National 5 Physics

Waves & Radiations

2014 to 2017 Past papers

1. The period of vibration of a guitar string is 8 ms.

The frequency of the sound produced by the guitar string is

A 0·125 Hz

B 12·5 Hz

C 125 Hz

D 800 Hz

E 8000 Hz.

2. A student makes the following statements about microwaves and radio waves.

I In air, microwaves travel faster than radio waves.

II In air, microwaves have a longer wavelength than radio waves.

III Microwaves and radio waves are both members of the electromagnetic spectrum.

Which of these statements is/are correct?

A I only

B III only

C I and II only

D I and III only

E II and III only

3. Which row describes alpha (α), beta (β) and gamma (γ) radiations?

	α	β	γ
A	helium nucleus	electromagnetic radiation	electron from the nucleus
B	helium nucleus	electron from the nucleus	electromagnetic radiation
C	electron from the nucleus	helium nucleus	electromagnetic radiation
D	electromagnetic radiation	helium nucleus	electron from the nucleus
E	electromagnetic radiation	electron from the nucleus	helium nucleus

4. A sample of tissue is irradiated using a radioactive source.
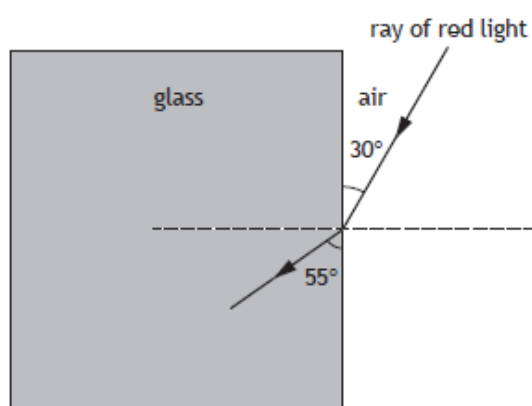
A student makes the following statements about the sample.

I The equivalent dose received by the sample is reduced by shielding the sample with a lead screen.

II The equivalent dose received by the sample is increased as the distance from the source to the sample is increased.

III The equivalent dose received by the sample is increased by increasing the time of exposure of the sample to the radiation.

Which of these statements is/are correct?

A I only

B II only

C I and II only

D II and III only

E I and III only

5.

The half-life of a radioactive source is 64 years.

In 2 hours, $1\cdot44 \times 10^8$ radioactive nuclei in the source decay.

What is the activity of the source in Bq?

A 2×10^4

B 4×10^4

C $1\cdot2 \times 10^6$

D $2\cdot25 \times 10^6$

E $7\cdot2 \times 10^7$

6.

A student makes the following statements about the fission process in a nuclear power station.

I   Electrons are used to bombard a uranium nucleus.

II   Heat is produced.

III   The neutrons released can cause other nuclei to undergo fission.

Which of these statements is/are correct?

A   I only

B   II only

C   III only

D   I and II only

E   II and III only

7.

A student writes the following statements about electromagnetic waves.

I Electromagnetic waves all travel at the same speed in air.

II Electromagnetic waves all have the same frequency.

III Electromagnetic waves all transfer energy.

Which of these statements is/are correct?

A   I only

B   II only

C   I and III only

D   II and III only

E   I, II and III

8.

A satellite orbiting the Earth transmits television signals to a receiver.

The signals take a time of 150 ms to reach the receiver.

The distance between the satellite and the receiver is

A $2\cdot0 \times 10^6$ m

B $2\cdot25 \times 10^7$ m

C $4\cdot5 \times 10^7$ m

D $2\cdot0 \times 10^9$ m

E $4\cdot5 \times 10^{10}$ m.

9. A wave machine in a swimming pool generates 15 waves per minute.

The wavelength of these waves is 2·0 m.

The frequency of the waves is

A   0·25 Hz

B   0·50 Hz

C   4·0 Hz

D   15 Hz

E   30 Hz.

10. For a ray of light travelling from air into glass, which of the following statements is/are correct?

I   The speed of light always changes.

II The speed of light sometimes changes.

III The direction of light always changes.

IV The direction of light sometimes changes.

A   I only

B   III only

C   I and III only

D   I and IV only

E   II and IV

11. A ray of red light is incident on a glass block as shown.

Which row in the table shows the values of the angle of incidence and angle of refraction?

|	Angle of incidence	Angle of refraction
A	35°	60°
B	30°	55°
C	30°	35°
D	60°	55°
E	60°	35°

12. A student writes the following statements about the activity of a radioactive source.

I   The activity decreases with time.
II The activity is measured in becquerels.
III The activity is the number of decays per second.

Which of these statements is/are correct?

A   I only
B   II only
C   I and II only
D   II and III only
E   I, II and III

13. A worker in a nuclear power station is exposed to 3·0 mGy of gamma radiation and 0·50 mGy of fast neutrons.

The radiation weighting factor for gamma radiation is 1 and for fast neutrons is 10.

The total equivalent dose, in mSv, received by the worker is

A   3·50
B   8·00
C   30·5
D   35·0
E   38·5.

14. The diagram represents a water wave.
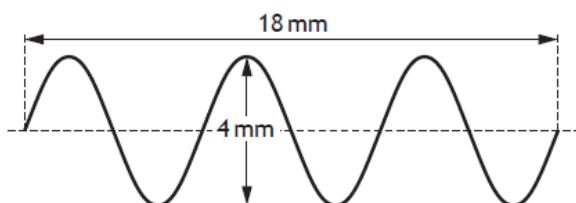
The wavelength of the water wave is

A   2 mm
B   3 mm
C   4 mm
D   6 mm
E   18 mm.

15. A student makes the following statements about different types of electromagnetic waves.

I   Light waves are transverse waves.
II   Radio waves travel at 340 m s^{-1} through air.
III Ultraviolet waves have a longer wavelength than infrared waves.

Which of these statements is/are correct?

A   I only
B   I and II only
C   I and III only
D   II and III only
E   I, II and III

16.   Alpha radiation ionises an atom.

Which statement describes what happens to the atom?

A   The atom splits in half.

B   The atom releases a neutron.

C   The atom becomes positively charged.

D   The atom gives out gamma radiation.

E   The atom releases heat.

17.

A student makes the following statements about waves.

I   In a transverse wave, the particles vibrate parallel to the direction of travel of the wave.

II   Light waves and water waves are both transverse waves.

III Sound waves are longitudinal waves.

Which of these statements is/are correct?

A   I only

B   II only

C   III only

D   I and II only

E   II and III only

18.   A sample of tissue receives an absorbed dose of 16 µGy from alpha particles.

The radiation weighting factor for alpha particles is 20.

The equivalent dose received by the sample is

A   0·80 µSv

B   1·25 µSv

C   4 µSv

D   36 µSv

E   320 µSv.

19.

For a particular radioactive source, 240 atoms decay in 1 minute.

The activity of this source is

A   4 Bq

B   180 Bq

C   240 Bq

D   300 Bq

E 14 400 Bq.

20. The letters X, Y and Z represent missing words from the following passage.

During a nuclear ......X...... reaction two nuclei of smaller mass number combine to produce a nucleus of larger mass number. During a nuclear ....Y....... reaction a nucleus of larger mass number splits into two nuclei of smaller mass number. Both of these reactions are important because these processes can release .....Z...... .

Which row in the table shows the missing words?

	X	Y	Z
A	fusion	fission	electrons
B	fission	fusion	energy
C	fusion	fission	protons
D	fission	fusion	protons
E	fusion	fission	energy

A student makes the following statements about waves.
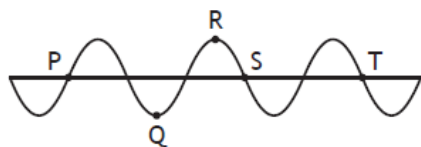
21.

I   Waves transfer energy.

II   A wave with a short wavelength diffracts more than a wave with a long wavelength.

III The amplitude of a wave depends on its wavelength.

Which of these statements is/are correct?

A   I only
B   II only
C   III only
D   I and II only
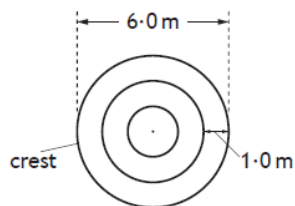E   I and III only

The diagram represents a wave.

22.

The wavelength of the wave is the horizontal distance between points

A   P and Q
B   P and S
C   Q and R
D   R and S
E   S and T.

23.

The diagram represents the position of the crests of waves 3 seconds after a stone is thrown into a pool of still water.
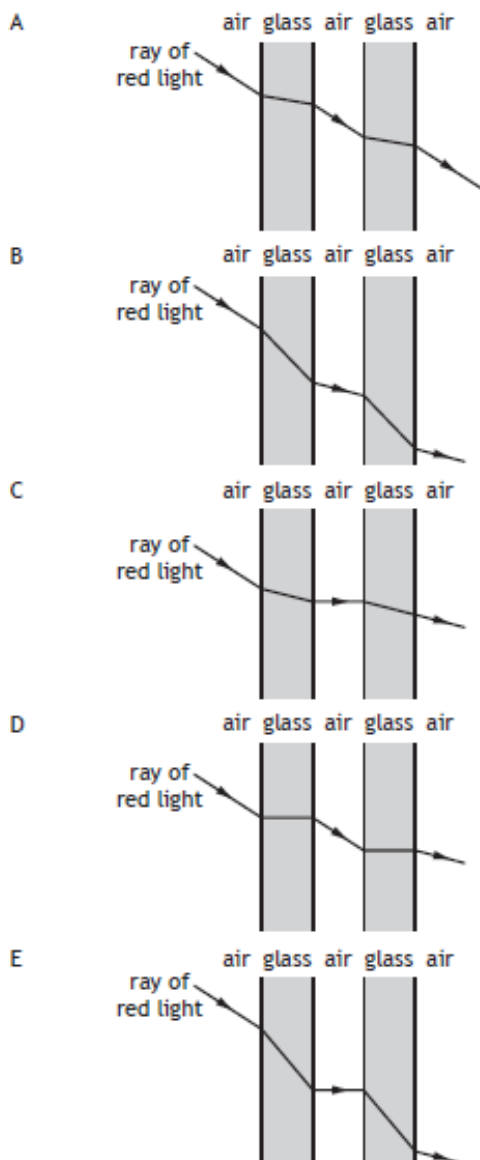

Which row in the table shows the speed and the frequency of the waves?

	Speed $(m\,s^{-1})$	Frequency (Hz)
A	0·33	3
B	0·33	1
C	1·0	1
D	1·0	3
E	1·0	4

24.

A ray of red light passes through a double glazed window.

Which diagram shows the path of the ray as it passes through the window?

25. Which row in the table shows how the mass and charge of an alpha particle compares to the mass and charge of a beta particle?

	Mass of an alpha particle compared to mass of a beta particle	Charge on an alpha particle compared to charge on a beta particle
A	larger	same
B	larger	opposite
C	same	same
D	smaller	opposite
E	smaller	same

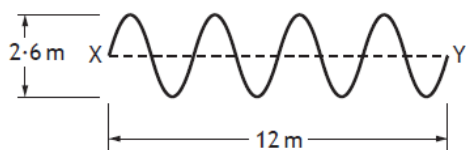**26.** During ionisation an atom becomes a positive ion.

Which of the following has been removed from the atom?

A   An alpha particle

B   An electron

C   A gamma ray

D   A neutron

E   A proton

27. The diagram represents a wave travelling from X to Y.

The wave travels from X to Y in a time of 0·5 s.

Which row in the table shows the amplitude, wavelength and frequency of this wave?

	Amplitude (m)	Wavelength (m)	Frequency (Hz)
A	1·3	1·5	2·0
B	2·6	1·5	24
C	1·3	3·0	8·0
D	2·6	3·0	8·0
E	1·3	3·0	24

28. A microwave signal is transmitted by a radar station.

The signal is reflected from an aeroplane.

The aeroplane is at a height of 30 km directly above the radar station.

The time between the signal being transmitted and the reflected signal being received back at the radar station is

A 5×10^{-5} s

B 1×10^{-4} s

C 2×10^{-4} s

D 5×10^{3} s

E 1×10^{4} s.

29.

A member of the electromagnetic spectrum has a shorter wavelength than visible light and a lower frequency than X-rays. This type of radiation is

A   gamma

B   ultraviolet

C   infrared

D   microwaves

E   radio waves.

30.

A sample of tissue is exposed to 15 μGy of alpha radiation and 20 μGy of gamma radiation. The total equivalent dose received by the tissue is
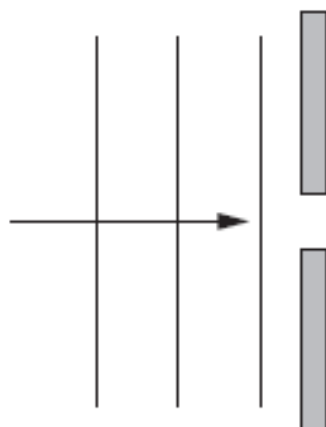
A   35 μSv

B   320 μSv

C   415 μSv

D   700 μSv

E   735 μSv.

Answers

1	C	11	E	21	A
2	B	12	E	22	E
3	B	13	B	23	C
4	E	14	D	24	A
5	A	15	A	25	B
6	E	16	C	26	B
7	C	17	E	27	C
8	C	18	E	28	C
9	A	19	A	29	B
10	D	20	E	30	B

1.

A water wave is diffracted when it passes through a gap in a barrier. The wavelength of the wave is 10 mm. The gap is less than 10 mm.

(a) Complete the diagram above to show the pattern of the wave to the right of the barrier. 2

(b) The diagram below represents the electromagnetic spectrum.

Radio & TV waves	A	Infrared radiation	Visible light	Ultraviolet light	X-rays	Gamma radiation

(i) Identify radiation A. 1

(ii) Apart from diffraction, state one property that all electromagnetic waves have in common. 1
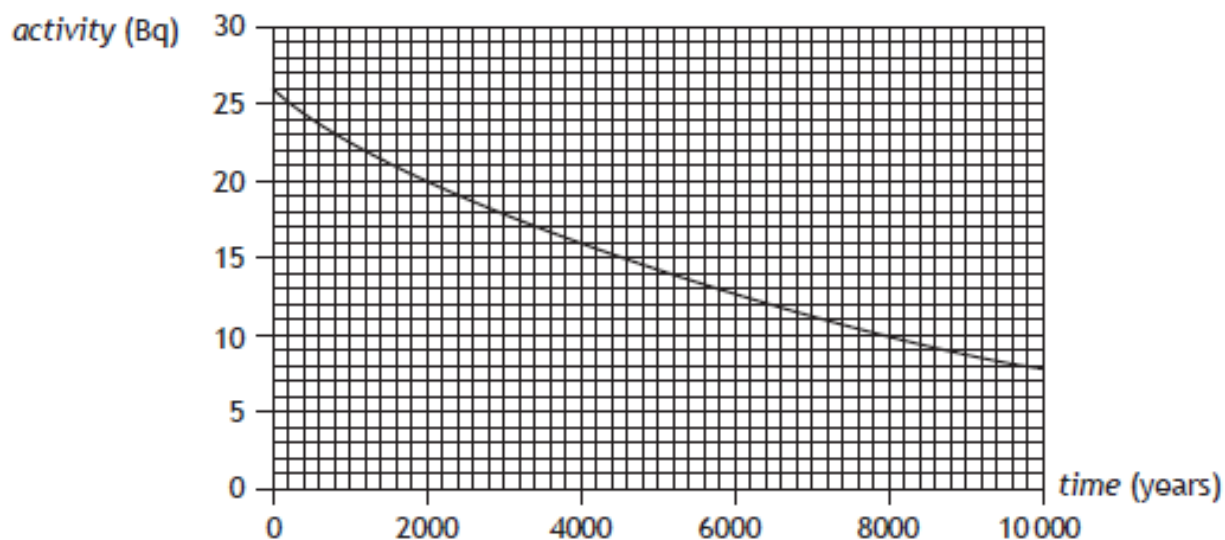
Total marks 4

2.

Trees continually absorb carbon-14 when they are alive. When a tree dies the carbon-14 contained in its wood is not replaced. Carbon-14 is radioactive and decays by beta emission.

(a) Following the tree's death, the activity of the carbon-14 within a 25 mg sample of its wood changes as shown.

(i) Use the graph to determine the half-life of carbon-14. 2

(ii) Calculate the time taken for the activity of this sample of carbon-14 to fall to 6·5 Bq. 3

Space for working and answer

(a) (continued)

(iii) During an archaeological dig, a 125 mg sample of the same type of wood was obtained. The activity of this sample was 40 Bq.

Estimate the age of this sample. 3

Space for working and answer

(b) Explain why this method could not be used to estimate the age of a tree that died 100 years ago. 1

Total marks 9

3.

A technician uses a radioactive source to investigate the effect of gamma rays on biological tissue.

(a) State what is meant by the term *gamma rays*.   1

(b) The wavelength of a gamma ray is $6 \cdot 0 \times 10^{-13}$ m.

Calculate the frequency of the gamma ray.   3

Space for working and answer

(c) In one experiment, a biological tissue sample of mass $0 \cdot 10$ kg receives an absorbed dose of $50 \, \mu$Gy.

Calculate the energy absorbed by the tissue.   3

Space for working and answer

(d) The radioactive source must be stored in a lead-lined container.

Explain why a lead-lined container should be used.   1

Total marks   8

4.

A student, fishing from a pier, counts four waves passing the end of the pier in 20 seconds. The student estimates that the wavelength of the waves is 12 m.
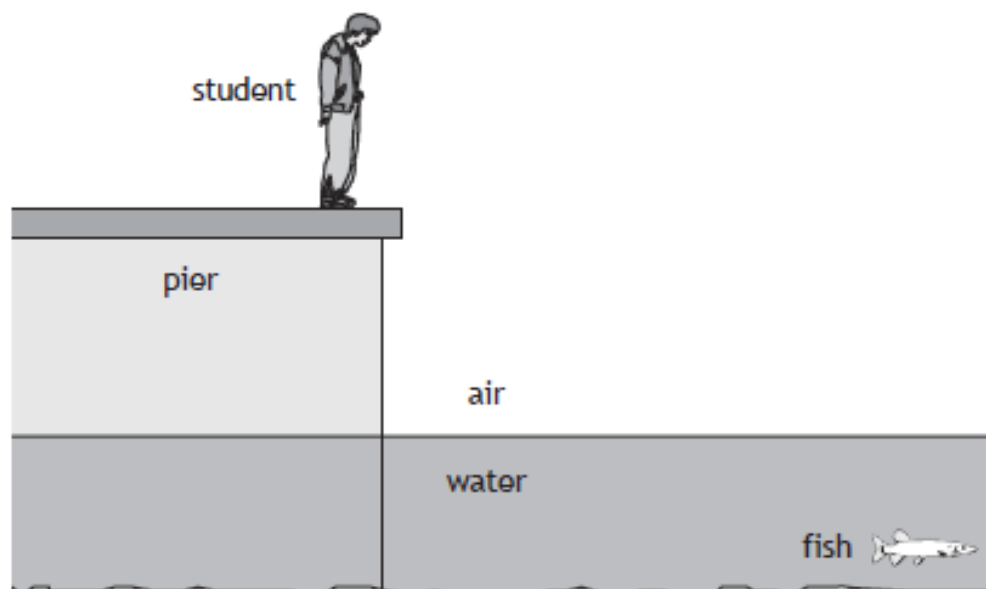

Not to scale
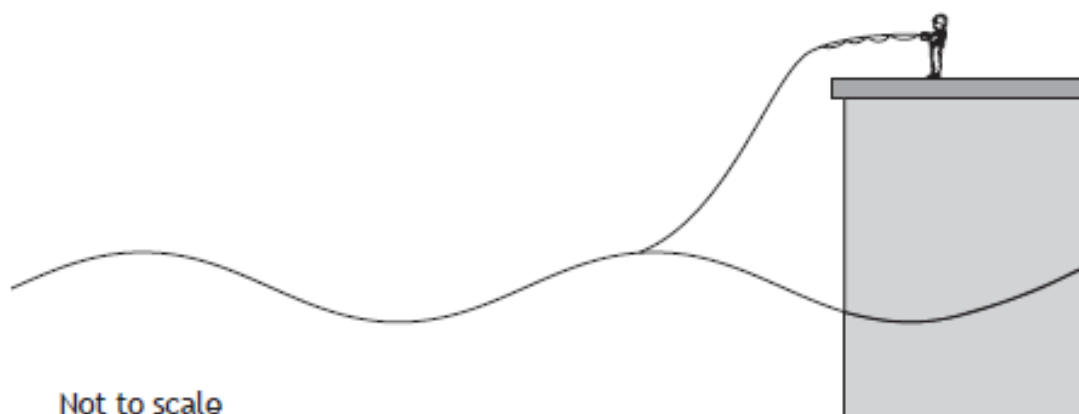
(a) Calculate the speed of the water waves.   4

   Space for working and answer

(b) When looking down into the calm water behind the pier the student sees a fish.

   Complete the diagram to show the path of a ray of light from the fish to the student.

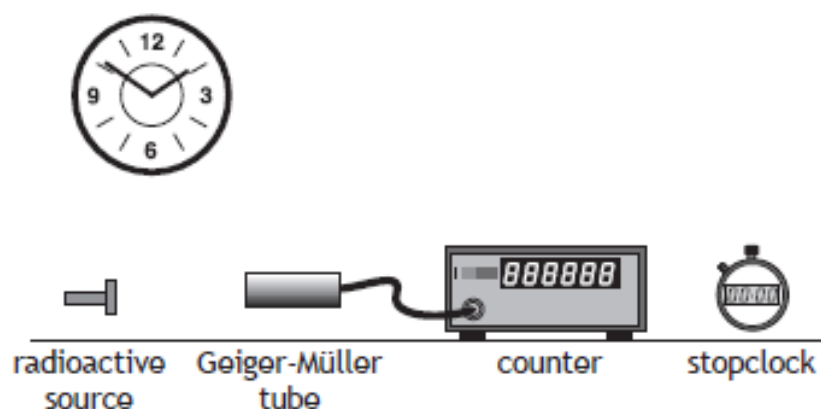   You should include the normal in your diagram.   3

   (An additional diagram, if required, can be found on *Page thirty-one*.)
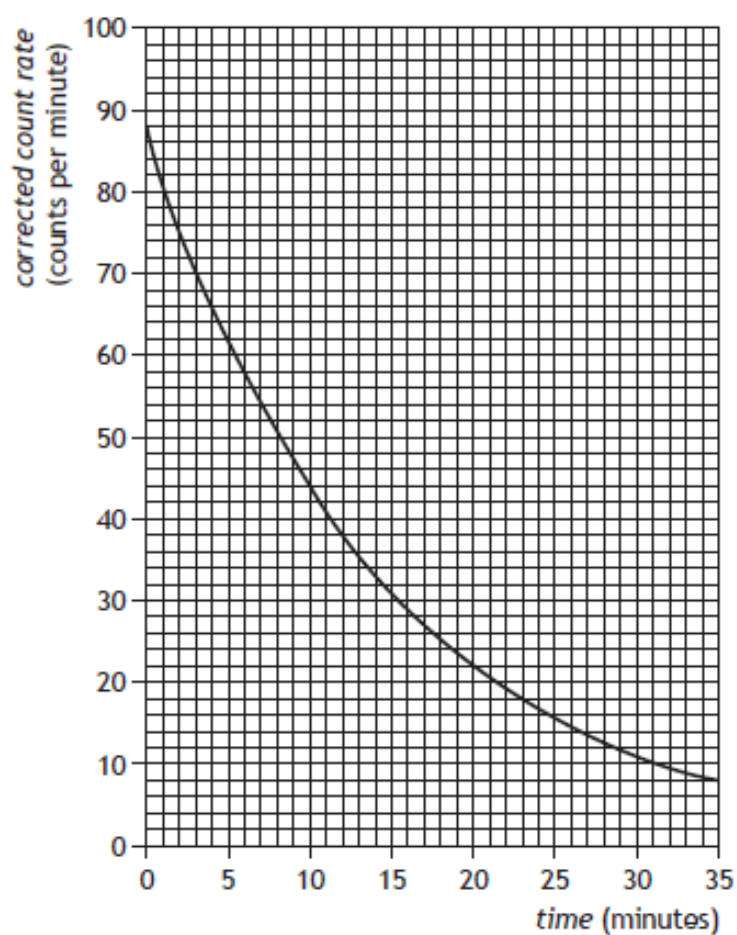
   Total marks   7

5.

A technician carries out an experiment, using the apparatus shown, to determine the half-life of a radioactive source.

radioactive source   Geiger-Müller tube   counter   stopclock

(a) State what is meant by the term *half-life*.   1

(b) The technician displays the data obtained from the experiment in the graph below.

(i) Describe how the apparatus could be used to obtain the experimental data required to produce this graph. 3

(ii) Use information from the graph to determine the half-life of the radioactive source. 1

(iii) Determine the corrected count rate after 40 minutes. 2

Space for working and answer

6.

An airport worker passes suitcases through an X-ray machine.

(a) The worker has a mass of 80·0 kg and on a particular day absorbs 7·2 mJ of energy from the X-ray machine.

(i) Calculate the absorbed dose received by the worker. 3

Space for working and answer

.

(ii) Calculate the equivalent dose received by the worker. 3

Space for working and answer

(b) X-rays can cause ionisation.

Explain what is meant by *ionisation*. 1
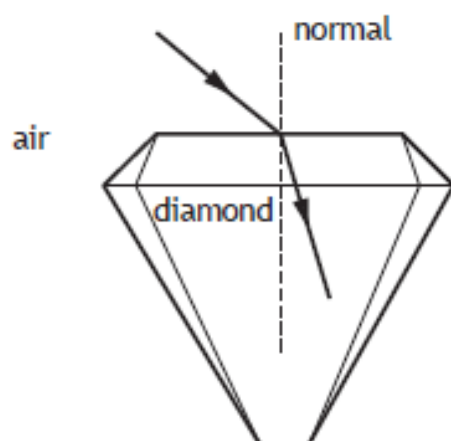
Total marks 7

7.

Diamonds are popular and sought after gemstones.

MARKS

Light is refracted as it enters and leaves a diamond.

The diagram shows a ray of light entering a diamond.

(a) On the diagram, label the angle of incidence *i* and the angle of refraction *r*. 1

(b) State what happens to the speed of the light as it enters the diamond. 1

(c) The optical density of a gemstone is a measure of its ability to refract light.

Gemstones of higher optical density cause more refraction.

A ray of light is directed into a gemstone at an angle of incidence of 45°.

The angle of refraction is then measured.

This is repeated for different gemstones.

Gemstone	Angle of refraction
A	24·3°
B	17·0°
C	27·3°
D	19·0°
E	25·5°

Diamond is known to have the highest optical density.

Identify which gemstone is most likely to be diamond. 1

(d) Diamond is one of the hardest known substances.

Synthetic diamonds are attached to the cutting edges of drill bits for use in the oil industry.

These drill bits are able to cut into rock.

cutting edge

single cutter

drill bit
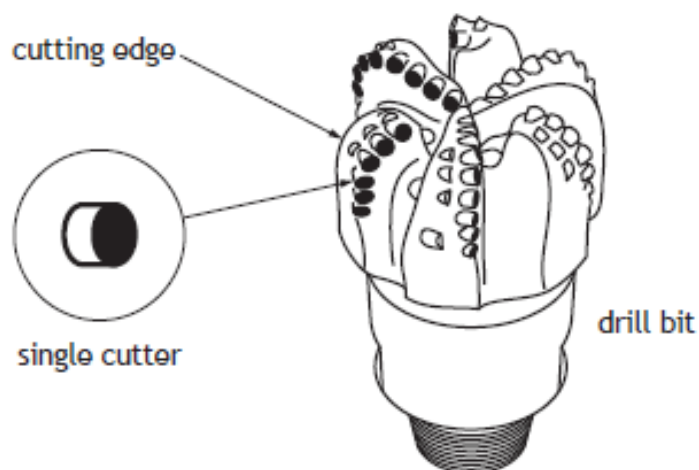
The area of a single cutter in contact with the rock is $1·1 \times 10^{-5} \, m^2$.

When drilling, this cutter is designed to exert a maximum force of 61 kN on the rock.

Calculate the maximum pressure that the cutter can exert on the rock. 3

Space for working and answer

8.

A paper mill uses a radioactive source in a system to monitor the thickness of paper.
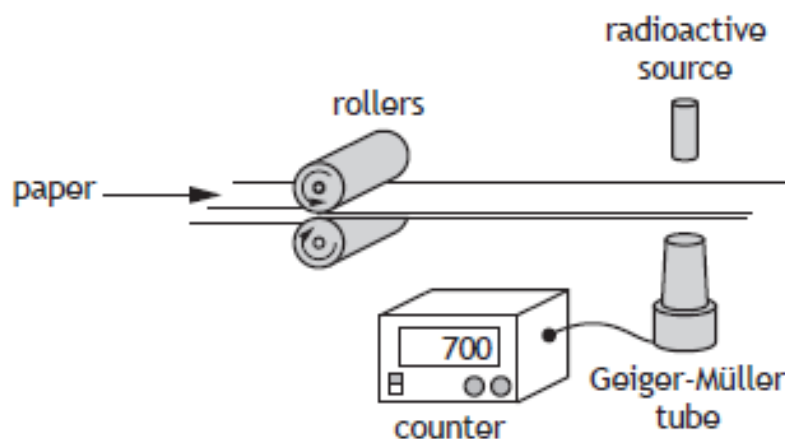
Radiation passing through the paper is detected by the Geiger-Müller tube. The count rate is displayed on the counter as shown. The radioactive source has a half-life that allows the system to run continuously.

(a) State what happens to the count rate if the thickness of the paper decreases.

1

(b) The following radioactive sources are available.

Radioactive Source	Half-life	Radiation emitted
W	600 years	alpha
X	50 years	beta
Y	4 hours	beta
Z	350 years	gamma

(i) State which radioactive source should be used.

You must explain your answer.

3

(b) (continued)

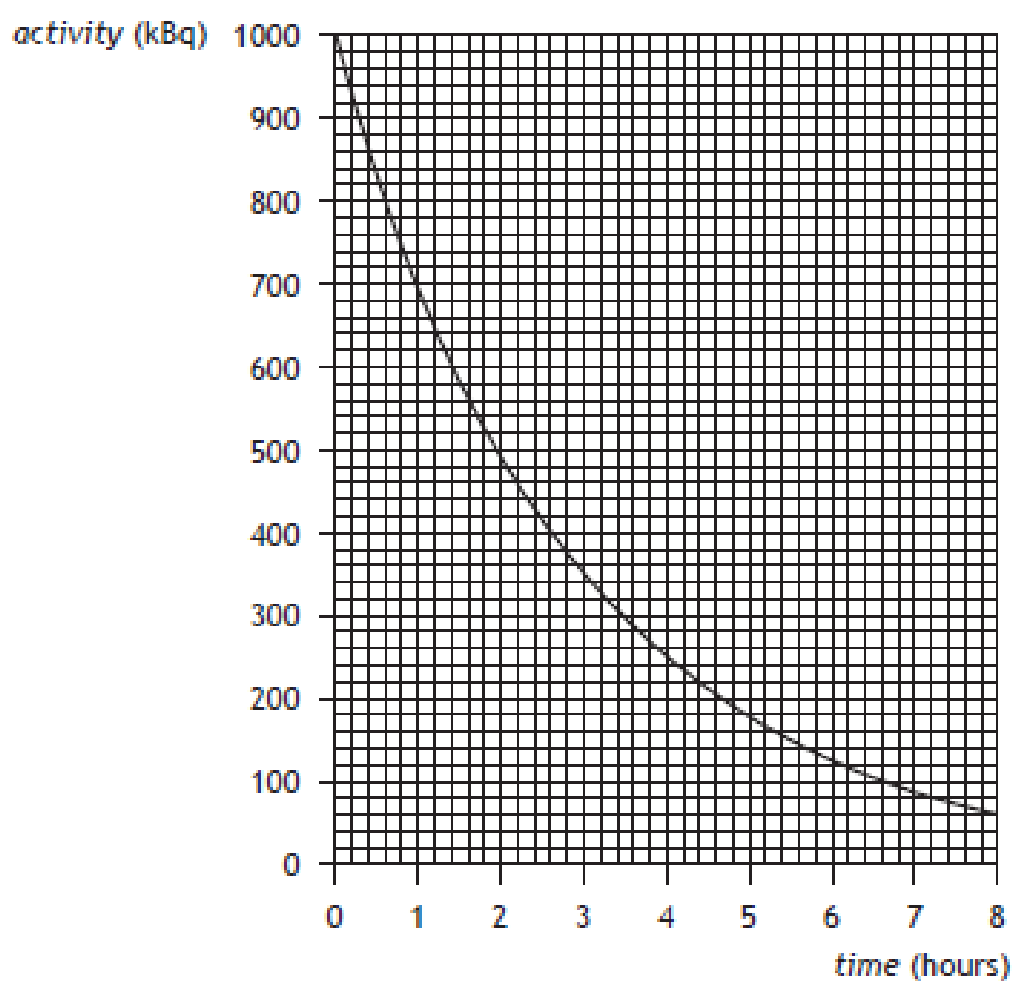   (ii) State what is meant by the term *half-life*.   1

    (iii) State what is meant by a gamma ray.   1

(c) The graph below shows how the activity of another radioactive source varies with time.

Determine the half-life of this radioactive source.   1

9.

The diagram shows some parts of the electromagnetic spectrum in order of increasing wavelength.

visible light

X-rays	ultra-violet		infrared	microwaves

10^{-10}　　　10^{-8}　　　10^{-6}　　　10^{-4}　　　10^{-2}　　　1
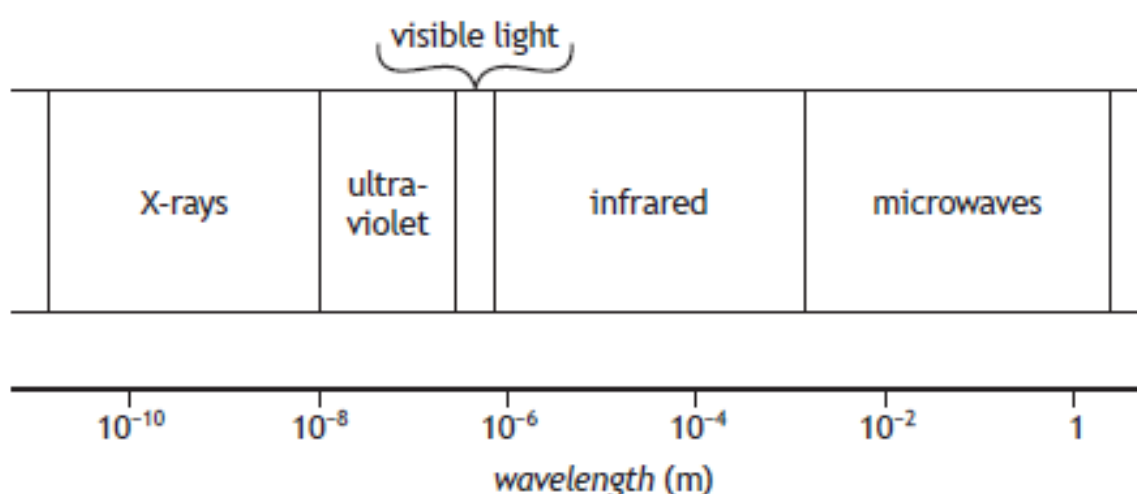
wavelength (m)

(a) State a detector of infrared radiation. **1**

(b) State which radiation in the electromagnetic spectrum has a wavelength shorter than X-rays. **1**

(c)　(i) An electromagnetic wave has a frequency of 1·2 GHz.

Show that the wavelength of this wave is 0·25 m. **2**

Space for working and answer

(ii) Identify the part of the spectrum that this wave belongs to. **1**

10.

A student directs a ray of red light into a Perspex block to investigate refraction.
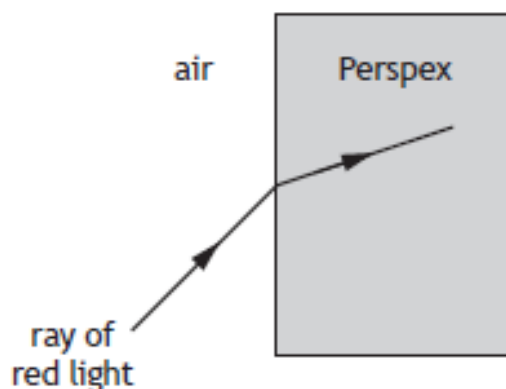
(a) On the diagram, draw and label:

    (i) the normal;   1

    (ii) the angle of incidence i and the angle of refraction r.   1

    (An additional diagram, if required, can be found on *Page 33*)

(b) The student varies the angle of incidence and measures the corresponding angles of refraction. The results are plotted on a graph.
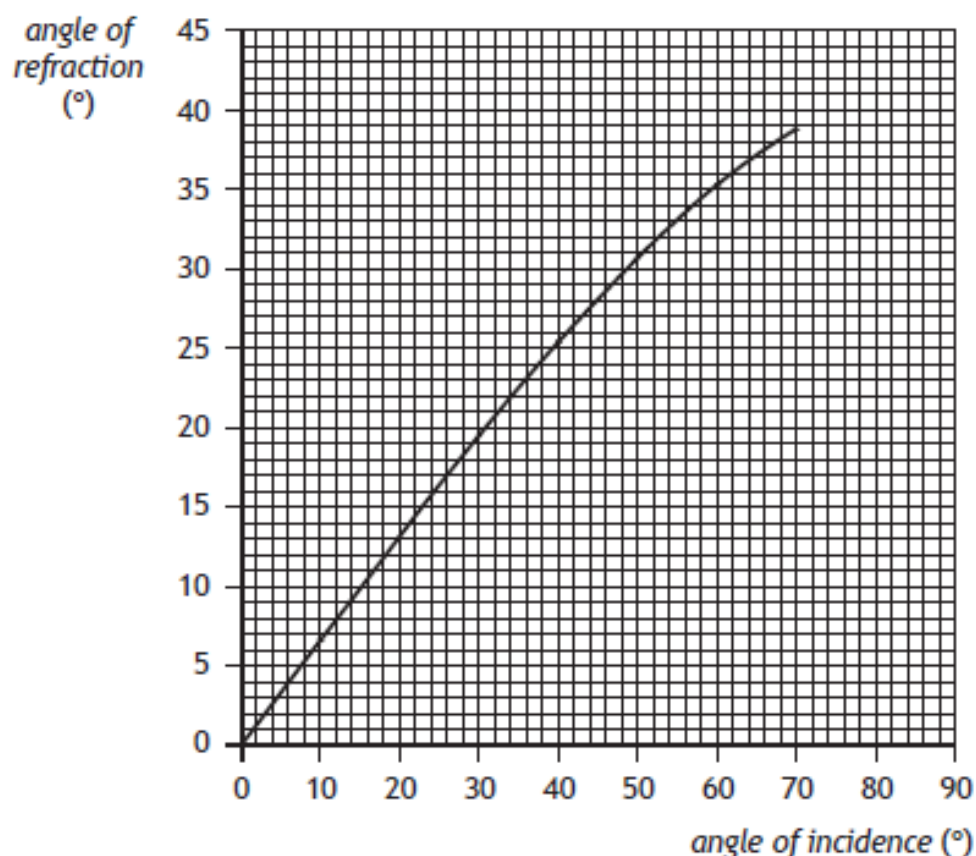
(b) (continued)

    (i) Determine the angle of refraction when the angle of incidence is 12°.

        1

    (ii) Use the graph to predict the angle of refraction the student would obtain for an angle of incidence of 80°.

        1

(c) Suggest why it would be good practice for the student to repeat the investigation a further three or four times.

        1

11.

A spacecraft uses a radioisotope thermoelectric generator (RTG) as a power source.

RTG
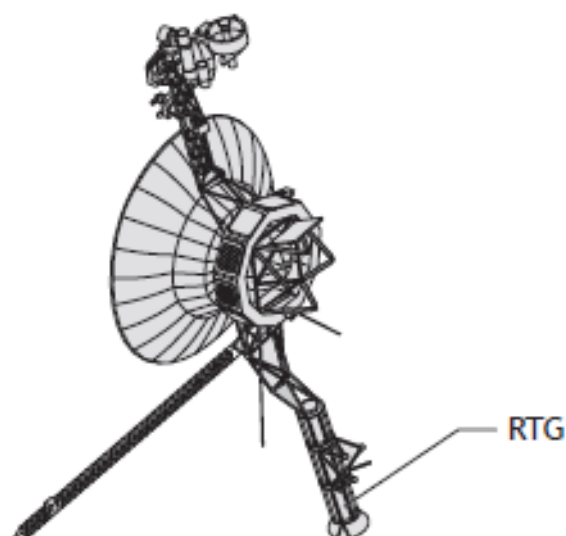
The RTG transforms the heat released by the radioactive decay of plutonium–238 into electrical energy.

(a) In 15 minutes, $7 \cdot 92 \times 10^{18}$ nuclei of plutonium-238 decay.

    Calculate the activity of the plutonium-238.

        3

    Space for working and answer

(b) Each decay produces heat that is transformed into $4 \cdot 49 \times 10^{-14}$ J of electrical energy.

Determine the power output of the RTG.　　　　　　　　　2

Space for working and answer

(c) Plutonium-238 emits alpha radiation.

Explain why a source that emits alpha radiation requires less shielding than a source that emits gamma radiation.　　　　　　1

12.

During medical testing a beta source is used to irradiate a sample of tissue of mass $0 \cdot 50$ kg from a distance of $0 \cdot 10$ m.

The sample absorbs $9 \cdot 6 \times 10^{-5}$ J of energy from the beta source.
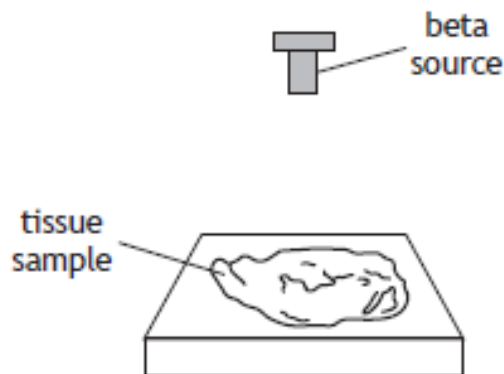
(a)　(i) Calculate the absorbed dose received by the sample.　　　3

Space for working and answer

(ii) Calculate the equivalent dose received by the sample.　　　3

Space for working and answer

(b) The beta source used during testing has a half-life of 36 hours.

The initial activity of the beta source is 12 kBq.

Determine the activity of the source 144 hours later.   3

Space for working and answer

13.

A student observes water waves entering a harbour.
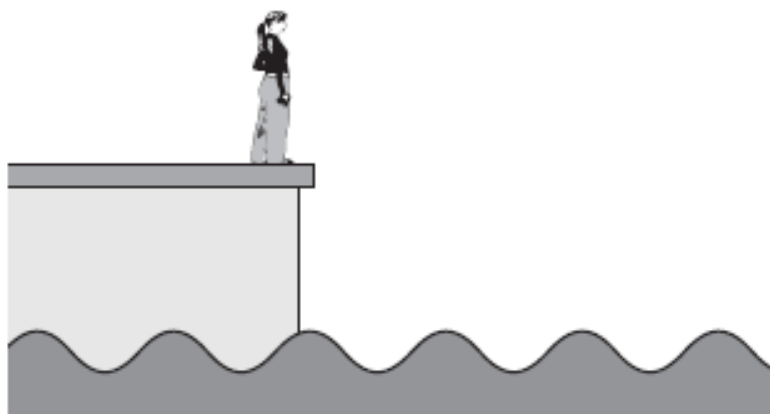
(a) To determine the frequency of the waves, the student measures the time taken for a wave to pass a point at the harbour entrance.

The student measures this time to be 2·5 s

(i) Calculate the frequency of the waves.   3

Space for working and answer

(ii) Suggest how the accuracy of the frequency determined by the student could be improved.   1

(b) The distance between one wave crest and the next crest is 8·0 m.

Calculate the velocity of the waves.   3

Space for working and answer

(c) Waves travel towards the entrance of the harbour as shown.

view from above

| harbour wall | | harbour wall |

wave crests

direction of travel of waves
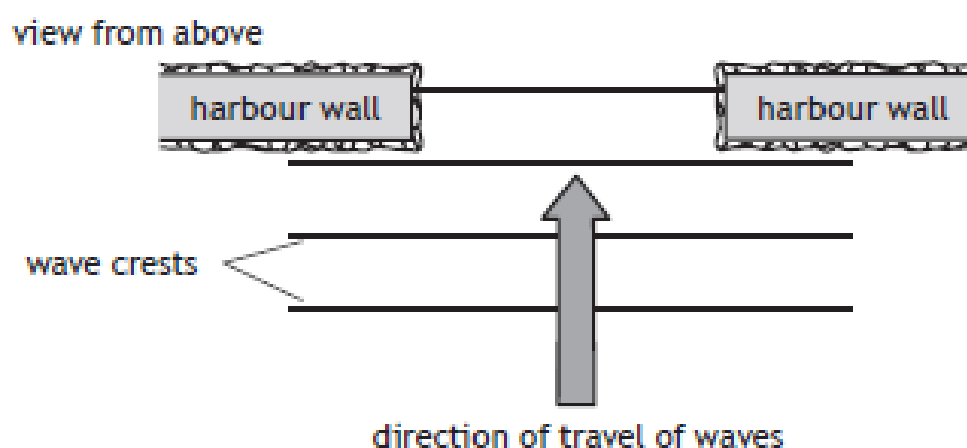
Complete the diagram to show the pattern of wave crests inside the harbour.   2

(An additional diagram, if required, can be found on *Page 28*)

(d) As the waves pass into the harbour the student observes that the amplitude of the waves decreases.

Explain this observation.   1

14.

A technician uses the apparatus shown to investigate the effect of shielding gamma radiation with lead.

ratemeter   Geiger-Müller   lead   gamma
tube   absorber   source
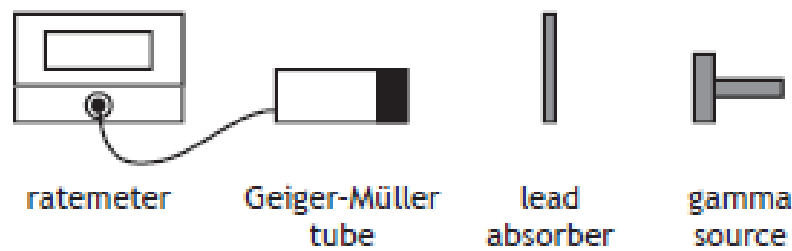
Gamma radiation passing through a lead absorber is detected by a Geiger-Müller tube. The count rate is displayed on the ratemeter.

The count rates for a range of different thicknesses of lead absorber are recorded.

Using these results the technician produces a graph of corrected count rate against thickness of lead absorber as shown.
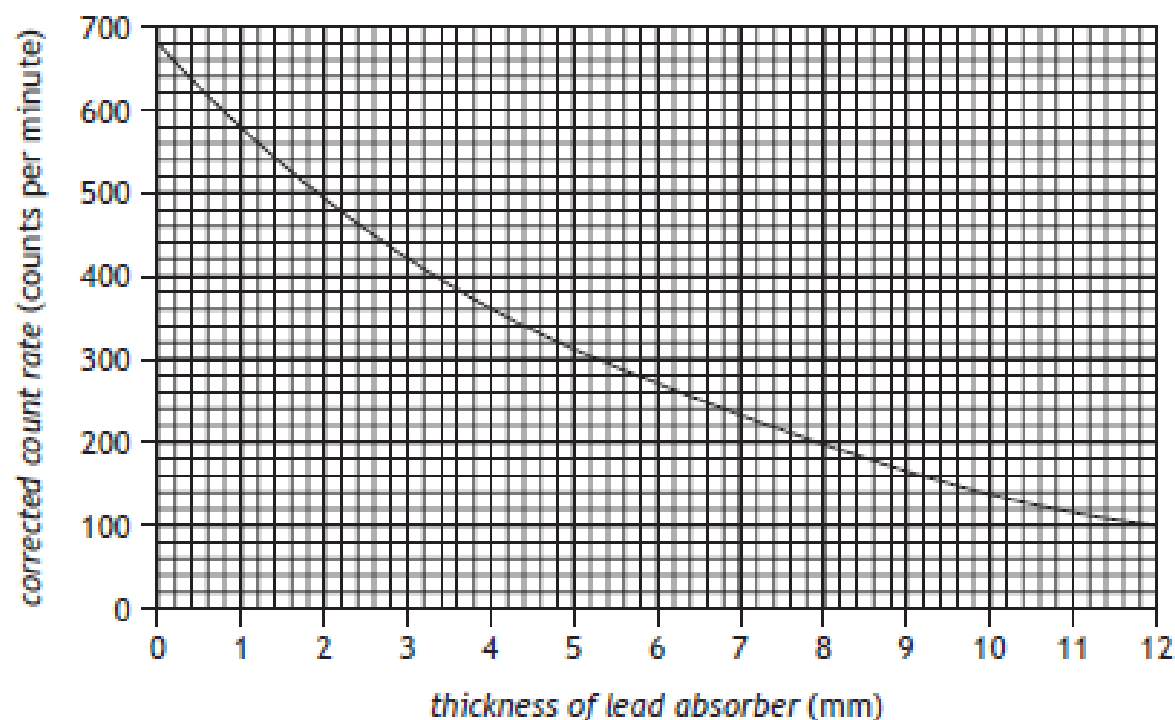
(a) State what additional measurement the technician must have made in order to determine the corrected count rate. 1

(b) The half-value thickness of a material is the thickness of material required to reduce the corrected count rate from a source by half.

    (i) Using the graph, determine the half-value thickness of lead for this source of gamma radiation.   **1**

    (ii) Determine the thickness of lead required to reduce the corrected count rate to one eighth of its initial value.   **2**

    Space for working and answer

    (iii) The technician suggests repeating the experiment with aluminium absorbers instead of lead absorbers.

    Predict how the half-value thickness of aluminium would compare to the half-value thickness of lead for this source.   **1**

(c) When working with the radioactive source the technician is exposed to an equivalent dose rate of $2 \cdot 5 \times 10^{-6}\,Sv\,h^{-1}$.

The annual equivalent dose limit for the technician is $20\,mSv$.

Calculate the maximum number of hours the technician may work with this source without exceeding this limit.   **3**

Space for working and answer

15.

Nuclear reactions are used to generate electrical energy in a nuclear power station.

(a) The fuel for the power station is in the form of pellets, containing uranium-235.

A fuel pellet has an activity of 80 kBq.

State what is meant by an *activity of 80 kBq*.   1

(b) In a nuclear reaction a uranium-235 nucleus is split by a neutron to produce two smaller nuclei, three neutrons, and energy.

uranium-235 nucleus

neutron
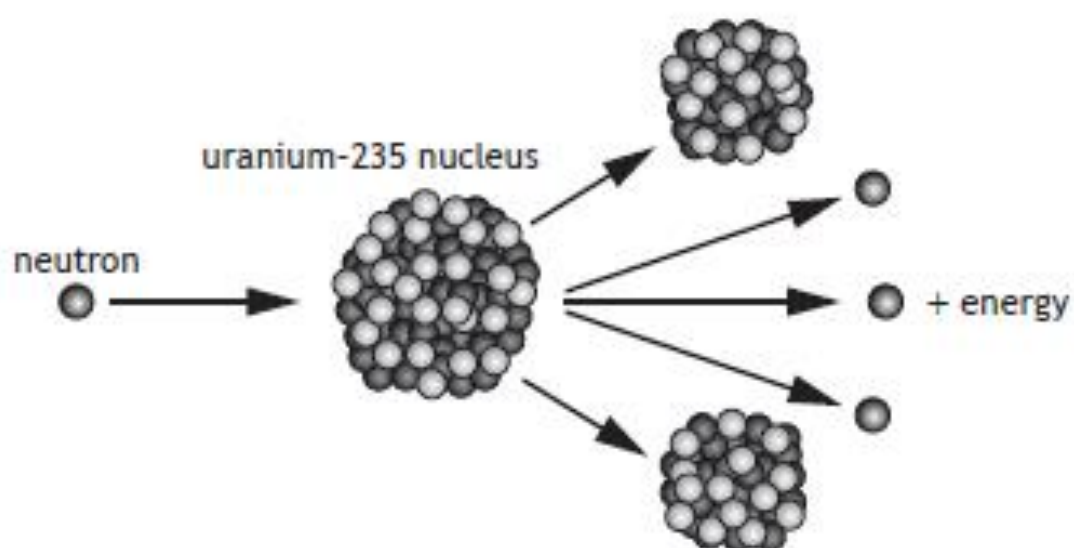
+ energy

(b) (continued)

    (i) Explain how a single reaction can lead to the continuous generation of energy.   **2**

    (ii) One nuclear reaction releases $3 \cdot 2 \times 10^{-11}$ J.
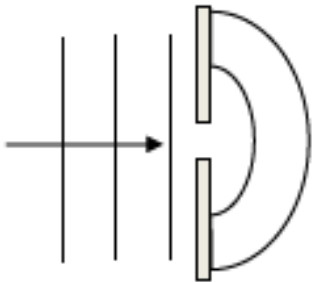
      In the reactor, $3 \cdot 0 \times 10^{21}$ reactions occur each minute.

      Determine the maximum power output of the reactor.   **4**

      Space for working and answer

(c) The nuclear reactor produces waste that emits nuclear radiation.

    State a use of nuclear radiation.   **1**

1

a			2	Circular wavefronts (1)
				Wavelength after the gap is the same as before the gap. A minimum of two wavefronts must be drawn. (1)
b	i	Microwaves	1	
b	ii	They all travel at the same speed through a vacuum OR in air. OR They all exhibit interference OR reflection OR refraction OR propagation.	1	

2
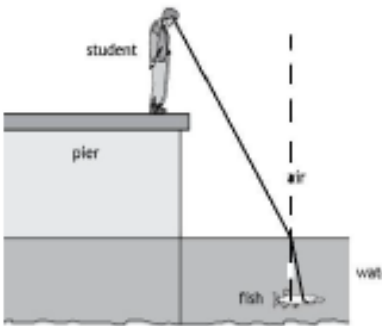
a	i	Identify 13 Bq as half of the initial activity. (1) Half-life is 5800 years. (1)	2	(Or choosing another activity value and halving it.)
a	ii	$26 \rightarrow 13 \rightarrow 6 \cdot 5 = 2$ half-lives (1) total time $= 2 \times 5800$ (1) $= 11\,600$ years (1)	3	Or consistent with (a)(i).
a	iii	Activity of 125 mg sample is 40 Bq. Activity of 8 mg of sample $= 1/5$ OR $\dfrac{25}{125} \times 40$ (1) $= 8$ (Bq) (1) (From graph, 8 Bq is at 9800 years.) Sample is approximately 9800 years old. (1)	3	1 mark for identifying 1/5 (or 25/125). 1 mark for calculating activity of 25 mg sample. 1 mark for selecting value from graph.
b		The half-life of carbon 14 is 5800 years. For 100 years the very small reduction in the activity would be difficult to measure accurately.	1	

3.

a	Gamma rays are electromagnetic waves.	1	
b	$f = \dfrac{v}{\lambda}$ (1) $= \dfrac{3 \times 10^{8}}{6 \times 10^{-13}}$ (1) $= 5 \times 10^{20}\,\text{Hz}$ (1)	3	
c	$D = \dfrac{E}{m}$ (1) $50 \times 10^{-6} = \dfrac{E}{0 \cdot 1}$ (1) $E = 5 \times 10^{-6}\,\text{J}$ (1)	3	
d	Gamma rays are absorbed by the lead.	1	

4.

| (a) | $f = N^{\circ}\ of\ waves/time$ $= \dfrac{4}{20}$ $= 0 \cdot 2\,(\text{Hz})$ (1) $v = f\lambda$ (1) $= 0 \cdot 2 \times 12$ (1) $= 2 \cdot 4\,\text{m s}^{-1}$ (1) | 4 | Alternative methods: $d = 12 \times 4 = 48\,(\text{m})$ (1) $v = \dfrac{d}{t}$ (1) $= \dfrac{48}{20}$ (1) $= 2 \cdot 4\,\text{m s}^{-1}$ (1) OR time for 1 wave $= \dfrac{20}{4}$ $= 5\ (\text{s})$ (1) $v = \dfrac{d}{t}$ (1) $= \dfrac{12}{5}$ (1) $= 2 \cdot 4\,\text{m s}^{-1}$ (1) |

(b)			3	Ignore arrows and any labelled angles.

(1) mark for ray changing direction at water/air boundary

(1) mark for angle in water less than angle in air.
Angle of incidence in water should be less than the angle of refraction in air.

    (1) mark for correct normal (must be placed at the point where a ray meets the water/air boundary)

Ignore arrows and any labelled angles.

Lines should be passably straight.

If the normal is not represented as a dotted line it must be labelled.

5.

(a)		The time taken for the activity / corrected count rate (of a radioactive source) to half.	1	Do not accept: Time for radiation / radioactivity / count rate to half.
(b)	(i)	Measure the count in a set time interval (1) Repeat at (regular) intervals (1) Measure background (count) and subtract (1)	3	(3) independent marks. Description must refer to the apparatus shown. If candidate response makes reference to using a rate meter then MAX (2) marks.
(b)	(ii)	(Half-life =) 10 minutes　　　(1)	1	Unit required (accept mins) +/- half box tolerance
	(iii)	$88 \longrightarrow 44 \longrightarrow 22 \longrightarrow 11 \longrightarrow 5 \cdot 5$ (1) mark for evidence of halving Count rate = 5·5 counts per minute　　　(1)	2	Or answer consistent with 6(b)(ii) Accept 5 or 6 counts per minute Accept calculation based on one halving of 11 counts per minute Unit required (accept c.p.m.) Alternative method: Accept calculation using division by 2^4 (equivalent to halving).

6.

(a)	(i)	$D = \dfrac{E}{m}$ (1)	3	
		$= \dfrac{7 \cdot 2 \times 10^{-3}}{80 \cdot 0}$ (1)		
		$= 9 \cdot 0 \times 10^{-5}$ Gy (1)		
	(ii)	$H = Dw_R$ (1)	3	Or answer consistent with 8(a)(i)
		$= 9 \cdot 0 \times 10^{-5} \times 1$ (1)		If wrong radiation weighting factor selected then (1) MAX for correct equation.
		$= 9 \cdot 0 \times 10^{-5}$ Sv (1)		
(b)		When an atom gains / loses / gains or loses electrons.	1	Ignore additional information.

7.

(a)		Correctly labelled the angle of incidence and angle of refraction	1	No need for arcs. Can use words or symbols, I, θ_i etc.
(b)		Decreases	1	Accept: 'slows down' 'changes to $1 \cdot 2 \times 10^8$ m s^{-1}' Do not accept: 'changes' alone
(c)		B	1	Or clearly identified, eg circled in table
(d)		$P = \dfrac{F}{A}$ (1) $= \dfrac{61000}{1 \cdot 1 \times 10^{-5}}$ (1) $= 5 \cdot 5 \times 10^9$ Pa (1)	3	Accept N m^{-2} Accept 1-4 sig fig: 6×10^9 Pa $5 \cdot 5 \times 10^9$ Pa $5 \cdot 55 \times 10^9$ Pa $5 \cdot 545 \times 10^9$ Pa

8.

(a)		Increases	1	
(b)	(i)	**Choice:** (source) X (1) **Explanation:** beta (source required) (1) long half-life (1)	3	First mark can only be awarded if an explanation is attempted. Choice correct + explanation correct (3) Choice correct + explanation partially correct (2) Choice correct + explanation incorrect (1) Choice correct + no explanation attempted (0) Incorrect or no choice made regardless of explanation (0) Having chosen source X, can explain why each of the other three sources should not be used. Having chosen source X, can explain that a beta source should be used but that source Y is not suitable because it has too short a half-life.
	(ii)	Time for activity to (decrease by) half OR Time for half the nuclei to decay	1	Do not accept: Time for radiation/radioactivity/ count rate to half
	(iii)	(high frequency) electromagnetic wave	1	Accept: 'EM wave' '(high energy) photon' 'electromagnetic radiation' Do not accept: 'electromagnetic ray' 'part of the electromagnetic spectrum' 'transverse wave' Ignore additional information
(c)		2 hours	1	Unit required Accept 1·9 to 2·1 h

9.

(a)		(black bulb) thermometer, photodiode, phototransistor, thermistor, thermocouple, CCD, thermochromic film	1	Do not accept: Skin (Infrared/thermal imaging) camera Photographic film thermogram
(b)		Gamma (radiation/rays)	1	
(c)	(i)	** SHOW THAT ** Must start with the correct equation or (0) $v = f\lambda$ (1) $3 \cdot 0 \times 10^{8} = 1 \cdot 2 \times 10^{9} \times \lambda$ (1) $\lambda = 0 \cdot 25$ m	2	Final answer of 0·25 m or its numerical equivalent, including unit, must be shown, otherwise a maximum of (1) can be awarded. For alternative methods calculating v or f there must be final statement to show that calculated value of v or f is the same as the value stated in the question/data sheet to gain the second mark.
	(ii)	Microwave (radiation)	1	Accept: 'microwaves'

10.
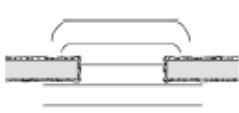
(a)	(i)	normal drawn and labelled	1	Must be 'passably' perpendicular and straight Does not need to be dashed Accept: 'N' or 'n' as label
	(ii)	Both angles indicated and labelled	1	Accept: i and r I and R θ_i and θ_r If normal has been incorrectly drawn, then this mark is still accessible, provided angles are indicated to the normal and labelled. Accept angles indicated either entering or leaving the Perspex block
(b)	(i)	8°	1	Allow ±0·5° tolerance Unit must be included
	(ii)	Any single value between 40° and 42° inclusive.	1	Unit must be included
(c)		Any one of: To obtain more reliable results Eliminate rogue results/outliers To allow an average/mean to be calculated More accurate	1	Do not accept: 'more precise' 'better results' 'to make it a fair test'

11.

(a)		$A = \dfrac{N}{t}$ (1) $A = \dfrac{7 \cdot 92 \times 10^{18}}{900}$ (1) $A = 8 \cdot 8 \times 10^{15}$ Bq (1)	3	Accept: 9×10^{15} Bq OR $A = \dfrac{N}{t}$ (1) $A = \dfrac{7 \cdot 92 \times 10^{18}}{15}$ (1) $A = 5 \cdot 28 \times 10^{17}$ decays permin (1)
(b)		$8 \cdot 8 \times 10^{15} \times 4 \cdot 49 \times 10^{-14}$ (1) $= 400$ W (1)	2	Or consistent with part (a) Accept: 400 W 395 W 395·1 W Alternative method: (not a standard three marker) ($P = \dfrac{E}{t}$) no mark for equation $P = \dfrac{7 \cdot 92 \times 10^{18} \times 4 \cdot 49 \times 10^{-14}}{900}$ (1) $P = 400$ W (1)
(c)		Any one of: (Alpha is) more easily absorbed/stopped/blocked (Alpha) is absorbed by thinner materials/less dense materials. Gamma is absorbed by thicker materials/more dense materials. (Alpha) is less penetrating (than gamma). Gamma is more penetrating (than alpha)	1	Must be a comparison. Do not accept: 'Alpha is absorbed by a sheet of paper' alone 'Gamma is absorbed by lead' alone Do not accept comparison of range in air alone

12.

(a)	(i)	$D=\dfrac{E}{m}$ (1) $D=\dfrac{9\cdot6\times10^{-5}}{0\cdot5}$ (1) $D=1\cdot9\times10^{-4}\,Gy$ (1)	3	Accept: $2\times10^{-4}\,Gy$ $1\cdot9\times10^{-4}\,Gy$ $1\cdot92\times10^{-4}\,Gy$ $1\cdot920\times10^{-4}\,Gy$ Accept: $J\,kg^{-1}$
	(ii)	$H=Dw_{R}$ (1) $H=1\cdot9\times10^{-4}\times1$ (1) $H=1\cdot9\times10^{-4}\,Sv$ (1)	3	Accept answer consistent with that given in part (i) If incorrect radiation weighting factor selected then (1) MAX for correct equation
(b)		No. of half-lives = $\dfrac{144}{36}=4$ (1) $12\rightarrow6\rightarrow3\rightarrow1\cdot5\rightarrow0\cdot75$ mark for evidence of activity halving (1) Final Answer: 0·75 kBq (1)	3	Accept: 750 Bq Accept calculation using division by 2^{4} eg $\left(A=\dfrac{A_{0}}{2^{n}}\right)$ $=\dfrac{12}{2^{4}}$ (1) +(1) $=0\cdot75$ kBq (1) substitution shows evidence of halving the activity (1) and 4 half-lives (1)

13.

(a)	(i)	$T=\dfrac{1}{f}$ (1) $2\cdot5=\dfrac{1}{f}$ (1) $f=0\cdot40$ Hz (1)	3	Accept: $f=\dfrac{N}{t}$ Accept 1-4 sig fig: 0·4 Hz 0·400 Hz 0·4000 Hz
	(ii)	measure the time for more waves to pass OR count the number of waves in a longer period of time OR repeat (the measurement) <u>and</u> average	1	Do not accept answers relating to precision eg a stopclock with more decimal places.
(b)		$v=f\lambda$ (1) $v=0\cdot40\times8\cdot0$ (1) $v=3\cdot2\,m\,s^{-1}$ (1)	3	Or consistent with (a)(i) Accept 1-4 sig fig: 3 m s⁻¹ 3·20 ms⁻¹ 3·200 ms⁻¹ Method 2: $d=vt$ (1) $8\cdot0=v\times2\cdot5$ (1) $v=3\cdot2\,m\,s^{-1}$ (1)
(c)		diffraction of waves into 'shadow' regions behind walls (1) straight sections in middle and consistent wavelengths before and after gap (1) 	2	
(d)		<u>energy</u> decreases/lost	1	Accept: description of <u>energy</u> being spread over greater area.

14.

(a)		background count (rate)	1	
(b)	(i)	4·4 mm	1	Accept answers in the range: 4·3 mm - 4·5 mm
	(ii)	Evidence of establishing 3 half-value thicknesses (1) (3 × 4·4) 13·2 mm (1)	2	Or consistent with (b)(i) Accept: 13 mm
	(iii)	greater	1	
(c)		$\dot{H} = \dfrac{H}{t}$ (1) $2 \cdot 5 \times 10^{-6} = \dfrac{20 \times 10^{-3}}{t}$ (1) $t = 8000$ (h) (1)	3	

15.

(a)		80 000 (nuclei) decay(s) per unit time	1	Accept: 'per second' in place of 'per unit time'
(b)	(i)	neutrons can go on to cause further (fission) reactions/split more (uranium) nuclei (1) causing a chain reaction/this process repeats (1)	2	Independent marks.
	(ii)	$(E) = 3 \cdot 0 \times 10^{21} \times 3 \cdot 2 \times 10^{-11}$ (1) $= (9 \cdot 6 \times 10^{10}$ J) $P = \dfrac{E}{t}$ (1) $= \dfrac{9 \cdot 6 \times 10^{10}}{60}$ (1) $= 1 \cdot 6 \times 10^{9}$ W (1)	4	Method 2: $A = \dfrac{N}{t}$ (1) $= \dfrac{3 \cdot 0 \times 10^{21}}{60}$ (1) $= (5 \times 10^{19}$ Bq) $P = 5 \times 10^{19} \times 3 \cdot 2 \times 10^{-11}$ (1) $= 1 \cdot 6 \times 10^{9}$ W (1) Calculation of power of one decay over a minute then multiplication by number of decays per minute is wrong physics MAX (1) for relationship
(c)		any suitable use (eg treating cancer/tracers/sterilisation/smoke detectors/measuring thickness of paper)	1	Must be a use of nuclear radiation