REVIEW QUESTIONS

Data for all questions

speed of light in vacuum	c	=	3.00×10^{8} m.s^{-1}
Planck constant	h	=	6.63×10^{-34} J.s= 4.14×10^{-15} eV.s
	hc	=	1.24 keV.nm
electronic charge	e	=	1.602×10^{-19} C
rest mass of electron	m_e	=	9.11×10^{-31} kg= 0.000 549 u

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1 In the emission spectrum of the sun, 100 photons are emitted at a wavelength of 500 nm to every 113 photons emitted at 650 nm.

Find the ratio of the irradiances at the two wavelengths.

[5 minutes]

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2 a) Explain the term *rest mass*.

b) Name two particles with zero rest mass.

c) Name two particles with non-zero rest mass.

[6 minutes]

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3 In one or two sentences each, describe experiments in which

a) electrons behave as waves,

b) photons behave as particles.

Include in the descriptions a statement of how the experiment illustrates the behaviour in question.

[12 minutes]

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4 a) What is the energy of a photon associated with a wavelength of 500 nm?

b) Calculate the wavelength of a non-relativistic electron with energy 2.0×10^{-19} J.

[6 minutes]

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5 A free electron is moving at a speed of 1.8×10^{8} m.s^{-1}.

a) What is its mass?

b) What is its total energy?

[6 minutes)

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7 Explain why atoms have line spectra.

[6 minutes]

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9 The energy of an isolated hydrogen atom in its ground state ($n = 1$) is E_1 = -13.6 eV. Energies of excited states ($n > 1$) are given by the formula:

$$E_n = \frac{E_1}{n^2}$$

a) What is the binding energy of the unexcited hydrogen atom?

b) Calculate the frequency of radiation emitted in the transition from state $n = 3$ to $n = 2$.

c) Can a hydrogen atom absorb a photon with energy of 15.0 eV? Explain.

[8 minutes]

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10 Use the data below to estimate the mean binding energy per nucleon of the helium nucleus. Show how the calculation is done and give your answer in MeV.

mass of proton	=	1.007 276 u
mass of neutron	=	1.008 665 u
mass of $^{4}_{2}$He nucleus	=	4.001 506 u
u	=	$1.660\ 566 \times 10^{-27}$ kg

[6 minutes]

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12 Explain each of the following terms:

a) spontaneous atomic transition,

b) stimulated atomic transition,

c) monochromatic radiation.

[9 minutes]

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13 a) What is the phenomenon of stimulated emission of radiation?

b) Explain how it is used in a laser.

[8 minutes]

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14 The concentration of copper in a sample may be determined by x-ray fluorescence. X rays from an x-ray tube excite the copper atoms which then emit characteristic x rays.

Given that the x rays emitted by the copper have a wavelength of 0.154 nm, what is the minimum voltage across the x-ray tube required to excite the fluorescence?

[6 minutes]

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15 The linear attenuation coefficients of dense concrete and lead for 125 keV x rays are 36 m^{-1} and 3.6×10^{3} m^{-1} respectively,

Calculate the thicknesses of the two materials required to attenuate the flux of 125 keV x-ray photons to 0.01 percent of the original flux.

[6 minutes]

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16 On the same diagram sketch the x-ray spectrum for two different accelerating voltages. On your diagram show

(i) which curve corresponds to the higher accelerating voltage,

(ii) the short wavelength cut-offs,

(iii) characteristic x rays.

[8 minutes]

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17 a) State the law which describes how a monochromatic beam of x-ray photons is attenuated by matter. Write the law as an equation and define the symbols used.

b) Although the attenuation law describes how photons are removed from the original beam it does not give an accurate description of the intensity or total energy flux in the beam. Briefly state why that is so.

[6 minutes]

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18 A wooden relic has an activity of 12 counts per minute for each gram of carbon in it. Living trees give 16 counts per minute for each gram of carbon.

Estimate the age of the wood in the relic.

(The half life of radioactive carbon is 5700 y.)

[5 minutes]

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19 a) Explain what is meant by the term radioactive *half life*.

b) An analysis of a sample of burnt wood from a prehistoric site gives a concentration of 1 part of carbon-14 to 1.0×10^{14} parts of carbon-12. An analysis of modern carbon gives a concentration of 1 part of carbon-14 to 1.0×10^{13} parts of carbon-12.

Estimate the age of the burnt wood.

(The half life of radioactive carbon is 5700 y.)

[8 minutes]

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20 The unstable isotope $^{213}_{84}$Po decays through an intermediate atom X to the stable isotope $^{209}_{83}$Bi. Write down a possible decay scheme for each of the two decays. Define any symbols you use. What are the atomic number and the mass number of X?

[6 minutes]

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21 The nucleus of an element is described by its atomic number Z and its mass number A. What properties of the nucleus does each of these numbers describe?

How do these numbers change when a radioactive nucleus emits

a) an alpha particle,

b) a beta particle,

c) a gamma ray photon?

[7 minutes]

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22 a) State what is meant by the half life of a radioactive isotope.

b) The half life of iodine-131 is 8.0 days. What period of time would have to elapse for the activity of a sample of this isotope to fall to l/16 of its original activity?

[6 minutes]

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23 a) How does a scintillator detect radiation?

b) Why is a photomultiplier used in conjunction with the scintillator?

c) Briefly describe the operation of any other detector of ionising radiation.

[8 minutes]

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24 a) What is a γ ray?

b) Describe the type of nuclear process that produces γ rays.

c) Briefly describe how a beam of gamma rays loses energy.

[9 minutes]

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25 Explain how a photomultiplier works.

[6 minutes]

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26 Radioactive technetium has a half life of 6 hours. It decays by emitting 0.14 MeV gamma rays.

A patient has a mass of 50 kg. If the amount of technetium that is injected into the patient's body has an activity of 2.0 GBq, and half the radiation is absorbed, calculate the initial whole body absorbed dose rate.

[6 minutes]

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27 a) Explain the connection between the terms **absorbed dose** and **dose equivalent**. Name and define the SI units for absorbed dose and dose equivalent.

b) A 60 kg patient is exposed to 1.25 MeV gamma rays from an 8.4×10^{13} Bq cobalt-60 source for 3 minutes. Given that 1 % of all the gamma rays emitted fall on the patient and that about half of those go through the patient's body without interacting, estimate the whole body absorbed dose.

[10 minutes]

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29 The isotope radium-226 decays, with a half life of 1.6×10^{3} years, by emitting 4.8 MeV alpha particles.

Comment on the health hazard of radium-226

a) when it is outside the body,

b) when it is absorbed inside the body.

[6 minutes]

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30 The table below shows energies associated with an electron in the K and L shells of a tungsten atom.

a) Estimate the accelerating voltage required to produce the Kα characteristic radiation in an x-ray tube with a tungsten anode.

b) What is the shortest wavelength of the Kα lines?

Shell	**Energy levels/keV**
K	69.6
L	12.1, 11.6, 10.2

[5 minutes]

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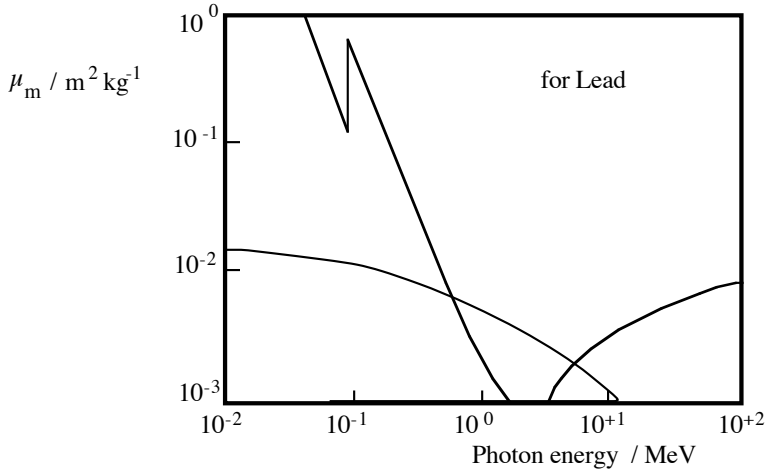
31 The photoelectric effect, the Compton effect and pair production can all contribute the absorption of a beam of gamma rays by solid matter. Briefly distinguish among the effects. How do the relative contributions of the different effects depend on photon energy?

[8 minutes]

3 2 The diagram below shows the variation of mass-attenuation coefficient for absorption of x rays and gamma rays by lead.



a) Explain what is meant by *mass attenuation coefficient*.

b) Sketch a copy of the diagram and label each of the three curves with the name of the effect which it describes.

c) What causes the vertical line on the curve in the upper left part of the diagram?

[8 minutes]

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3 3 Briefly describe the three main physical processes by which a beam of energetic charged particles loses energy as it passes through bulk matter.

[8 minutes]

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3 4 a) Explain what is meant by the stopping power of a material for charged particles.

b) Describe how stopping power varies with particle energy. (A good answer will include a sketch graph.)

[8 minutes]

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3 5 a) What is meant by the range of an ionising radiation? What factors affect the range?

b) All the alpha particles from a particular radioactive decay have about the same range, but electrons from a particular beta decay have many different ranges. Why is that so?

c) Why does it not make sense to specify the range of gamma rays?

[8 minutes]

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3 6 Outline the operating principles of a Geiger counter.

[6 minutes]

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3 7 Describe one source of background radiation which is hazardous to humans. Explain the nature of the hazard and suggest ways of reducing the hazard.

[6 minutes]
