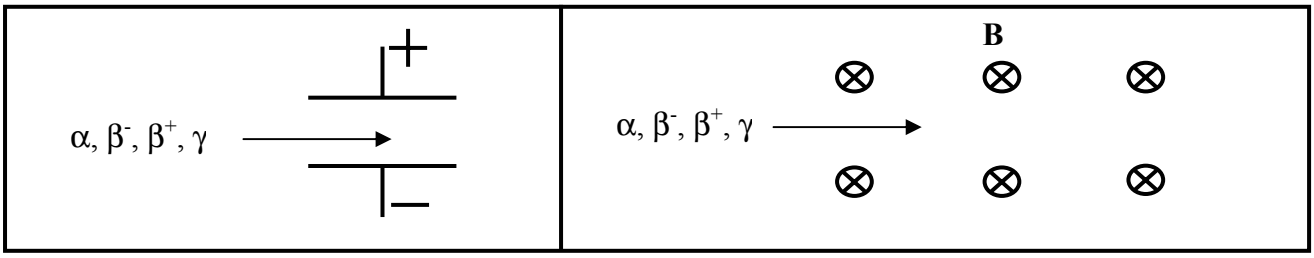
Workshop Tutorials for Technological and Applied Physics

QR15T: Interactions with Radiation

A. Qualitative Questions:

1. Beams of α, β^- and γ radiation of approximately the same energy pass through electric and magnetic fields as shown below.



a. Show the path taken by each particle in the two fields. Why do they follow these paths?
b. Which particle is the most penetrating? Explain your answer.
c. Which has the highest ionising power?
d. How are β^-, β^+ and electrons different?
e. How are x-rays, γ rays and photons different?

2. People who work with radiation, such as dentists using x-ray machines, usually use shielding of some type, such as lead aprons, to protect themselves from the radiation.
a. Why do materials composed of heavy elements make the best radiation absorbers for x-rays?
The research reactor at Lucas Heights is used to produce medical isotopes and is a source of neutrons for experiments and materials testing, for example aeroplane components. To use neutrons for some experiments, they have to be slowed down, or moderated. This is done by allowing them to repeatedly collide with atoms or molecules at a lower temperature than the neutrons
b. What would the properties of an ideal moderator material be?
c. Neutrons, electrons and x-rays can all be used to investigate the structure of materials. What information do neutrons give that electrons and x-rays don't?

B. Activity Questions:

1. Measuring Radiation

Several different means of measuring radiation are shown.
Explain how they work.
Which ones would be suitable monitoring devices for persons working in a radiation area?

2. Nuclear Power Stations

Use the diagram to explain how the energy from the nuclear decay is used to produce electricity.
What forms does the energy take before becoming electrical energy?
What do the control rods of a nuclear reactor control and how do they do this? How are they operated (i) to reduce the power level and (ii) on a long term basis as fuel is consumed?

C. Quantitative Questions:

1. The proportion of γ radiation penetrating a material decreases exponentially with the thickness of the material. A shielding material is rated according to its attenuation coefficient, μ = ln2/HVL. The HVL is the half-value layer, which is the thickness which stops one half of the incident radiation. This thickness depends on the material, and also on the radiation. It will be greater for more penetrating radiation.

a. Write an equation which gives the γ radiation intensity at a distance *d* through some material.

b. Sketch the intensity of the γ radiation as a function of distance.

c. Name another process which follows this form.

There are several isotopes of potassium which are radioactive. They emit γ and β radiation. The half value layers for the γ radiation from ^{40}K for several materials are shown below.

material	HVL (cm)
Lead	1.2
Iron	1.8
aluminium	5.0
water	12
air	10,000
concrete	5.6

d. By what fraction would the radiation be decreased by 25 cm of aluminium?

e. You are designing a shield for a hospital storage room in which ^{40}K is to be stored. If the radiation must be reduced to 1% of its unshielded level, what thickness of lead do you need to use?

f. What thickness would you need in part **e** if you were using concrete? Why do you think concrete is more commonly used as a shield?

2. Gold-198* is used to trace factory waste and sewage causing ocean pollution, and to trace sand movement in river beds and on ocean floors. It decays as follows

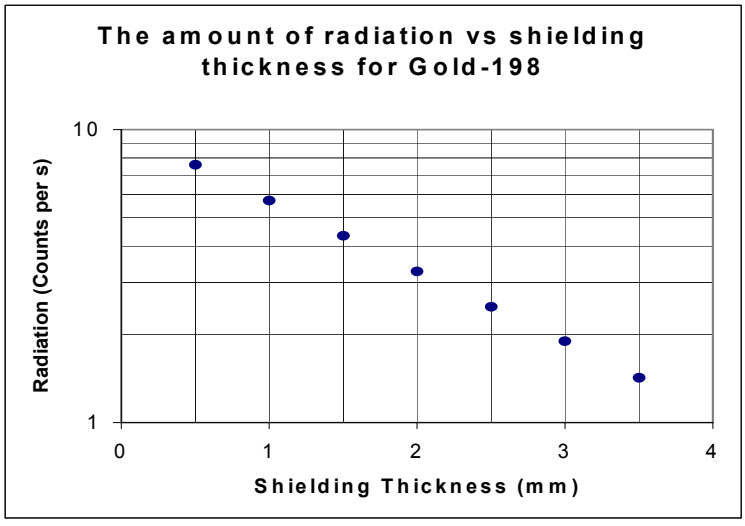
$$^{79}Au \rightarrow {}^{80}Hg + \beta^- + \gamma.$$

You are measuring the attenuation of the γ radiation from a sample of ^{198}Au through a particular type of shielding material. Use the graph below to answer the following questions.

a. What is the half thickness of this shielding?

b. What is the attenuation coefficient of the shielding?

c. Using the graph below, estimate the radioactivity directly in front of the source with no shielding.



d. You directly measure this activity with a Geiger counter and find that it is much higher than that predicted by the graph. Why is this? (Look at the decay equation and consider the penetrating power of different radiation types.)