately. Staff should always follow special procedures and the local rules for unsealed radioactive sources should always be applied.

3.7 Wash hands thoroughly, immediately after working with any radioactive source.

[3] Some Principals/Education Departments do not permit the use of radon-220 generators.

4. Local rules for unsealed radioactive sources (staff only)

e.g. during preparation of protactinium or radon-220 generators and disposal of radiochemicals.

4.1 Do not carry out work with unsealed radioactive sources (such as radiochemicals) if there are any open or partly healed wounds on your hand.

4.2 Wear a lab coat and disposable plastic gloves. Use eye protection if other hazardous chemicals are in use (such as concentrated hydrochloric acid used in the protactinium generator).

4.3 Where the radiochemical is a fine powder (e.g. thorium compounds used in the radon-220 generator), the working area should be draught-free (a fume cupboard with the fan switched **off** is often suitable). Wear a disposable dust mask.

4.4 Prepare the work area as follows:

- the bottom layer will need to be impervious to liquids (e.g. an enamel tray or polythene on a wooden bench)
- above this, use two or more layers of absorbing paper towel to catch spills
- place all glassware, test-tube racks and source containers on the paper
- have a box of tissues immediately to hand
- keep all other equipment off the paper, but within reach.

4.5 If you are operating equipment (such as a balance), hold a clean tissue in your gloved hand so that the knobs etc cannot be contaminated.

4.6 The member of staff who carries out any procedure with unsealed radioactive sources is to clear up immediately after the work is complete. In doing so, he or she should:

- flush liquid residues down a fast-flowing sink using plenty of water
- wash all glass and plastics-ware in a bowl and wash with detergent
- place all paper, tissues, dust mask, gloves etc in a strong, unlabelled plastic bag, which is tied for disposal in the refuse
- place the bag directly into a main waste bin outside the building, which will be emptied by a refuse contractor.

4.7 The member of staff should always record the times of issue and return of radioactive materials in the use log. This will also involve recording the mass of any radiochemical used.

4.8 Wash hands thoroughly, immediately after working with any radioactive source.

5. Local rules, documentation

Documentation	Location
Radioactive source history	
Use log for radioactive sources	
Monitoring record for radioactive sources and store	

6. Local rules, contact details

Radiation Regulatory Authority	Name:
	Address:
	Telephone:

Annex 5

Checks on Radioactive Sources

A5.1 Inspections and Wipe Tests

Regular inspections and wipe tests ensure that the mechanisms for preventing dispersal of radioactive materials are functioning as intended. You should carry out an inspection and wipe test once a year on each source kept in the radioactive materials store, including stock bottles of radio chemicals. A simple record will be necessary for each source.

You should wear a lab coat and disposable plastic gloves (and a disposable dust mask if items containing thorium powders are involved). Carry out the work in a large tray (ideally enamel) or on at least two sheets of newspaper. When work is complete, place disposable materials that were used in a strong plastic bag, which is tied for disposal with normal garbage.

Inspect and test one source at a time. Keep other sources, in their normal containers, at least 2 m away.

Physical inspection

Specific details relevant to several types of source are provided in Annex 3.

Carry out the inspection of each source in good lighting. Keep the eyes at least 20 cm away. A mirror placed on the working surface enables the most active areas, e.g. foils, to be viewed when facing away from the eyes. You need to check for any damage or deterioration, particularly to foils, plastic bottles and seals, which might result in the enclosed radioactive material escaping from the source.

If a source has any small blemishes, scratches etc, which will not affect its safe use, it is useful to make a note of these on the radioactive source history sheet (a sketch may be appropriate). This information can assist in future inspections, allowing damage or deterioration to be detected more easily.

Wipe test

Specific details relevant to several types of source are provided in Annex 3.

The basic procedure for carrying out a wipe test is given below:

- A working radiation detector will be required.
- With all radioactive sources at least 2 m away, count the background radiation in the working area for 2 minutes.
- **For cup sources**, place a clean, dry, paper tissue in the tray or on the newspaper. Remove the source from its container with forceps. Gently wipe the open end over an area of the tissue about the size of the window of the radiation detector.
- **For other radioactive sources**, including bottles, which cannot be wiped on a tissue easily, fold a clean, dry, paper tissue to make a small pad with an area about the size of the window of the radiation detector. Hold the tissue in forceps (or metal or plastic tongs) and gently wipe the pad over the surfaces of the source.
- Where appropriate, return the source to its container.

- Remove the source to a distance of at least 2 m from the radiation detector.
- Hold the radiation detector very close to, but not touching, the wiping surface of the tissue. It may be convenient to set up a jig or a clamp to do this. Count the radioactivity on the tissue for 2 minutes.
- If the count from the tissue is less than 1.5 times background, the source has passed the wipe test.

Results of inspection and wipe tests

A simple pass or fail indication on each radioactive source history is sufficient. You do not need to make a permanent record detailing the actual counts made.

However, if the source appears to be damaged or fails its wipe test, note the action taken. Keep any such source inside its normal container and place it in a strong plastic bag. Seal and suitably label this bag and keep it in the usual store. Consult the radiation regulatory authority. You may need to dispose of the source.

A5.2 CONTAMINATION CHECKS

You should carry out contamination checks using precautions and procedures similar to those described for the wipe tests above. Contamination checks should be made on any containers or store where there is a possibility that radioactive materials have deposited on surfaces. In particular, check radium source containers and the main radioactive materials store every year and clean if necessary.

Radium sources

The slight emission of radon-222 gas by radium sources, which is inevitable, may deposit small quantities of radioactive progeny on the outside of the source and the inside of its container. This may cause a radium source to fail its wipe test because its outer surface is contaminated, even though the source is not leaking radium. Every year, when the radium source is wipe tested, the contamination level in its container should be checked by wiping the inside of the empty container with a clean, dry, paper tissue, held by forceps. You should then check the tissue as for the wipe test.

When a radium source fails the wipe test or its container fails the contamination test, you should carefully clean the source and its container using a tissue moistened with detergent, again held by forceps. The two should then be rechecked after about a month. If contamination persists, consult the radiation regulatory authority.

Radioactive materials store

Each year, you should remove all the radioactive sources from the radioactive materials store to a distance of at least 2 m. An initial visual inspection may indicate possible areas of contamination. Then you need to scan a radiation detector very slowly over the inside of the store, keeping the window as close as possible to the surface without touching it. In particular, check areas where possible contamination is visible and all horizontal surfaces.

If the radiation detector does not have an audible output, it may be helpful to have one person watch the display while the other does the scanning.

Investigate any areas of apparently increased count rate over background in more detail, keeping the radiation detector within 5 mm of the surface. If a 2 minute reading of the activity of a suspect area reveals a count of more than 1.5 times background, careful cleaning will be required using paper towels or tissues moistened with a detergent solution and held by forceps or tongs.

If you find contamination in a radioactive materials store, it is important to find the origin of the contamination (e.g. a poorly-sealed radiochemical stock bottle), and deal with it following the procedures for inspection and wipe testing described above.

Annex 6

Calibration of Radiation Detectors

If your radiation detector does not directly indicate a dose rate, you can use the gamma factor given in Annex 2 for 'point' gamma sources to estimate the dose rate at specific distances, e.g. 10, 20, 30 cm from one of your gamma emitting radioactive sources. Then measure the count rate at these distances with your radiation detector. A plot of your results will give you a very rough calibration for your counter in terms of count rate versus microsieverts per hour. You will need to take the age of the source into account when you do this, particularly if it has a short half-life. Annex 2 includes the half-lives of the isotopes.

You could also get a very rough calibration from measurements of background radiation. This is approximately 0.1-0.2 μSv/h.

You can obtain a very rough calibration of count rate versus Bq or Bq/cm^2 by holding the radiation detector close to, but not touching, one of your sources whose activity and surface area you know. Calculate the ratio of count rate to activity or activity per cm^2. You can use this ratio to estimate the activity or activity per cm^2 of an unknown source of the same isotope for the same geometry.

Annex 7

Health Effects of Ionizing Radiation and Standards for Control of Exposure

Annex 7 was removed January 2015.

For information on the health effects of ionising radiation, refer to

RPS F-1 Fundamentals for Protection Against Ionising Radiation (2014)

Annex 7 was removed January 2015.

For information on the health effects of ionising radiation, refer to

RPS F-1 Fundamentals for Protection Against Ionising Radiation (2014)

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Part 2: Lasers

An Overview for Teachers

This part of the Safety Guide deals with the safe use of **laser**s in teaching applications or wherever students can be exposed or potentially exposed to **laser radiation** in primary schools, secondary schools and colleges. This Safety Guide is intended as a guide to safe practices and should be applied with sound judgment to specific situations.

The information contained in this part of the Safety Guide will allow teachers to understand the potential hazards associated with the use of lasers and the classification and labelling scheme for **laser product**s that reflects these potential hazards. Based on this understanding, teachers should be able to develop risk assessments for their intended use of a laser in the classroom.

It is recommended that each school draws up its own risk assessments covering the types of use of lasers. Further, each school should have an accident reporting procedure based on any relevant legislation and this Safety Guide.

This Safety Guide is *not intended* for any other uses of lasers for which separate codes, standards or regulations exist. For example, the use of alignment lasers for construction or renovation work on school facilities does not come under the scope of this Safety Guide (this is addressed by Australian Standard AS 2397: *Safe use of lasers in the building and construction industry*).

In situations where lasers are used on school premises for entertainment purposes, compliance with the Australian/New Zealand Standard AS/NZS 2211.3:2002: *Safety of laser products - Guidance for laser displays and shows* or relevant other codes of practice should be confirmed. AS/NZS 2211.3 provides guidance on the planning and design, set-up and conduct of displays and shows that use high power lasers. This Standard is identical with and has been reproduced from the International Electrotechnical Commission (IEC) laser standard IEC 60825-3:1995.

It is important to note that while this part of the Safety Guide deals specifically with the hazards associated with the **coherent light** emitted by lasers, teachers should also be aware that extremely bright incoherent light sources, such as laser flash lamps or super bright Light Emitting Diodes (LEDs), may also pose optical hazards.

The criteria for assessing the safety of these incoherent (broad-band) sources may be found in the International Commission on Non-Ionizing Radiation Protection's (ICNIRP) *Guidelines on Limits of Exposure to Broad-Band Incoherent Optical radiation (0.38 to 3 μm)* or in AS/NZS IEC 62471:2011 (or as amended): *Photobiological safety of lamps and lamp systems.*

What Lasers should be used?

Australian/New Zealand Standard AS/NZS IEC 60825.1:2011: *Safety of laser products – Part 1: Equipment classification and requirements* defines a number of laser hazard classes based on the levels of accessible laser radiation.

Further information on the laser classification scheme is given in Section 8 of this Safety Guide. It is expected that in most circumstances only Class 1 and Class 2 laser products should need to be used in schools.

It is important that the classification of the laser product is correct, and that the labelling on the laser indicating its class either complies with the requirements of AS/NZS IEC 60825.1:2011 or else provides a means of confirming the class of the laser product consistent with the requirements of AS/NZS IEC 60825.1:2011.

It is also important to remember that laser classification is made on the basis of the *entire* laser product.

Australian Guidelines

This document contains detailed guidelines for using lasers in Australian primary schools, secondary schools and colleges. It provides a basic guide to storing and using lasers wherever your school is located in Australia. You should however check your State or Territory radiation protection legislation and your school's local rules regarding the use of lasers.

Part 2 Overview

Table 5 provides an overview of the sections included in Part 2 of the Safety Guide.

Table 5: Overview of Sections

Section 6 – Introduction	
Basics	Why use lasers in secondary schools including the benefits of using laser products at school/college
Scope	What this part of the document applies to
Purpose	What this part of the document will be used for
Australian radiation regulations	Laws, rules and authorities controlling people using lasers
Section 7 – Lasers	
Basics	Why use lasers in secondary schools including the benefits of using laser products at school/college
Properties	How lasers and **optical fibre systems** work
Potential Hazards	Hazards and potential for injury from laser operation
Use of Optical Fibre Systems	Guidance on optical fibre systems used for demonstrations or experiments at school and their hazards
Section 8 – Classification of Laser Products	
System of Laser Classification	How the potential hazards from lasers have been formalised into a hazard classification scheme
Signs and Labels	Information on the labelling requirements for lasers

Section 9 – Safety Policies	
Acquiring or Purchasing a Laser	What to do when you buy a laser
Use of Lasers in Schools	Persons who are or should be allowed to use a laser in a school, safe handling of lasers and protection of the eyes
Storage	How lasers should be stored
Reporting Incidents	Recommendations for reporting of any incident or accidents involving lasers in schools
Constructing or modifying laser products at school	Recommendations for classifying and assessing the risk from laser products constructed or modified at school
Section 10 – Developing a Risk Assessment for the Use of a Laser at School	
Laser Risk Assessment	How a laser risk assessment is developed and performed

6. Introduction

This part of the Safety Guide contains information about the most appropriate lasers to be used in primary schools, secondary schools and colleges and how teachers may use risk assessments when designing experiments.

Persons responsible for the use of lasers in schools should refer to this Safety Guide and follow its recommendations for best practice.

6.1 Scope

This part of the Safety Guide covers all laser radiation used for teaching purposes in Australian primary schools, secondary schools and colleges.

6.2 Purpose

This part of the Safety Guide provides practical advice and guidance on procedures for using lasers and preparation of a risk assessment that, if followed, will:

- reduce the likelihood of inadvertent or deliberate exposure of staff and students to laser radiation
- promote the safety of all persons where lasers are used for teaching purposes in schools.

6.3 Reasons to Use Lasers in Primary Schools, Secondary Schools and Colleges

Teachers may wish to use lasers in the classroom for many reasons. It could be as simple as wanting to have a ‘white board pointer’ in a primary school, or it could be to teach geometric optics to secondary students or to carry out more advanced optics or electronic experiments with college students.

Whatever the reason, practical work with a laser will provide a unique opportunity to undertake investigations of a technology that has provided a wide range of new medical, scientific and industrial applications. As well as revolutionising the storage and transmission of information, the laser has numerous applications within medicine (bloodless surgery, eye surgery and vision correction, dentistry and skin treatments being some), manufacturing (for example cutting, micromachining and welding) and science (such as laser interferometry, spectroscopy and fluorescence microscopy).

Providing students with ‘hands-on experience’ with lasers offers many benefits for the teaching of science and technology. While ray-tracing through optical systems, diffraction and interference experiments can be performed using software, the highly collimated nature of laser light provides opportunities to perform real experiments with lenses and diffraction gratings.

Laser diodes may provide an opportunity for students to understand how digital signals can be transmitted via optic fibre, and with due care students could design a system to modulate a laser diode and thereby construct an optical communications links.

Laser pointers are useful in the classroom (as an alternative to the wooden stick pointer) and may be necessary for interacting with 'smart boards' or similar devices.

When teaching astronomy, lasers pointers can be used as 'sighting' aids so that a region of interest in the sky can be indicated to groups of people. In these situations the lowest practicable laser power should be used. Please note the restrictions on laser pointers mentioned in Section 6.5 of this Safety Guide.

As with any other potentially hazardous equipment or electrical appliance, it is important to follow some rules so that the lasers are used safely and appropriately. It should be stressed that even though Class 1 laser products are considered inherently safe there is no reason to deliberately expose anyone to the direct beam of a laser.

6.4 Choice of Lasers for Primary Schools, Secondary Schools and Colleges

Careful choice of lasers and good control measures will ensure that the use of lasers in primary schools, secondary schools and colleges is safe.

It is important that the lowest power laser product required for the particular purpose is used.

Section 8 of this Safety Guide provides detail on how lasers are classified. *Be wary of laser products that are unlabelled or do not bear labels in accordance with a recognised standard as their power (potential hazard) may be unknown.*

6.5 Regulation and Control of Lasers in Australia

In some Australian States and Territories high power (Class 3B and Class 4) lasers require authorisation and therefore could be subject to the requirements of other standards, codes, guidelines or licensing arrangements. It is recommended that the relevant radiation regulatory authority (see page 97) is consulted to determine the requirements in the particular State or Territory. This will need to be addressed prior to purchasing or acquiring a Class 3B or Class 4 lasers.

Further, all States and Territories have placed restrictions on the possession of laser pointers unless there is a valid reason. Typically a laser pointer is a hand held, battery powered device that emits visible laser light. Most States and Territories have placed the restrictions on laser pointers emitting more than 1 milliwatt, classing them as controlled/prohibited weapons (see Table 6). This will need to be taken into account when purchasing or acquiring laser pointers. Local regulatory authorities (usually Police and/or Emergency Services) need to be consulted to determine the requirements in the particular State or Territory.

Table 6: Laser Pointer Regulation in Australia

Australian Customs	Laser pointers designed or adapted to emit a laser beam with an accessible emission level of greater than 1 milliwatt are prohibited from importation unless written permission is given by the Minister or authorised person.
Australian Capital Territory	A laser pointer with an accessible emission level of 1 milliwatt is defined as a prohibited weapon in the Australian Capital Territory. A person is able to possess and use a laser pointer if the possession or use is reasonably necessary in all the circumstances for the lawful pursuit of the person's occupation, education, training or hobby.
New South Wales	A laser pointer is defined as a prohibited weapon in New South Wales and penalties apply to the possession and use of laser pointers above 1 milliwatt. There are exemptions to this for valid uses of laser pointers.
Northern Territory	A laser pointer with an **accessible emission limit** of greater than 1 milliwatt is defined as a controlled weapon in the Northern Territory. A person must not possess, carry or use a controlled weapon without a lawful excuse.
Queensland	A laser pointer with a power output of more than 1 milliwatt is a restricted item in Queensland. It is an offence to acquire or posses a restricted item unless you have a reasonable excuse, such as being part of a recognised astronomical organisation or it is required by your occupation or you have a licence to possess the laser pointer.
South Australia	A laser pointer with an accessible emission level of greater than 1 milliwatt is defined as a prohibited weapon in South Australia. There are certain exemptions which allow a person to possess or use a prohibited weapon.
Tasmania	In Tasmania, a person must not possess, carry or use a laser pointer without a lawful excuse.
Victoria	A laser pointer with an accessible emission limit of greater than 1 milliwatt is defined as a prohibited weapon in Victoria and penalties apply to the possession and use of laser pointers above 1 milliwatt. There are exemptions to this for valid uses of laser pointers.
Western Australia	A laser pointer is defined as a controlled weapon in Western Australia. A person cannot carry or possess a controlled weapon without a lawful excuse.

Please note: This table was correct at the time of printing but is subject to change from time to time.

7. Lasers

7.1 Laser Radiation and Its Properties

Radiation is part of our everyday life and comes in many different forms, such as heat, light, or radio waves. Radiation is often described in terms of the electromagnetic spectrum and is divided into two types – ionizing and non-ionizing, as illustrated in Figure 2 (page 7).

Non-ionizing radiation

Non-ionizing radiation is found at the long wavelength end of the spectrum and may have enough energy to excite molecules and atoms causing them to vibrate faster. This is very obvious in a microwave oven where the radiation causes water molecules to vibrate faster creating heat.

Non-ionizing radiation ranges from extremely low frequency radiation, through the radiofrequency, microwave, **infrared** and visible portions of the spectrum into the ultraviolet range. The approximate wavelength and frequency regions are indicated in Figure 2.

Lasers are capable of producing non-ionizing radiation in the ultraviolet (100–400 nm), in the visible (400-700 nm) and in the infrared (near infrared 700-3000 nm, mid- and far-infrared greater than 3000 nm and up to 1 mm). Most lasers will emit in the wavelength range 200 nm-10 µm. Lasers used in schools would most likely be visible, for optical experiments, or infrared for digital communication projects.

Properties of laser radiation

In order to use lasers safely it is important to understand how they work and why even low power lasers can present a hazard.

The word LASER is an acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation, which describes the process by which lasers generate light (electromagnetic radiation).

Light produced by a laser has fundamentally different properties to light produced by conventional light sources. These properties are what makes laser light attractive for many applications, but also mean that laser light can be much more hazardous than conventional light.

There are three properties that distinguish laser light from conventional light. Firstly, it is **monochromatic**, that is, the emitted light is concentrated at a single wavelength. Secondly, it is coherent, which means that the light waves remain in phase as they propagate. Finally, the light is collimated which means that it can travel long distances with a very small divergence. This last property is the most important one from a hazard perspective because it means that a laser beam can retain high intensity over great distances.

To compare, the **output power** of a ten watt incandescent light bulb is propagated more or less evenly in all directions (isotropically) and the

irradiance will decrease rapidly as the distance to the light source is increased. However, a laser with the same output power can produce a collimated narrow beam with an extremely high irradiance. This irradiance is maintained for considerable distances from the laser source if the beam has a very small divergence. Such a laser would invariably be classified as Class 4. The irradiance of the light bulb only approaches that of the laser at very small distances from the filament (less than 0.5 millimetres).

There are many different types of lasers, each type with its own characteristic output wavelength(s). Laser wavelengths range from the ultraviolet to the far infrared regions of the electromagnetic spectrum; both extremes are well beyond the range of **visible light**. Laser wavelengths between 400 nm and 1400 nm are of particular importance as these wavelengths are readily transmitted through the eye to the **retina**. These wavelengths are sometimes referred to as the *retinal hazard zone* as the lens of the eye **focus**es the light onto a small area on the retina, as shown in Figure 5. For a laser beam in the retinal hazard zone, the irradiance of the image formed on the retina is about 100,000 times the irradiance of the laser beam at the **cornea**. Retinal burns may result in serious and permanent impairment of vision or even blindness in the eye affected. Note that all visible lasers emit in the retinal hazard zone.

Figure 5: Laser radiation is usually more dangerous to the retina of the eye than other light sources because the beam can be focused by the eye onto a very small area of the retina.

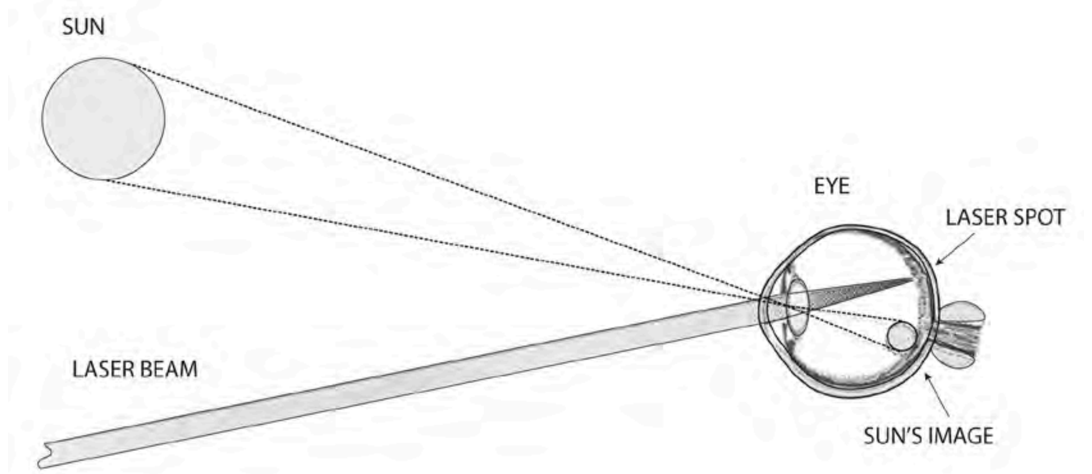


Image first published in RHS 36 *Code of practice for the safe use of lasers in schools (1995).*

Lasers emit light either continuously (**continuous wave** laser) or in pulses (pulsed laser). Some of the pulsed lasers are capable of producing extremely short pulses. This can increase the hazard further as all the energy in one pulse is delivered during a very short time. This can result in a very high peak power even though the average power might be quite low.

7.2 Potential for Injury

Lasers other than Class 1 are capable of causing injury. Such injury occurs principally through heating effects which result in burns. The organs most susceptible to injury are the cornea and the retina of the eye, and the skin. However, by only using Class 1 or Class 2 lasers in schools the likelihood of permanent eye injury is small and there are no risks from exposure of the skin. While permanent eye injury from Class 1 or Class 2 lasers is extremely unlikely it should be noted that temporary flash blindness (similar to the effect of an electronic camera flash seen at close range) may occur during brief accidental exposures and the associated visual impairment may lead to other accidents.

7.3 Other Hazards Associated with Laser Operation

Electrical hazards

Many lasers employ high voltage internal power supplies; such voltages may present a hazard if a laser is used incorrectly. Requirements for electrical safety are given in Australian/New Zealand Standard AS/NZS 3100:2009: *Approval and test specification - General requirements for electrical equipment*. Additional hazards usually associated with Class 3B and Class 4 laser products are described in Section 6 of AS/NZS IEC 60825.14:2011 *Safety of laser products – Part 14: A user's guide*.

Hazardous Plumes

High power lasers can be used to cut materials; however they may be constructed such that they meet the requirements of a Class 1 laser product. For example, while the 'cutting laser' may be a Class 4 CO2 laser, the laser may be fully enclosed in an interlocked housing, which together with other controls may render it a Class 1 laser product.

These types of laser products are finding application in sign making, model making or 3D realisation of designs produced by a CAD (computer aided design) system. While the engineered controls often place these laser products at the very safe end of the laser classification scale, they can produce hazardous plumes while cutting that need to be appropriately managed.

7.4 Optical Fibre Systems

Optical fibre technology is continually advancing, mainly being driven by the need to transmit digital signals over long distances. This has resulted in a number of different technologies such as graded refractive index fibres (GRIN) and photonic crystal fibres (PCF), however the following description is sufficient to understand the basic principles of how optical fibres work.

An optical fibre is a relatively flexible fibre made from glass (silica). The central core of the fibre is transparent and is surrounded by a transparent cladding material with a refractive index lower than that of the core. In this way the fibre can totally internally reflect light and act as a 'waveguide' allowing light to propagate between the two ends of the fibre.

The flexible nature of an optical fibre, and its ability to transmit light with very low loss, means that fibres are used in digital communications and in applications where light needs to be collected from or transmitted to difficult to access locations.

For the most part, optical fibres are used to transmit visible and near-infrared wavelengths. The output beam from the fibre emerges as a divergent cone and the irradiance decreases with increasing distance from the fibre end (see Figure 6A). Consequently, optical fibre systems are most hazardous at distances close to the output end of the fibre. However, it should be realised that laser emissions from an optical fibre may still be hazardous at significant distances from the end of the fibre depending on laser power, wavelength and beam divergence. It is also important to understand that the hazard can be increased if a lens is used to re-collimate the beam emerging from an optical fibre (as shown in Figure 6B).

Figure 6: A. The beam from an optical fibre usually diverges
B. The hazard can extend to greater distances if the beam is collimated with a short focal length lens

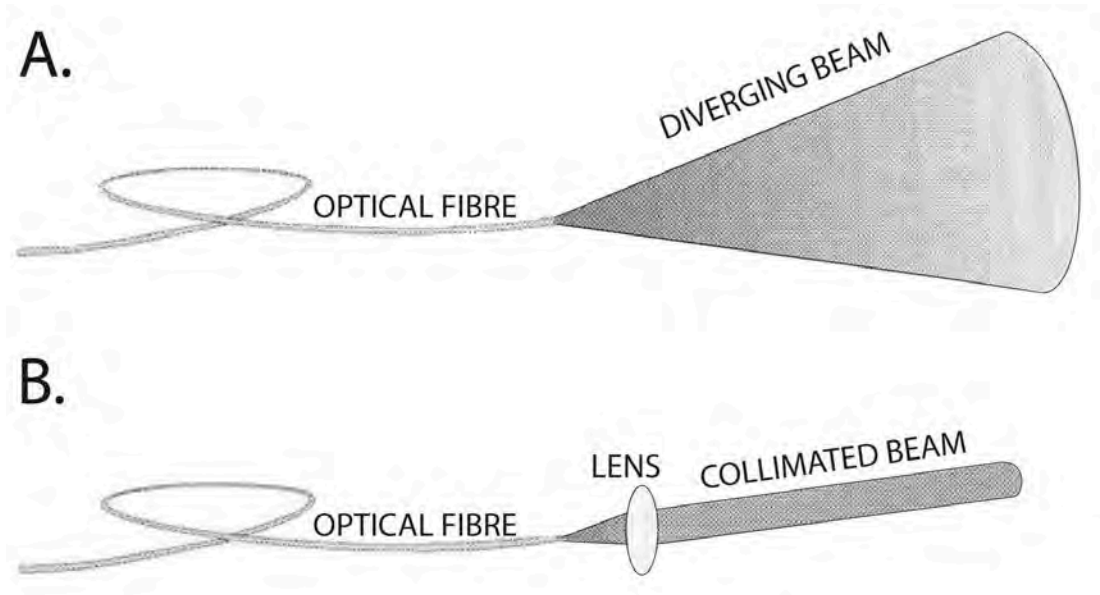


Image first published in RHS 36 *Code of practice for the safe use of lasers in schools (1995).*

When an optical fibre is used in a laser experiment, the risk assessment described in Section 10 of this Safety Guide should take into account the properties of optical fibres while they are energised with laser radiation (see Section 7.5) as well as the additional hazards described in Section 7.6.

7.5 Optical Hazards Associated with Optical Fibres Energised with Laser Radiation

The optical fibre alone should not be relied on as a safe enclosure for laser radiation. The fibre can break if it is bent too much and the breakage may result in an uncontrolled hazardous emission of laser radiation from the broken fibre end. Similarly, partial cuts or scratches in the fibre affect its ability to totally internally reflect light and may result in a hazardous radiation emission.

Prior to use, a careful inspection of the optical fibres for breaks and damage will help to reduce the risk of a hazardous radiation emission. The fibre should only be inspected for damage while it is disconnected from the laser source and for close inspection the use of a magnifying glass or microscope is recommended. Any damage to a fibre is a reason for it not to be energised with laser radiation. It is important that all persons working with optical fibres energised with laser radiation are instructed never to view a fibre end on.

7.6 ADDITIONAL HAZARDS FROM OPTICAL FIBRES

Due to the fact that optical fibres are constructed from glass, there are additional and non-laser related hazards associated with their use that should form part of any risk assessment when they are used in laser experiments.

Firstly, there is the risk of mechanical injury to the eye associated with handling intact but unclad or small diameter fibres that can be difficult to see. Further, there is a potential for eye injury from small particles of fibre (glass) when fibres are cut or broken and finally there are hazards associated with any solvents or chemicals used to clean or bond the fibre.

The use of protective eyewear when cutting or otherwise preparing optical fibres minimises the risk of injury to the eye in such circumstances. Other risk reduction strategies include ensuring that procedures are in place to keep the work area clean and free of small particles of glass. Use of a lab coat also minimises the chances of small glass particles clinging to clothing.

8. Classification of Laser Products

The previous section of this Safety Guide showed how lasers can be hazardous. This section will explain how these potential hazards have been formalised into a System of Hazard Classification. An understanding of this system, and its associated labelling requirements, is important as it will allow users to recognise the potential hazard they are dealing with.

8.1 System of Hazard Classification

Australian/New Zealand Standard AS/NZS IEC 60825.1:2011: *Safety of laser products – Part 1: Equipment classification and requirements* defines a hazard classification scheme for laser products based upon the maximum level of laser radiation to which human access is possible during conditions of normal operation. Design, labelling and user information requirements applicable to the specific laser class and the intended use of the product are also specified in AS/NZS IEC 60825.1:2011 as well as AS/NZS IEC 60825.14:2011: *Safety of laser products – Part 14: A user's guide.*

The classification of a laser product gives an indication of its potential hazard. Associated hazards (that is, hazards other than those directly attributable to exposure to the laser beam) that may also be present during use of a laser do not affect the laser's hazard classification.

It is important to remember that laser classification is made on the basis of the *entire* laser product. This means it is possible that a Class 1 laser product could contain a high power laser and the product as a whole has been made safe under reasonably foreseeable conditions of operation via engineered means. This point is vital should a school wish to disassemble laser products such as CD players, which can contain Class 3B lasers.

The AS/NZS IEC 60825.1:2011 laser hazard classifications are summarised as follows (for more complete details of classification consult AS/NZS IEC 60825.1:2011):

Class 1

Class 1 lasers are safe under reasonably foreseeable conditions of use – either because of the inherently low emission of the laser itself, or because of its engineering design, such that it is totally enclosed and human access to higher levels of internal laser radiation is not possible during normal operation.

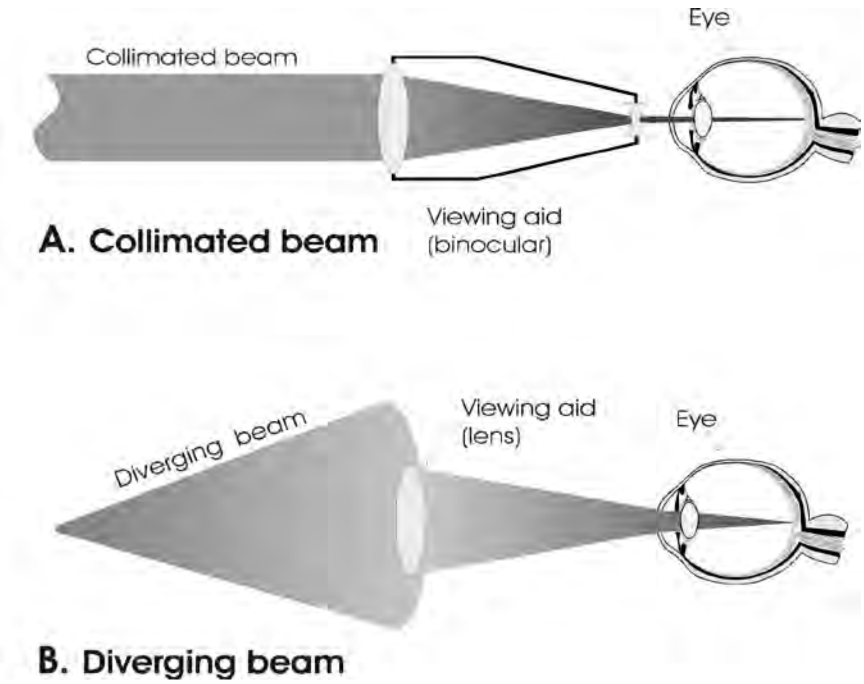
Class 1M

Class 1M lasers can exceed the permitted accessible emission limit (AEL) for Class 1 but, because of the geometrical spread of the emitted radiation, cannot cause harmful levels of exposure to the unaided eye. However, if magnifying viewing instruments are used, it is possible to exceed the safe limit for ocular exposure and injury is possible (see Figure 7). Such instruments include:

(a) binoculars and telescopes (in the case of large-diameter **collimated laser beams**: see Figure 7A), or

(b) magnifying lenses and microscopes (in the case of highly-divergent beams: see Figure 7B).

Figure 7: The use of certain types of viewing aids, such as binoculars and theodolites and jeweller's loupes etc., can increase beam irradiance at the cornea and increase the power entering the eye



In both cases hazardous exposure can result as more energy enters the eye compared with viewing the laser beam with an unaided eye.

Class 2

Class 2 lasers are low power devices that emit visible light. They are safe for the skin but are not inherently safe for the eyes. For these lasers, eye protection is normally afforded by natural aversion responses to bright light (such as closing the eyes or turning away) and accidental eye exposure is therefore normally safe. The natural aversion response can be overridden by holding the eyelid open and staring into the beam, and can also be influenced by taking alcohol or drugs.

Class 2M

Class 2M lasers can emit levels of visible radiation that exceed the AEL for Class 2, but, because of the geometrical spread of the emitted radiation, are normally safe for viewing with an unaided eye. As for Class 2 lasers the protection relies on the aversion response. As for Class 1M lasers injury is possible, if magnifying viewing instruments are used (see Figure 7). Such instruments include:

(a) binoculars and telescopes (in the case of large-diameter collimated laser beams: see Figure 7A), or

(b) magnifying lenses and microscopes (in the case of highly-divergent laser beams: see Figure 7B).

Class 3R

Class 3R laser products have a level of accessible emission up to five times the limits for Class 1 (if invisible) or Class 2 (if visible). The risk of an injury is generally low provided that only accidental exposure occurs. Class 3R lasers should only be used where direct **intrabeam viewing** is unlikely.

Class 3B

Class 3B lasers emit either invisible or visible radiation and direct intrabeam viewing is hazardous to the eye. **Diffuse reflections** are generally safe. Higher power lasers in this class may also cause skin burns. However, skin injury is normally prevented by the reflex response of the skin to heat.

Class 4

Class 4 is the most hazardous classification. Lasers in this class are high power devices capable of causing injury to both the eyes and skin. Diffuse reflections may also be hazardous. The laser emission can also be sufficient to ignite materials on which it impinges and therefore presents a fire hazard. Hazardous fumes can be created in the interaction with target materials.

8.2 Classification Scheme Requirements

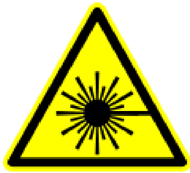
The basis of this classification scheme relies on specifications governing the following areas:

- compliance with the specified AEL of laser radiation applicable to the particular class
- the provision of engineering features appropriate to the particular class
- the provision of specific written safety information to the user (incorporated into the instruction manual)
- labelling requirements. Every class of laser requires an explanatory label. Lasers of Class 2 and above are also required to have a warning label (sunburst symbol – see Table 7 of this Safety Guide).

8.3 Classification Caution Signs and Labels

In order to assess the potential risk associated with a laser product, it is important to be able to ascertain that in the first instance it is a laser product and subsequently identify its class, wavelength and any other cautionary information. In Australia, the Australian/New Zealand Standard AS/NZS IEC 60825.1:2011: *Safety of laser products – Part 1: Equipment classification and requirements* is the national Standard for classifying laser products. This Standard is adopted from the International Electrotechnical Commission publication IEC 60825-1. Additionally laser products may also claim compliance with the American Standard ANSI Z136.1.

Table 7: Reproductions of labels that would appear on lasers classified under AS/NZS IEC 60825.1:2011

Class 1 laser products are identified by a text label only.	CLASS 1 LASER PRODUCT
Class 1M laser products will have a label stating	LASER RADIATION DO NOT VIEW DIRECTLY WITH OPTICAL INSTRUMENTS CLASS 1M LASER PRODUCT
In addition to labels containing text, the equilateral triangle surrounding a sun-burst pattern warning label will appear on all laser products classified as Class 2 or greater.	
Class 2	LASER RADIATION DO NOT STARE INTO BEAM CLASS 2 LASER PRODUCT
Class 2M	LASER RADIATION DO NOT STARE INTO BEAM OR VIEW DIRECTLY WITH OPTICAL INSTRUMENTS CLASS 2M LASER PRODUCT
Class 3R	LASER RADIATION AVOID DIRECT EYE EXPOSURE CLASS 3R LASER PRODUCT
Class 3B	LASER RADIATION AVOID EXPOSURE TO BEAM CLASS 3B LASER PRODUCT
Class 4	LASER RADIATION AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION CLASS 4 LASER PRODUCT

ANSI Z136.1 (the American National Standard) and AS/NZS IEC 60825.1:2011 share the same numbering scheme for lasers, i.e. Class 1, 1M, 2, 2M, 3R 3B and 4. One area where ANSI Z136.1 differs is in laser labelling requirements. Figure 8 provides an example of a label that would be required for a Class 3B laser, which is noticeably different from Class 3B labelling requirements of AS/NZS IEC 60825.1:2011.

Figure 8: Example of a Class 3B Label according to ANSI Z136.1

The word 'Danger' is used with all labels for Class 3R, 3B, and 4 lasers and 'Caution' is used for labels of Class 2 and 2M lasers. Precautionary instructions or protective actions required by the user are located above the tail of the sunburst. The text below the tail of the sunburst identifies either the type of laser (as shown); or the emitted wavelength, pulse duration (if appropriate) and the maximum output (power). Text at the bottom right has the laser classification.	

Old lasers may be classified according to old (pre-2001) laser classification systems (Class 1, 2, 2A, 3A, 3B and 4). In the US, class numbers were designated using roman numerals (I-IV) or Arabic numerals (1-4) and lower case letters. For the purposes of safety, lasers with the old classification system can be compared to the new ANSI and AS/NZS standard in the following way:

- Lasers classified as Class 1, 2, 3B and 4 (old classification system) can generally be considered (for safety purposes) the same as the classifications of the current AS/NZS and ANSI system.
- Some lasers that were previously Class 3B now belong to Class 1M or 2M, as they are considered safe for viewing with the naked eye.
- Class 3A of the old scheme is a combination of Class 1M, 2M and 3R of the new scheme. The maximum power level that is accessible (including with use of optical instruments) is limited to 5 mW in Class 3A.
- The old Class 2A covers the low power end of Class 2 where continuous viewing up to 1000 seconds is considered safe.

9. Safety Policies

Depending on the specific requirements of the occupational health and safety (OHS) legislation a school is subject to in its jurisdiction, if possible the following recommendations should be incorporated into the school's OHS system for dealing with other potentially hazardous chemicals or equipment used for teaching.

If a school has a number of lasers that are used regularly for experiments or demonstrations, then consideration should be given to appointing a **Laser Safety Officer (LSO)**. The LSO would normally be a staff member who is familiar with this Safety Guide, understands the laser classification system and has a good working knowledge in the use of lasers. The LSO would be available to assist other staff with performing risk assessments and may assume the role of ensuring all staff comply with the safe storage requirements that are part of the school's safety policies.

9.1 Requirements Relating to the Acquisition and Storage of Lasers in Schools

Acquisition of lasers

The school should develop a policy to cover the acquisition of lasers. Ideally only lasers that fully comply with AS/NZS IEC 60825.1:2011 should be purchased, as these will bear labels indicating the lasers class, and other appropriate warnings. However, this may not always be possible especially if lasers are being purchased from educational equipment suppliers who may import overseas products. In these situations it is recommended that schools satisfy themselves that the laser being purchased complies with a recognised national or international standard, and bears appropriate labelling as required by those Standards. It is important that the laser is purchased through a reputable supplier. There have been a number of cases where the class of the laser has exceeded what is indicated by the labelling. Be aware that lasers are frequently sold on the internet with the wrong classification. Section 8.3 of this Safety Guide provides further information regarding this. Refer to Section 6.5 regarding lasers that may be regulated in various States and Territories.

Storage of lasers

It is important that schools have in place processes to ensure lasers are securely stored and only accessed and used by teaching or support staff who are knowledgeable in the potential hazards associated with the use of lasers and are specifically granted permission for this purpose by the school.

When not in use it is important that lasers are stored securely and are unable to be easily accessed by students. For example, a lockable cupboard in a laboratory 'prep room' should be sufficient. It is recommended that for Class 3B lasers and above, a log book be kept indicating when a laser has been taken from the store, by whom it was taken and when it was returned. This will not only assist with tracking the whereabouts and use of a laser but will also help indicate if a laser has been misplaced or lost. Additionally, the keys required to operate Class 3B and 4 lasers should be stored securely and separate from the lasers and access to the keys controlled and logged.

A log book is not considered necessary for low power laser pointers (maximum of Class 2) used with whiteboards and projection systems. For these lasers, teachers should be encouraged not to leave the laser pointer unattended in the classroom or to leave them in unlocked cupboards or drawers that students may easily access.

9.2 Information Relating to Lasers Used Within the School

The following information should be held in a secure place and should be readily available on request:

- A copy of this Safety Guide.
- Instructions for the assembly and safe use of the laser, and the risk assessments for particular experiments, including precautions to avoid exposure to harmful radiation; a list of controls, adjustments and procedures for operation and maintenance of the laser with the warning:

CAUTION:	Use of controls or adjustments or performance of procedures other than those specified may result in hazardous radiation exposure.

- Maintenance instructions necessary to keep the laser within its stated classification.
- Information on emitted wavelength(s) and the maximum output power and class of the laser.
- A warning that certain modifications to the laser will require a reassessment of its classification (see Section 9.11).
- A log book of the type recommended in Storage of lasers in Section 9.1.

9.3 Persons Who May Be Permitted to Use Lasers

The use of low power laser pointers (maximum of Class 2), in conjunction with whiteboards and projection systems, will generally not require teaching or support staff to have any specialist knowledge about the risks associated with lasers. Familiarity with Sections 7 and 8 of this Safety Guide should be sufficient for the laser pointer to be used safely.

In all situations where lasers above Class 2 are used for teaching, schools should have a policy that ensures only teaching and support staff that are knowledgeable in the use of lasers and understand their potential hazards, are able to access lasers and use them for teaching purposes. These teaching and support staff should be specifically granted permission by the school to use lasers. In particular, teaching and support staff should be able to perform a risk assessment for an intended use of a laser for teaching purposes. Model risk assessments are presented in Section 10.

9.4 New Demonstrations and Experiments

Before a new demonstration or experiment is introduced into the curriculum a trial should be carried out, without any students present, to evaluate the safety aspects of the demonstration or experiment.

9.5 SUPERVISED USE OF LASERS FOR TEACHING

Class 3R and Class 3B lasers should only be used in experiments performed by students when used in **supervised locations** and under the direct supervision of teaching or support staff who are permitted by the school to use these classes of lasers. It is highly unlikely that a school would ever need to use a Class 4 laser during an experiment or demonstration, and this Safety Guide recommends that schools should always use a laser of the lowest possible power. In all cases, schools should make every effort to avoid the use of Class 4 lasers in the classroom.

In general, supervision should only be undertaken by teaching and support staff who are fully conversant with the information contained in this Safety Guide, and any relevant risk assessments.

9.6 ACCESS TO THE CLASSROOM WHEN A LASER IS IN USE

A laser controlled area should be established wherever there is a reasonably foreseeable risk of harm arising from the use of laser equipment. Access to the controlled area should be limited to persons granted permission by the school and to persons under their control. Warning signs should be clearly displayed on the outside of all laser controlled areas (see Section 8.4 in AS/NZS IEC 60825.14 for more detail).

9.7 PROTECTIVE EYEWEAR

Provided the guidance given in this part of the Safety Guide is followed in the use of Class 1, Class 2 and Class 3R (visible output) lasers protective eyewear is not considered necessary for teachers or students. For Class 3R (invisible output), Class 3B and Class 4 lasers the failure to use protective eyewear could result in serious injury to the eye. It is important to ensure that the eyewear provides adequate protection in the wavelength of operation of the laser. The following factors need to be considered when determining the appropriate protective eyewear:

- the laser wavelength(s) in use
- the possible exposure levels (irradiance and **radiant exposure**);
- the **maximum permissible exposure** (see AS/NZS IEC 60825.1 or AS/NZS IEC 60825.14)
- the damage threshold of the eyewear
- the attenuation provided by the eyewear at the laser wavelength(s). For visible laser wavelengths, the need for good vision has to be weighed against the necessity for adequately high attenuation to ensure safety to the wearer.

The supplier of the laser can often advise on appropriate laser eyewear for that particular laser. For more information, refer to Annex B.

9.8 REPORTING OF INCIDENTS

In line with occupational health and safety legislation, this Safety Guide assumes that schools have incident or accident reporting systems in place, regardless of whether such incidents involve students or teachers. In addition to these this Safety Guide recommends that any incident or accidents involving lasers in schools are also reported to the relevant regulatory/advisory authority (see page 97).

The relevant regulatory/advisory authority should also be advised in writing of any case of failure of laser equipment, controls or procedures which may lead to a hazardous exposure to laser radiation.

9.9 General Warnings Relating to Constructing or Modifying Laser Products

While the terminology 'laser' and 'laser product' are often used interchangeably, many laser products (especially Class 1 products) are only able to meet the relevant AEL through specific engineering design features, such as shielded enclosures and special optical systems. It is even possible that a Class 1 laser product could have Class 4 radiation levels inside. Modifications made to such laser products may therefore allow inadvertent access to more harmful levels of laser radiation than the initial laser product classification would indicate.

Therefore modification of a previously classified laser product would normally lead to the classification being reassessed, especially if the modification affects any aspect of the laser's performance or safety characteristics. In such circumstances the laser should be treated as though it had been 'constructed at school' and the guidance given in Section 9.10 would apply.

9.10 Lasers Constructed at School

Constructing a laser at school may provide many educational benefits, however some types of lasers could be expensive and complex to construct. For example, constructing a CW Argon laser would require expensive mirrors, vacuum equipment and a substantial power supply. It is therefore recommended that lasers constructed at school are restricted to being Class 1 or Class 2 lasers containing commercially available low power laser diodes, or Helium-Neon (HeNe) lasers as these can provide excellent optical characteristics.

This Safety Guide recommends that schools do not construct a laser where its power will be unknown or its classification may exceed Class 1 or Class 2. If the output power of the laser diode or tube is unknown, and without access to specialist measuring equipment which would enable the laser to be classified, carrying out a risk assessment is problematic. If such a laser were constructed, the extra safety features that would need to be implemented would require advanced mechanical and electrical skills to construct, and would probably be beyond the scope of a school project. Examples of some (but not all) of these extra safety features are:

- a **beam stop**/shutter, such that the shutter is normally closed
- a keyed switch on its power supply
- an emergency off switch readily accessible to the operator

- mechanical stability so that the optics are not easily moved or misaligned when bumped
- laser warning labels which include an indication of the laser aperture's location.

Further, a laser of this type will most likely require a number of risk assessments to be carried covering the various stages of its construction and subsequent operation.

Note: Class 3B and Class 4 lasers are regulated in some Australian jurisdictions (see Section 6.5 of this Safety Guide).

9.11 LASER CLASSIFICATION IN DOUBT

If the classification of any laser is in doubt it may be prudent not to use the laser. If the laser is to be used then the risk assessment pertaining to its use should assume the laser is a Class 3B or Class 4 laser. Purchasing or acquiring a laser without knowing its classification is not recommended and this has previously been discussed in Section 9.1 of this Safety Guide.

10. Developing a Risk Assessment for the Use of a Laser at School

Given the knowledge of laser hazards and the laser classification scheme presented previously, it now becomes possible to carry out a risk assessment for any particular use of a laser product. Section 10.1 contains a general example of a laser risk assessment and Section 10.2 shows how this example would be used for a particular experiment. A blank template risk assessment that you could copy and use can be found in Annex C.

10.1 Laser Risk Assessment – General Example

By working through the following example laser risk assessment it should be possible to identify the potential hazards and implement the suggested control measures to reduce risk.

Note: Inherent risk is the risk without control measures whereas the residual risk is the risk after control measures have been implemented.

General Example: Using a Class 3R or 3B laser in a physics experiment

A. Experiment details	
Name of assessor	Name of the person undertaking the risk assessment
Date	Date assessment done
Laboratory	Laboratory proposed to be used for the experiment
Description of experiment	Brief description so that the experiment can be identified
Laser training/experience of teacher	List any laser specific course attended and/or practical expertise gained during tertiary training
Laser classification	List the classification of the laser to be used in the experiment (using AS/NZS IEC 60825.1:2011)
Laser emission	State the emission of the laser to be used
Pulsed or CW (continuous wave)	State whether the laser is to be pulsed or continuous wave
Laser wavelength	State the wavelength of the laser to be used
Protective eyewear required:	State what eyewear is required and when it is to be worn

B. Risk assessment

Hazard description	Inherent risk	Control measures in place to reduce risk	Residual risk
1. Beam deflected in an uncontrolled way	High	• Align at low power. • Secure optics properly to the optical table. • Reflective objects should be inserted into the beam in a controlled way.	Low
2. Unwanted hazardous reflections or existence of stray beams	High	• The teacher should be trained appropriately so as to have a good understanding and experience working with lasers. • Check existence of reflections and stray beams at low power. • Use beam stops, screens etc to stop reflections. • Use lasers with visible output. • Use appropriate safety glasses.	Low
3. Student not aware of the laser hazard	High/ Moderate	• Warning signs on laser. • Warning signs in working area/laboratory. • Students should be trained on laser safety.	Low
4. Unsuitable laboratory environment	Moderate	• Ensure that room is well lit (light coloured walls etc). • Laser beam should not be at eye level (preferably at waist height). • No desks or working areas where students could be sitting down (the laser beam might then be in eye level).	Low
5. Beam-initiated fire	Moderate	• Unlikely for Class 3R and 3B laser; however, ensure that beam stops and enclosures are not made of combustible materials.	Low
6. Non laser hazards (electrical, chemical, compressed gases, explosion, optical fibre breakage, hot objects etc.)	High/ Moderate/ Low	• Ensure non-laser hazards are mitigated against.	Low

Risk rating:

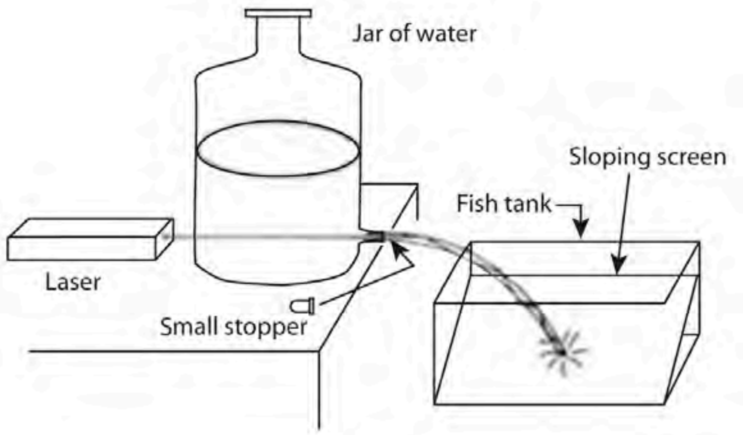
High – Unacceptable risk, control measures required
Moderate – Unacceptable risk, control measures required
Low – Acceptable risk

The experiment should not be performed unless the residual risk is ‘low’.

10.2 LASER RISK ASSESSMENT – LIGHT TRAPPED IN STREAM OF WATER

The following is an example of a specific experiment that may be used as a demonstration of total internal reflection.

Figure 9: Light Trapped in a Stream of Water



Courtesy of the University of Melbourne Department of Physics

This intriguing demonstration of total internal reflection shows how light may be trapped and guided by an unbroken stream of water flowing from a glass jar. A laser beam is initially aimed at the back of a small stopper, through the opposite side of the glass jar. When the stopper is removed the beam is guided by the stream of water and shows up as a brilliant spot where the stream lands. The effect is made visible to a large audience by catching the stream in a large fish tank and inserting a sloping white screen onto which the stream of water splashes.

A risk assessment providing the relevant information as described in the general example above is shown here. Control measures to reduce the risk have been suggested.

Specific Example: Using a Class 3R laser in a physics optics experiment

A. Experiment details	
Name of assessor	Ms Smith – Head of Science
Date	30 May 2011
Laboratory	Physics 3 Classroom
Description of experiment	Total internal reflection of light inside a water spout. To be conducted as a classroom demonstration by the teacher. NOTE: This experiment could be done with a Class 1 or Class 2 laser but the school only possesses a high power 'red' laser pointer.
Laser training/experience of teacher	Used Class 1, 2 and 3R lasers during undergraduate physics. Familiar with this part of the Safety Guide.
Laser classification	3R
Laser emission:	5 mW
Pulsed or CW (continuous wave)	Continuous
Laser wavelength	671 nm
Protective eyewear required	Yes for direct beam and will be worn during set up. Not required for scattered laser light.

B. Risk assessment			
Hazard description	**Inherent risk**	**Control measures in place to reduce risk**	**Residual risk**
1. Beam deflected in an uncontrolled way	Moderate	• Set up laser whilst there are no students in the classroom. • Align the laser beam with the back of the stopper whilst wearing laser protective eyewear. • Fix the laser pointer to a 'lab jack' and anchor the lab jack with clamps to the bench top.	Low
2. Unwanted hazardous reflections or existence of stray beams	Moderate	• Fill the flask and check for the existence of reflections and stray beams. Note if there are any partially reflected beams towards where the students will sit. If so mask these with beam stops or tape on the flask. Ensure that there is a beam stop in direct line with the laser in case the flask becomes empty and the laser bean continues in a straight line.	Low
3. Student not aware of the laser hazard	Moderate	• Warning signs on laser are visible and conform to AS/NZS IEC 60825.1:2011. • A warning sign will be placed on the door at the classroom's entrance. • Students will be told about the potential hazards from viewing a Class 3R laser and they will be informed that the laser has previously been aligned and stray reflections removed.	Low
4. Unsuitable laboratory environment	Moderate	• The classroom is well lit. • The laser beam will be on a low table below the student's eye level when seated. • The laser beam will be directed perpendicular to the student's line of sight so they can observe the 'spout' against the white background.	Low
5. Beam-initiated fire	Not applicable for a Class 3R laser	• Unlikely for Class 3R and 3B laser; however, ensure that beam stops and enclosures are not made of combustible materials.	Low
6. Non-laser hazards (electrical, chemical, compressed gases, explosion, optical fibre breakage, hot objects, etc.)	Low	• The laser is battery powered and there are no hazardous chemicals involved in this experiment. The flask is made of glass but it is not handled during the experiment.	Low

Risk rating:

High – Unacceptable risk, control measures required
Moderate – Unacceptable risk, control measures required
Low – Acceptable risk

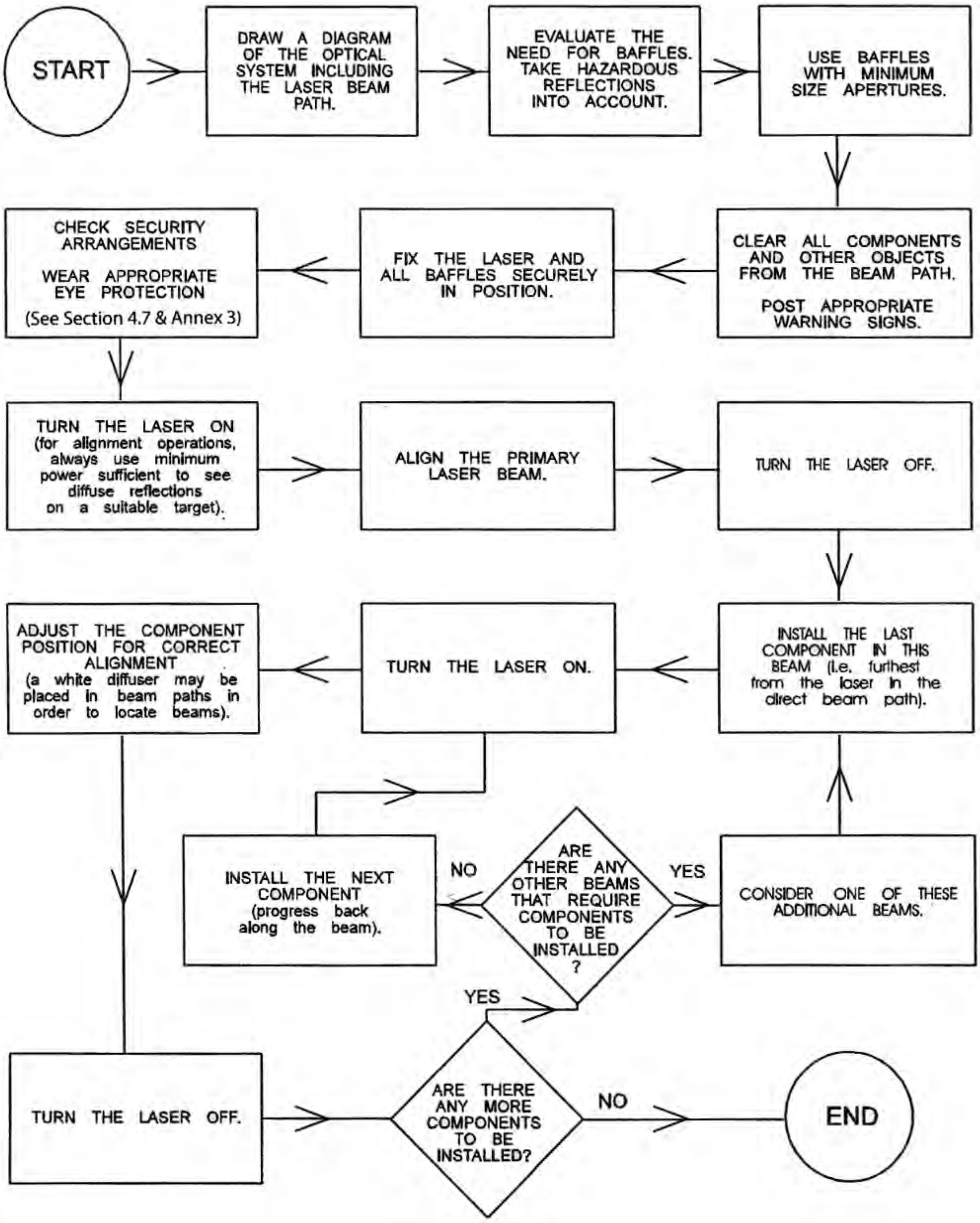
After carrying out the risk assessment all residual risks are low when the specified control measures are in place. Therefore the experiment may be carried out as a classroom demonstration with students remaining seated at their desks.

Annex A

Recommended Alignment Procedures

In addition to the usual precautions, special care is usually required during alignment tasks. Procedures should be planned in advance.

Figure 10: General alignment procedure for visible laser light systems



A.1 Alignment Procedure for Lasers with Visible Beams

A flowchart diagram of a recommended alignment procedure for a low power visible beam laser system (up to Class 3R) is shown in Figure 10. As an example, Figure 11 shows a diagram of a laser and several optical components as they may occur in a laboratory experiment.

Figure 11: Optical arrangement

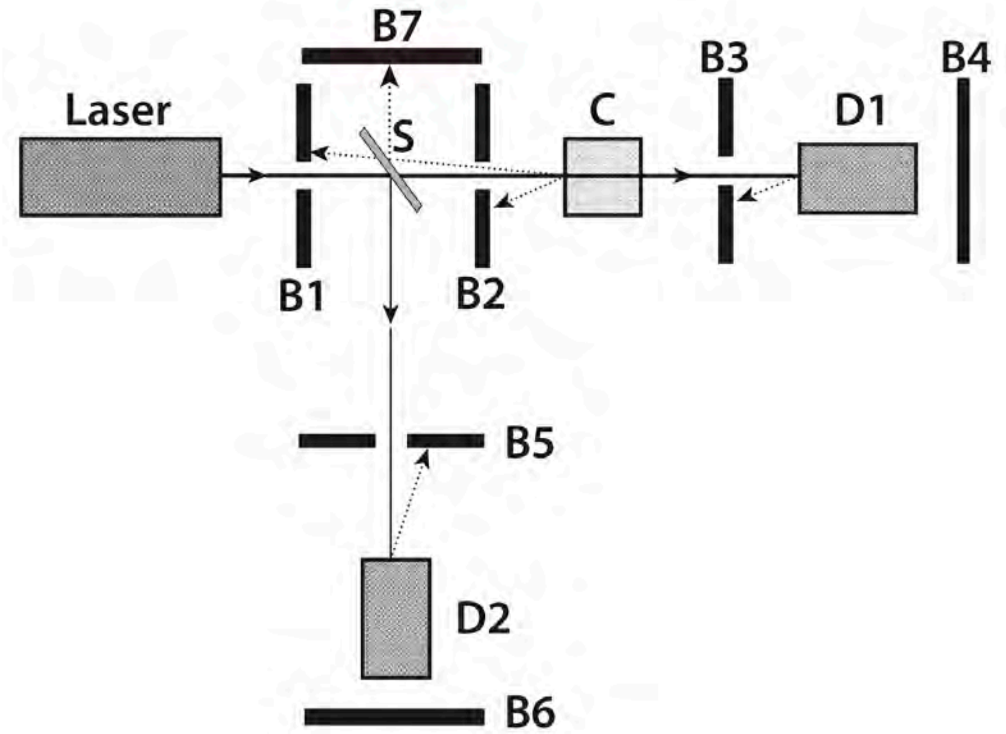


Image first published in RHS 36 *Code of practice for the safe use of lasers in schools (1995).*

Components are indicated as follows: S=beam splitter, D=detector, C=sample cell and B=**baffle**. Direct and reflected beams are indicated by arrowed lines.

The baffles shown in the diagram are used to intercept hazardous reflections from optical surfaces or to intercept misaligned beams that would otherwise travel beyond the area intended. Conforming with the flowchart in Figure 10, the general procedure for the safe alignment of this system is as follows:

a) Draw a diagram of the intended laser system and evaluate the requirement for baffles by taking into account all possible hazardous reflections. This diagram would be similar to Figure 11.

b) The size of holes in baffles should be kept to a minimum consistent with clear passage of the laser beam and allowing for some misalignment in beam position (a diameter of about twice the expected beam diameter plus about 2 mm is usually adequate).

c) Clear all components and other objects from the intended path of the laser beam.

d) Post appropriate warning signs.

e) Fix the laser and all baffles securely into position.

f) Turn the laser on at minimum power[4] sufficient to see diffuse reflections and establish correct alignment of the primary beam baffles B1, B2, B3 and B4.

NOTE: The laser beam can be detected with a narrow strip of white paper (1 cm wide strip is usually sufficient). Do not use gloss finish paper because under some circumstances this can give rise to hazardous reflections. The position of the beam is located by moving the paper about. The beam can be seen by its diffuse reflection on the paper when the paper is moved into the beam. If a reflection is being sought, be sure that the main beam is not accidentally blocked (by paper strip, hands, arm etc).

g) Turn the laser off and install detector D1.

h) With the laser operating at suitably low power, centre detector D1 in the beam and align it correctly.

NOTE: Ideally, components should be centred in the beam and oriented so that reflections are intercepted by the first baffle (i.e. they are intercepted by the closest baffle, B3 in this case, and do not pass back through the aperture in the baffle).

i) Turn the laser of and install the sample cell C.

j) With the laser operating at suitably low power, adjust the sample cell C for proper alignment in the beam.

k) Turn the laser off and install beam splitter S.

l) With the laser operating at suitably low power, adjust beam splitter S for correct orientation (make sure that the secondary beam to baffle B5 is correctly aligned).

m) Turn the laser off and install detector D2.

n) Finally, with the laser operating at suitably low power, centre detector D2 in the beam and align it so that any reflections are intercepted by baffle B5. This completes the alignment procedure.

A.2 Alignment Procedure for Lasers with Invisible Beams

A suggested alignment procedure that can be used for lasers with invisible beams is similar to that given above for visible light laser systems, except that, instead of using a diffusing target to locate the beam, an appropriate instrument or device is to be used to detect and locate the invisible beam. For ultraviolet and infrared beams a UV or IR viewing card is often used.

[4] Some lasers do not have controls to vary the output power. In such cases an adjustable attenuator device may be placed in the beam path to control the laser beam power.

Annex B

Laser Protective Eyewear

Laser protective eyewear is required to be permanently labelled to indicate the level of protection offered. Labelling is according to one of two (or both) schemes.

1. Optical density/wavelength

Two values are used:

- the optical density, abbreviated as OD. OD simply refers to the degree of attenuation provided, in a logarithmic scale starting with 1.
- the wavelength or band of wavelengths to which this OD applies (always marked as nm).

For example 'OD>5 1064 nm' means an optical density of at least 5 at 1064 nm.

2. Scale number, wavelength and laser operation mode (AS/NZS 1337.4:2011)

Three values are used (with an optional fourth):

- the wavelength or wavelength band in nm - note that the unit is omitted
- a test condition letter D, I, R or M, denoting whether the eyewear is tested with a laser in continuous or various pulsed modes
- the level of protection as a scale number (denoted as LB in the current standard and L in the previous standard), from 1 (minimum) to 10 (maximum). The scale number has a different meaning to OD, and relates to the maximum power or energy density which can be incident on the eyewear surface while still providing sufficient protection to the wearer.
- an optional mechanical strength mark, which relates to impact protection.

For example, '1064 D LB3' means an LB value of 3 at 1064 nm, for a continuous wave laser.

Annex C

Laser Risk Assessment Template for Use When Assessing Experiments

A. Experiment details	
Name of assessor	
Date	
Laboratory	
Description of experiment	
Laser training/ experience of teacher	
Laser classification	
Laser emission	
Pulsed or CW (continuous wave)	
Laser wavelength	
Protective eyewear required	

B. Risk assessment

Hazard description	**Inherent risk**	**Control measures in place to reduce risk**	**Residual risk**
1.	High/Moderate /Low		High/Moderate /Low
2.	High/Moderate /Low		High/Moderate /Low
3.	High/Moderate /Low		High/Moderate /Low

4.	High/Moderate /Low		High/Moderate /Low
5.	High/Moderate /Low		High/Moderate /Low
6.	High/Moderate /Low		High/Moderate /Low

Risk rating:

High – Unacceptable risk, control measures required
Moderate – Unacceptable risk, control measures required
Low – Acceptable risk

The experiment should not be performed unless the residual risk is 'low'.

Radiation Regulatory Authorities

Where advice or assistance is required from the relevant radiation regulatory authority, it may be obtained from the following officers:

COMMONWEALTH, STATE/TERRITORY	CONTACT	
Commonwealth	Chief Executive Officer ARPANSA PO Box 655 Miranda NSW 1490 Email: info@arpansa.gov.au	Tel: (02) 9541 8333 Fax: (02) 9541 8314
New South Wales	Manager Hazardous Materials, Chemicals and Radiation Environment Protection Authority PO Box A290 Sydney South NSW 1232 Email: radiation@epa.nsw.gov.au	Tel: (02) 9995 5959 Fax: (02) 9995 6603
Queensland	Director, Radiation Health Unit Queensland Health PO Box 2368 Fortitude Valley BC QLD 4006 Email: radiation_health@health.qld.gov.au	Tel: (07) 3328 9987 Fax: (07) 3328 9622
South Australia	Manager, Radiation Protection Environment Protection Authority GPO Box 2607 Adelaide SA 5001 Email: radiationprotection@epa.sa.gov.au	Tel: (08) 8463 7826 Fax: (08) 8124 4671
Tasmania	Senior Health Physicist Radiation Protection Unit Department of Health and Human Services GPO Box 125 Hobart TAS 7001 Email: radiation.protection@dhhs.tas.gov.au	Tel: (03) 6222 7256 Fax: (03) 6222 7257
Victoria	Team Leader, Radiation Safety Department of Health GPO Box 4541 Melbourne VIC 3001 Email: radiation.safety@dhs.vic.gov.au	Tel: 1300 767 469 Fax: 1300 769 274
Western Australia	Secretary, Radiological Council Locked Bag 2006 PO Nedlands WA 6009 Email: radiation.health@health.wa.gov.au	Tel: (08) 9388 4999 Fax: (08) 9382 0701
Australian Capital Territory	Manager Radiation Safety Health Protection Service ACT Health Directorate Locked Bag 5005 Weston Creek ACT 2611 Email: hps@act.gov.au	Tel: (02) 6205 1700 Fax: (02) 6205 1705
Northern Territory	Manager Radiation Protection Radiation Protection Section Department of Health GPO Box 40596 Casuarina NT 0811 Email: envirohealth@nt.gov.au	Tel: (08) 8922 7152 Fax: (08) 8922 7334

Please note: This table was correct at the time of printing but is subject to change from time to time. For the most up-to-date list, the reader is advised to consult the ARPANSA website (www.arpansa.gov.au). For after hours emergencies only, the police will provide the appropriate emergency contact number.

Where advice or assistance is required from the relevant occupational health and safety regulator, you should contact your Workplace Safety Authority. Details are available at the Heads of Workplace Safety Authorities website (www.hwsa.org.au/about_us/about_us-associated_internet_sites.aspx).

Radiation Protection Series Publications

ARPANSA has taken over responsibility for the administration of the former NHMRC Radiation Health Series of publications and for the codes developed under the *Environment Protection (Nuclear Codes) Act 1978*. The publications are being progressively reviewed and republished as part of the *Radiation Protection Series*. All of the Nuclear Codes have now been republished in the Radiation Protection Series.

All publications listed below are available in electronic format, and can be downloaded free of charge by visiting ARPANSA's website at www.arpansa.gov.au/Publications/codes/index.cfm.

Radiation Protection Series publications are available for purchase directly from ARPANSA. Further information can be obtained by telephoning ARPANSA on 1800 022 333 (freecall within Australia) or (03) 9433 2211.

RPS 1	Recommendations for Limiting Exposure to Ionizing Radiation (1995) and National Standard for Limiting Occupational Exposure to Ionizing Radiation (republished 2002)
RPS 2	Code of Practice for the Safe Transport of Radioactive Material (2008)
RPS 2.1	Safety Guide for the Safe Transport of Radioactive Material (2008)
RPS 3	Radiation Protection Standard for Maximum Exposure Levels to Radiofrequency Fields – 3 kHz to 300 GHz (2002)
RPS 4	Recommendations for the Discharge of Patients Undergoing Treatment with Radioactive Substances (2002)
RPS 5	Code of Practice and Safety Guide for Portable Density/Moisture Gauges Containing Radioactive Sources (2004)
RPS 6	National Directory for Radiation Protection, July 2011
RPS 7	Recommendations for Intervention in Emergency Situations Involving Radiation Exposure (2004)
RPS 8	Code of Practice for the Exposure of Humans to Ionizing Radiation for Medical Research Purposes (2005)
RPS 9	Code of Practice and Safety Guide for Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing (2005)
RPS 9.1	Safety Guide for Monitoring, Assessing and recording Occupational Radiation Doses in Mining and Mineral Processing (2011)
RPS 10	Code of Practice and Safety Guide for Radiation Protection in Dentistry (2005)
RPS 11	Code of Practice for the Security of Radioactive Sources (2007)
RPS 12	Radiation Protection Standard for Occupational Exposure to Ultraviolet Radiation (2006)
RPS 13	Code of Practice and Safety Guide for Safe Use of Fixed Radiation Gauges (2007)
RPS 14	Code of Practice for Radiation Protection in the Medical Applications of Ionizing Radiation (2008)
RPS 14.1	Safety Guide for Radiation Protection in Diagnostic and Interventional Radiology (2008)
RPS 14.2	Safety Guide for Radiation Protection in Nuclear Medicine (2008)

RPS 14.3	Safety Guide for Radiation Protection in Radiotherapy (2008)
RPS 15	Safety Guide for Management of Naturally Occurring Radioactive Material (NORM) (2008)
RPS 16	Safety Guide for the Predisposal Management of Radioactive Waste (2008)
RPS 17	Code of Practice and Safety Guide for Radiation Protection in Veterinary Medicine (2009)
RPS 18	Safety Guide for the Use of Radiation in Schools (2012)
RPS 19	Code of Practice for Radiation Protection in the Application of Ionizing Radiation by Chiropractors (2009)
RPS 20	Safety Guide for Classification of Radioactive Waste (2010)

Those publications from the NHMRC ***Radiation Health Series*** that are still current are:

RHS 9	Code of practice for protection against ionizing radiation emitted from X-ray analysis equipment (1984)
RHS 13	Code of practice for the disposal of radioactive wastes by the user (1985)
RHS 15	Code of practice for the safe use of microwave diathermy units (1985)
RHS 16	Code of practice for the safe use of short wave (radiofrequency) diathermy units (1985)
RHS 21	Revised statement on cabinet X-ray equipment for examination of letters, packages, baggage, freight and other articles for security, quality control and other purposes (1987)
RHS 22	Statement on enclosed X-ray equipment for special applications (1987)
RHS 24	Code of practice for the design and safe operation of non-medical irradiation facilities (1988)
RHS 25	Recommendations for ionization chamber smoke detectors for commercial and industrial fire protection systems (1988)
RHS 28	Code of practice for the safe use of sealed radioactive sources in borehole logging (1989)
RHS 30	Interim guidelines on limits of exposure to 50/60Hz electric and magnetic fields (1989)
RHS 31	Code of practice for the safe use of industrial radiography equipment (1989)
RHS 34	Safety guidelines for magnetic resonance diagnostic facilities (1991)
RHS 35	Code of practice for the near-surface disposal of radioactive waste in Australia (1992)
RHS 38	Recommended limits on radioactive contamination on surfaces in laboratories (1995)

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Glossary

Accessible emission limit (AEL)

The maximum accessible emission level of laser radiation permitted for a particular class of laser product (see Section 8 of this Safety Guide for a description of laser product classifications).

Alpha particles

A charged particle, consisting of two protons and two neutrons, emitted by the nucleus of a radionuclide during radioactive decay (α-decay).

Atom

The smallest portion of an element that can combine chemically with other atoms.

Baffle (Mask)

A sheet of material (often with a small aperture in the centre for the passage of the useful laser beam) designed to stop a laser beam travelling in unwanted directions. A mask should be capable of withstanding, without penetration, the maximum anticipated level of laser radiation.

Beam stop

An object that is designed to terminate the useful path of a beam of laser radiation by absorbing or diffusely reflecting the radiation.

Beta particle

An electron or positron emitted by the nucleus of a radionuclide during radioactive decay (β-decay).

CLEAPSS

Consortium of Local Education Authorities for the Provision of Science Services in the UK.

Coherent light

Coherent light is light with a high degree of coherence. Coherence is a measure of the degree to which the emitted waves remain in phase. Laser light is extremely coherent whereas the emission from conventional light sources is very incoherent.

Collimated laser beam

A beam where the light rays are essentially parallel (that is, with very little divergence or convergence).

Contamination

The presence of radioactive substances in or on a material or the human body or other place where they are undesirable or could be harmful.

Continuous wave

Describes laser radiation that is emitted continuously with a stable power output over time. In particular, there are no short pulses (that is, less than 0.25 second duration) present. This term is often abbreviated to 'cw' or 'c.w.'.

Cornea

The transparent anterior covering of the eye.

Diffuse reflection

Reflected light spread out and widely scattered into small components, usually caused by light striking a matt surface or passing through a medium filled with minute particles.

Electromagnetic radiation

Also abbreviated to '**radiation**' in this Safety Guide.

Electromagnetic spectrum

The possible range of components of electromagnetic radiation. Note that the term 'spectrum' is also frequently used in relation to a particular source of electromagnetic radiation. In such circumstances it refers to the distribution of the energy radiated (this is usually measured as a function of wavelength).

Electron

An elementary particle with low mass, $^{1}/_{1836}$ that of a proton, and unit negative electric charge. Positively charged electrons, called positrons, also exist. See also beta particle.

Energy in the form of a wave, consisting of oscillating electric and magnetic fields, that propagate at the speed of light. Electromagnetic radiation can be characterised by its wavelength, which determines the properties of the electromagnetic radiation. The part of the electromagnetic spectrum which the eye is able to detect is called visible light. The term 'light' is also used in this Safety Guide to mean electromagnetic radiation that lies within the optical region of the electromagnetic spectrum.

Exposure

The circumstance of being exposed to radiation.

Focus

Point at which electromagnetic radiation (for example, visible light) converges to after reflection or refraction.

Gamma radiation

Electromagnetic radiation emitted spontaneously from the nucleus of an atom in the process of a nuclear transition.

Half-life

In relation to radioactive decay, the time required for the quantity of a radionuclide to decrease to one half of its initial value.

Infrared

Describes electromagnetic radiation of longer wavelength than visible light, that is, within the 700 nanometre to 1 millimetre range.

Intrabeam viewing

The viewing condition whereby the laser beam is incident on the eye and the eye is directed towards the beam so that the eye is exposed to all or part of the laser beam.

Ion

Electrically charged atom or grouping of atoms.

Ionization

The process by which one or more electrons are removed from, or sometimes added to, an atom leaving the atom in a charged state.

Ionizing radiation

Electromagnetic or particulate radiation capable of producing ions directly or indirectly, but does not include electromagnetic radiation of a wavelength greater than 100 nanometres.

Irradiance

Incident power per unit area, normally given in watts per square metre (W/m^2). Also referred to as power density.

Laser

Acronym for Light Amplification by Stimulated Emission of Radiation. Any device which can be made to produce or amplify electromagnetic radiation in the wavelength range from 100 nanometres to 1 millimetre by the process of controlled stimulated emission. Also used in this Safety Guide as an abbreviation for 'Laser product'.

Laser product

Any product or assembly of components which constitutes or incorporates a laser, with required design features, operation and service manuals, and warning labels (see Section 8 for laser product classification scheme). The abbreviated term 'laser' is often used in this Safety Guide.

Laser radiation

Electromagnetic radiation produced by laser action.

Laser safety officer (LSO)

A person who is competent in the evaluation and control of laser hazards and has authority for supervision of the control of laser hazards.

Legislation

Acts and Regulations covering radiation protection, which are in place in Australian jurisdictions.

Light

Electromagnetic radiation within the optical region of the electromagnetic spectrum (i.e. within the wavelength range from 100 nanometres to 1 millimetre). The term 'light' sometimes refers to electromagnetic radiation that can be seen by the unaided eye, but in this Safety Guide it is used more generally to include electromagnetic radiation that can be manipulated with optical components.

Maximum permissible exposure (MPE)

The maximum allowable level of laser radiation to which, under normal circumstances, persons may be exposed without suffering adverse effects. See AS/NZS IEC 60825.1 or AS/NZS IEC 60825.14 for MPE values and further detail.

Monochromatic

Light consisting of radiation of a single wavelength only. For visible light, this means that it has a single pure colour. In practice, no radiation is truly monochromatic, but laser radiation often approaches this characteristic.

NDRP

The *National Directory for Radiation Protection*. Radiation Protection Series No. 6.

Non-ionizing radiation

Electromagnetic radiation of a wavelength greater than 100 nanometres.

Optical fibre

A device used to transmit laser or other optical radiation, which is usually a fine fibre of glass or plastic material.

Optical fibre system

An assembly of one or more optical fibres, associated connectors and input and output terminations.

Output power

The total power in a beam (radiant power) emitted from a laser in the form of **radiation** produced by laser action.

Radiant exposure

Energy per unit area, normally given in joules per square metre (J/m^2). Also referred to energy density.

Radiation

Electromagnetic waves or quanta and/or sub-atomic particles, propagated through space or through a material medium.

Radiation source

Anything that emits ionizing radiation.

Radioactive material

Material which spontaneously emits ionizing radiation as a consequence of radioactive decay.

Radioactive source

A sealed radioactive source or an unsealed radioactive source.

Retina

The layer of tissue at the back of the eye which is sensitive to visible light.

RPS1

The *Recommendations for limiting exposure to ionizing radiation (1995) (NOHSC guidance note)* and the *National standard for limiting occupational exposure to ionizing radiation.* Radiation Protection Series No. 1.

Sealed radioactive source

A radioactive substance bonded within metals or sealed in a capsule or other container in such a way as to:

(a) minimise the possibility of escape or dispersion of the radioactive substance

(b) allow the emission of ionizing radiation for use as required.

Supervised location

An area that is under the direct supervision and control of a suitably qualified person who is familiar with this Safety Guide and who has a clear understanding of laser hazards and safety precautions.

Target

An object towards which radiation is intentionally directed.

Ultraviolet radiation

Describes electromagnetic radiation of shorter wavelength than visible light, that is, within the 100 nanometre to 400 nanometre range. It is found between X-rays and light in the electromagnetic spectrum. Has subregions UVA, UVB, UVC.

Unsealed radioactive source

A radioactive source that is not a sealed radioactive source.

Visible light

Describes electromagnetic radiation visible to the eye. The region 400-700 nm is defined as visible in laser safety. The eye can normally see wavelength outside this region (approximately 380 - 780 nm), but the sensitivity of the eye is much lower.

Wavelength

A parameter used to describe a particular property of light (electromagnetic radiation). Wavelength is usually quoted when describing the spectral properties of visible light. The value of the wavelength defines its colour (for example, light with a wavelength of 500 nanometres is green).

X-ray

Ionizing electromagnetic radiation emitted during the transition of an atomic electron to a lower energy state or during the rapid deceleration of a charged particle.

Contributors to Drafting and Review

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