Surname	Centre Number	Candidate Number
First name(s)		0

GCSE

3420U20-1

S24-3420U20-1

FRIDAY, 24 MAY 2024 – MORNING

PHYSICS – Unit 2:
Forces, Space and Radioactivity
FOUNDATION TIER

1 hour 45 minutes

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**6**	
2.	**6**	
3.	**6**	
4.	**6**	
5.	**10**	
6.	**9**	
7.	**12**	
8.	**5**	
9.	**10**	
10.	**10**	
Total	**80**	

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ADDITIONAL MATERIALS

In addition to this paper you will require a calculator and a ruler.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen or correction fluid.

You may use a pencil for graphs and diagrams only.

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions.

Write your answers in the spaces provided in this booklet. If you run out of space use the additional page at the back of the booklet, taking care to number the question(s) correctly.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part-question.

The assessment of the quality of extended response (QER) will take place in question **6(c)**.

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Equations

speed = $\frac{\text{distance}}{\text{time}}$	
acceleration [or deceleration] = $\frac{\text{change in velocity}}{\text{time}}$	$a = \frac{\Delta v}{t}$
acceleration = gradient of a velocity-time graph	
resultant force = mass × acceleration	$F = ma$
weight = mass × gravitational field strength	$W = mg$
work = force × distance	$W = Fd$
force = spring constant × extension	$F = kx$
momentum = mass × velocity	$p = mv$
force = $\frac{\text{change in momentum}}{\text{time}}$	$F = \frac{\Delta p}{t}$
u = initial velocity v = final velocity t = time a = acceleration x = displacement	$v = u + at$ $x = \frac{u + v}{2} t$
moment = force × distance	$M = Fd$

SI multipliers

Prefix	Symbol	Conversion factor	Multiplier
milli	m	divide by 1000	1×10^{-3}
centi	c	divide by 100	1×10^{-2}
kilo	k	multiply by 1000	1×10^{3}
mega	M	multiply by 1 000 000	1×10^{6}

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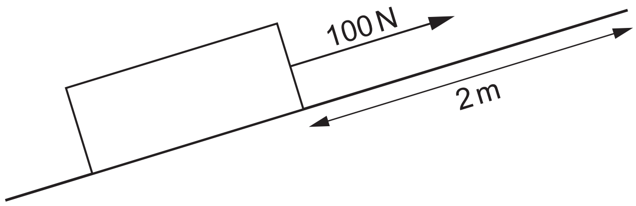
Answer **all** questions.

1. (a) Draw straight lines to match the energy store on the left with an example on the right. [2]

Energy store	Example
kinetic energy	ball held above the ground
elastic energy	stretched rubber band
gravitational potential energy	ball rolling along level ground

(b) A box is pulled 2 m up a slope by a force of 100 N.



(i) Use the equation:

work done = force × distance

to determine the work done by the 100 N force. [2]

work done = ... J

(ii) State how much energy is transferred by the force.
Include a unit with your answer. [2]

energy transferred = ...

unit = ...

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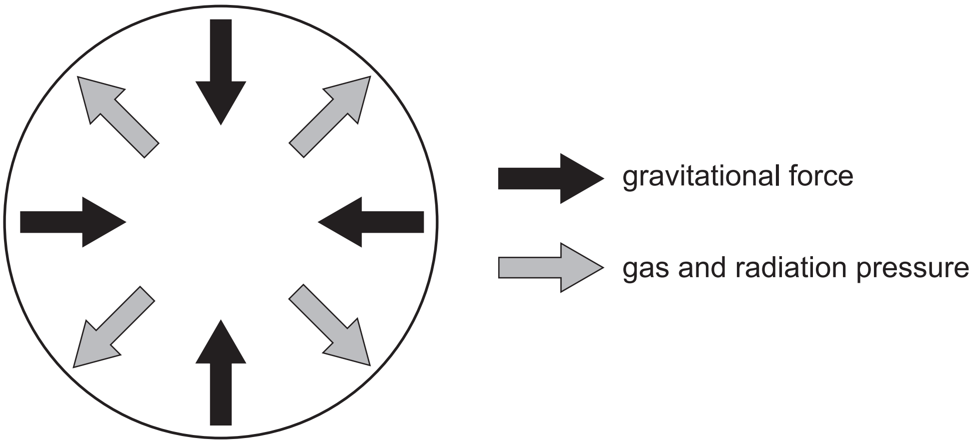
2. The diagram below shows the forces acting on a high-mass star that is on the main sequence.



(a) Complete the sentences below by circling the correct answer.

(i) The star is (**burning** / **fusing** / **melting**) hydrogen. [1]

(ii) The star is currently stable because the forces acting on it are (**balanced** / **unbalanced** / **zero**). [1]

(b) (i) Use the words from the box to complete the diagram to show the stages in the life cycle of a **high-mass** star. [3]

supergiant	protostar	yellow dwarf	red giant	neutron star	white dwarf

....	main sequence	....	supernova	....

(ii) Tick (✓) the box next to the correct statement to complete the following sentence. [1]

During the supernova stage of the star's life cycle:

the star is red shifted	☐
heavy elements are returned to space	☐
nuclear fission takes place	☐

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3. (a) (i) Air bags help to keep passengers safe in the event of an accident.

Underline the words that correctly complete the sentences below. [3]

Air bags (**increase** / **decrease** / **remove**) the time it takes to reduce the passengers' (**momentum** / **inertia** / **mass**) to zero.

This (**increases** / **decreases** / **doubles**) the force acting on them.

(ii) Air bags are one safety feature of cars designed to reduce harm to passengers. Name **one** other safety feature. [1]

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(b) Explain why cars are designed to have a more aerodynamic shape. [2]

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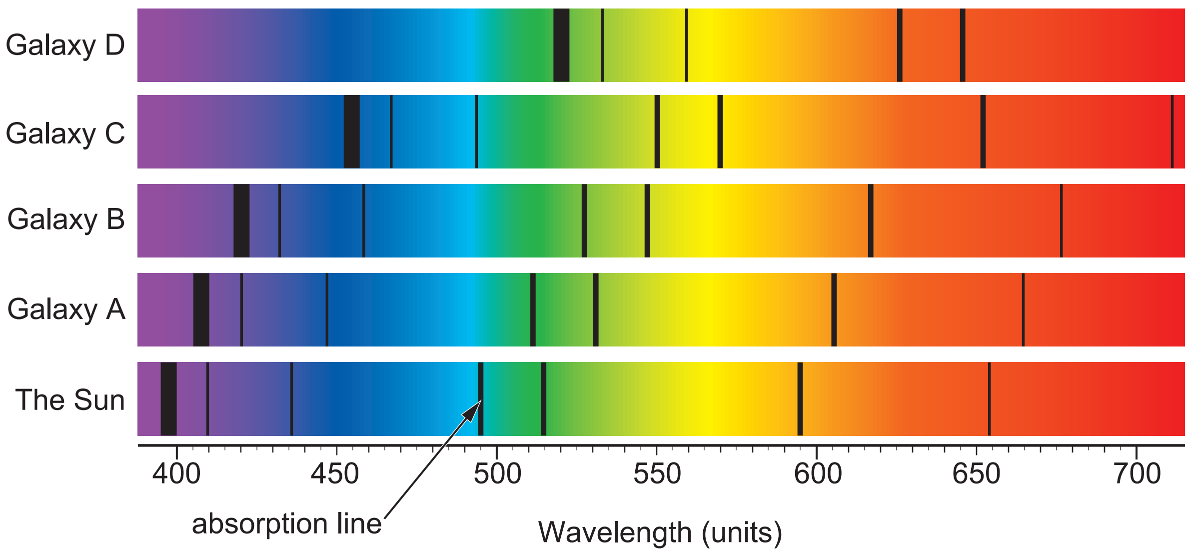
4. The diagram below shows the absorption spectra of 4 different galaxies compared to part of the Sun's absorption spectrum.



(a) (i) One absorption line in the spectrum from the Sun is labelled.
The wavelength of the same absorption line from each galaxy is given in the table below.
Complete the table with the estimated wavelength of that absorption line in galaxy C. [1]

Star or galaxy	Wavelength (units)
The Sun	495
Galaxy A	512
Galaxy B	528
Galaxy C	....
Galaxy D	626

(ii) The absorption lines in the galaxies are red shifted.
State which galaxy is furthest from the Sun.
Explain how you know. [2]

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(iii) State what the red shift of these lines tells us about the Universe. [1]

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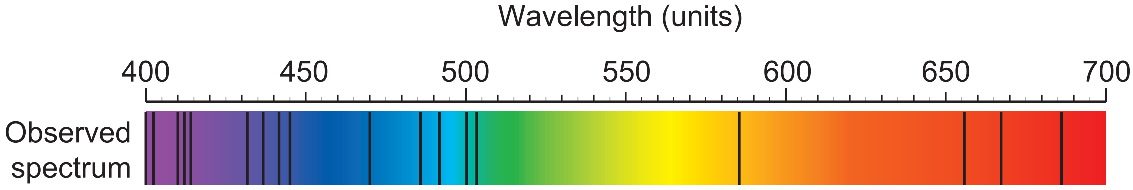
(b) Absorption lines can tell us which elements are present in a star.
The table shows the wavelengths of one absorption line from some common elements.

Element	Wavelength of absorption line (units)
helium	587
calcium	430
magnesium	516
iron	527

The observed spectrum from a star is shown below.



Rhodri states that the star contains helium and iron.
Use the information from the table and the observed spectrum to explain whether you agree. [2]

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5. The diagram below shows two ice skaters, Abi and Rachel, skating in the same direction.

mass = 50 kg
velocity = 3 m/s
momentum = 150 kg m/s

mass = 40 kg
velocity = 2 m/s

(a) (i) Use the diagram above and the equation:

momentum = mass × velocity

to calculate **Rachel's** momentum. [2]

Rachel's momentum = ... kg m/s

(ii) Use your answer to (a)(i) and information from the diagram to determine the total momentum of the ice skaters. [1]

total momentum = ... kg m/s

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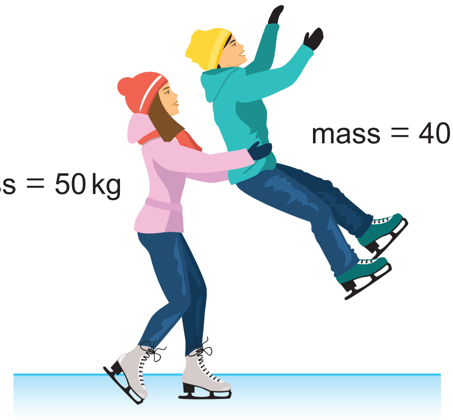
(iii) Abi catches up with Rachel and lifts her as shown below.
This can be thought of as a collision.



State the total momentum of the ice skaters after this collision has taken place. [1]

total momentum = ... kg m/s

(iv) Use the equation:

$$\text{velocity} = \frac{\text{total momentum}}{\text{mass}}$$

to calculate the velocity of the ice skaters after the collision. [2]

velocity = ... m/s

(v) The ice skaters glide freely from this velocity, u.
After a time, t, of 25 s their velocity, v, is 0 m/s.

Use the equation:

$$x = \frac{1}{2}(u + v)t$$

to calculate the distance, x, that they travel. [2]

x = ... m

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(b) Abi suggests that if she doubles her velocity the total momentum of Abi and Rachel will also double.
Explain whether Abi is correct. [2]

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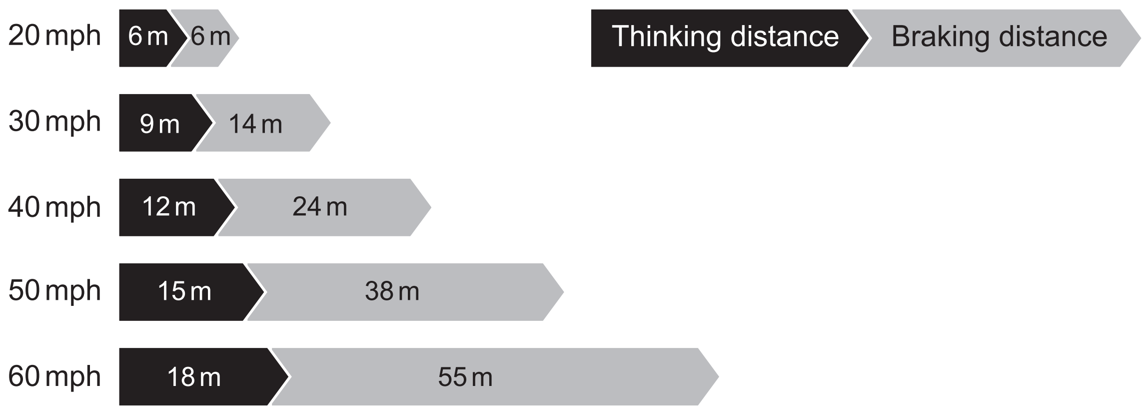
6. The highway code has the following information about stopping distances.



(a) Calculate the overall stopping distance for a car travelling at 30 mph. [1]

overall stopping distance = ... m

(b) Use the data from the diagram to describe the relationship between speed and thinking distance. [2]

....

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(c) One factor that affects thinking distance is the age of the driver.

State what is meant by the terms thinking distance and braking distance **and** describe some other factors that affect each of these distances. [6 QER]

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7. There are two types of nuclear reaction: fission and fusion.

(a) Two isotopes of hydrogen ${}^{2}_{1}\mathrm{H}$ and ${}^{3}_{1}\mathrm{H}$ can fuse together to form helium (He).

(i) **Complete** the equation for this fusion reaction. [2]

$${}^{2}_{1}\mathrm{H} + {}^{3}_{1}\mathrm{H} \longrightarrow {}^{\cdots\cdots}_{\cdots\cdots}\mathrm{He} + {}^{1}_{0}\mathrm{n}$$

(ii) **Complete** the table below to give the number of protons and neutrons in the nuclei of each hydrogen isotope. [4]

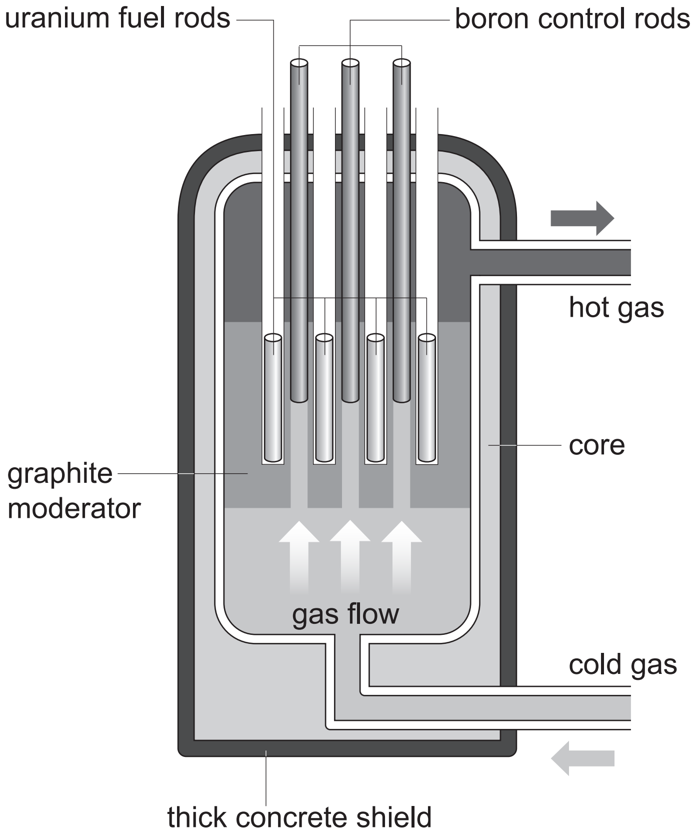
Isotope	${}^{2}_{1}\mathrm{H}$	${}^{3}_{1}\mathrm{H}$
number of protons		
number of neutrons		

(iii) State **two** reasons why nuclear fusion is difficult to achieve on Earth. [2]

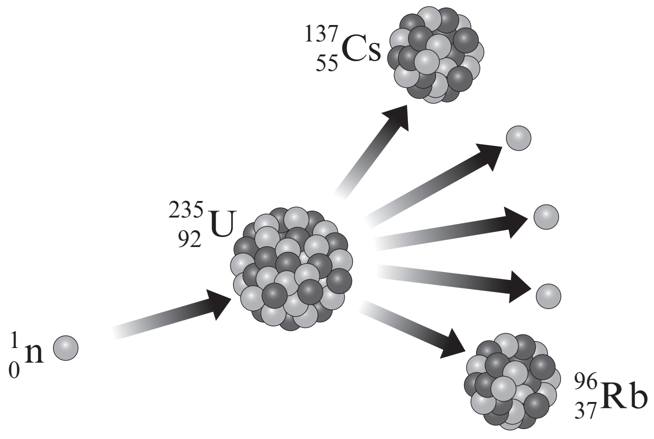
1. ....

2. ....

(b) Nuclear fission is used to produce electricity in power stations.



In a nuclear power station, a neutron is absorbed by a uranium nucleus, producing two lighter nuclei and more neutrons.
Part of the chain reaction is shown below.



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(i) State the number of neutrons produced in the fission reaction shown in the diagram. [1]

number of neutrons = ...

(ii) State which part of a nuclear reactor slows down neutrons. [1]

....

(iii) State why neutrons need to be slowed down. [1]

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....

(iv) State the purpose of the control rods. [1]

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Turn over.

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8. Brachytherapy is a form of radiotherapy used in treating prostate cancer. Small pellets containing radioactive material are planted inside the prostate.

(a) One patient has 75 pellets containing iodine-125 planted in his prostate. **Each pellet has an initial activity of 16 MBq.**

(i) Calculate the initial activity of **all** 75 pellets. [1]

initial activity = ... MBq

(ii) The iodine-125 has a half-life of 60 days. This means that the activity halves every 60 days. Calculate the activity of the 75 pellets after 120 days. [2]

activity after 120 days = ... MBq

(b) Iodine-123 is another isotope of iodine. It has a half-life of 13 hours. Explain why iodine-123 is not suitable for this treatment. [2]

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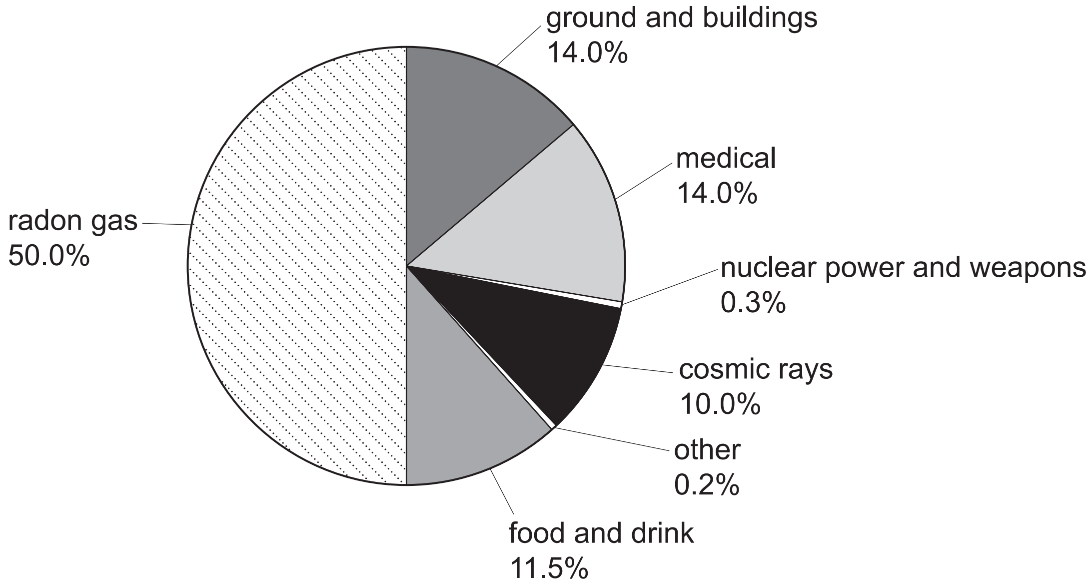
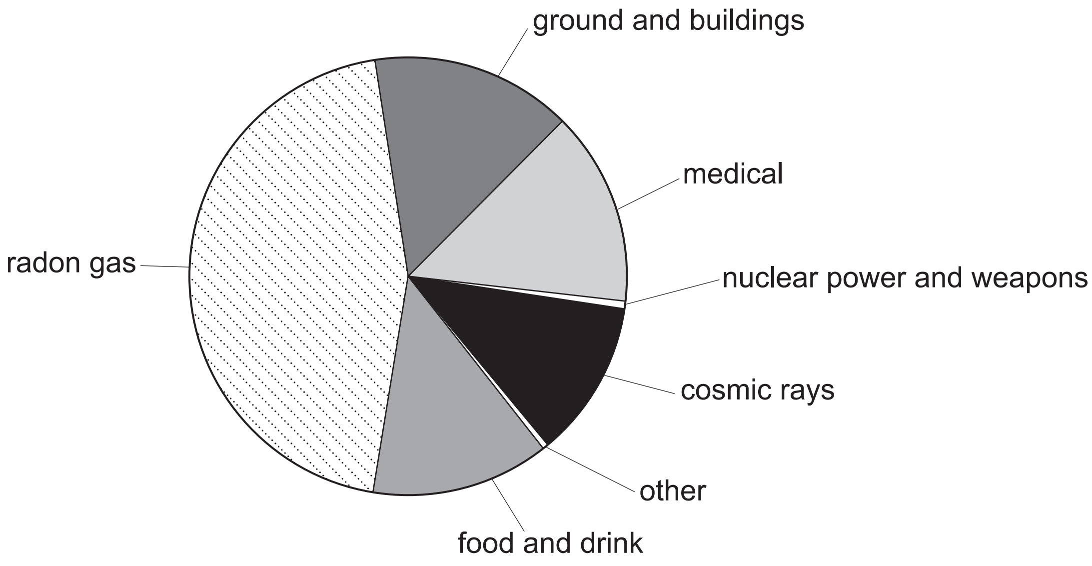
9. A group of students is investigating background radiation.

(a) They find the pie charts below, which show the background radiation in 3 different locations, A, B and C, in the UK.

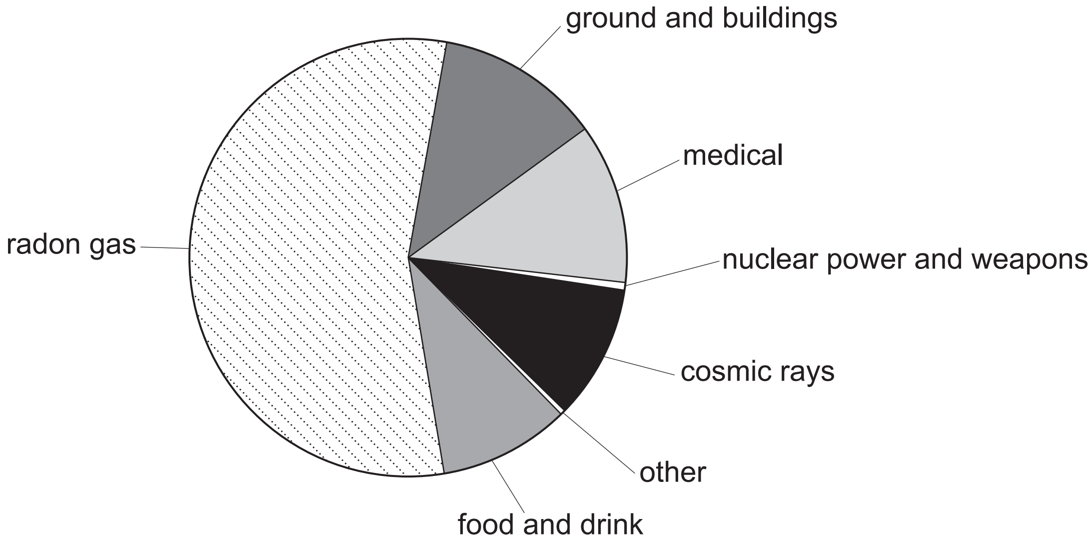
Location A



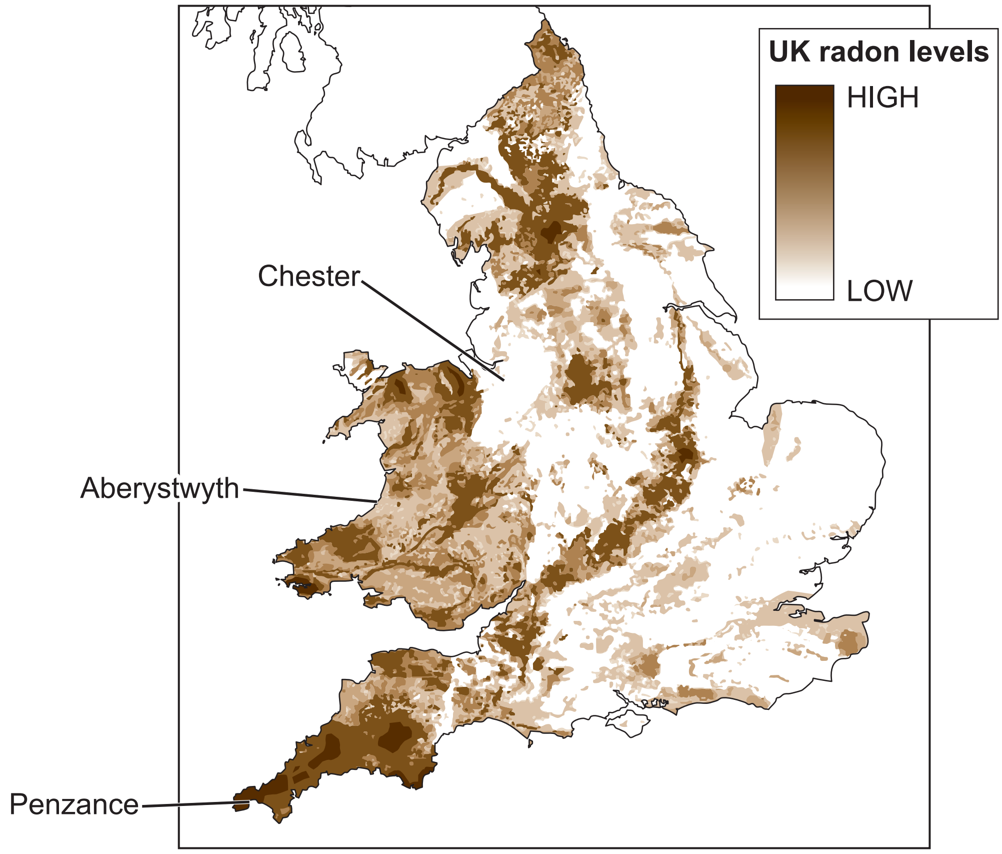
Location B



Location C



The map below shows radon levels across the UK.
The 3 locations, A, B and C are shown on the map.
The darker the area on the map the higher the levels of radon.



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(i) Adam studies the diagrams and concludes that **location A** must be Aberystwyth. Explain whether you agree. [2]

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(ii) Their teacher measures the background count in **location A**. The teacher records 30 counts in 60 seconds.

I. Determine the count rate in counts per second. [1]

count rate = ... cps

II. Use information from the pie chart to determine how many of the 30 counts are due to radon gas. [1]

counts due to radon = ...

(iii) Chloe states that people are more at risk from man-made sources of background radiation than natural sources.
Use data from the pie chart for **location A** to explain whether you agree. [2]

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(b) The table shows how much radiation people receive from some different sources.

Source of radiation	Radiation received (units)
mean background radiation (per year)	2.7
8 hour flight from London to New York	0.09
dental X-ray	0.005
chest X-ray	0.014
CT scan of head	1.4
CT scan of chest	6.6
worker in a nuclear power station (per year)	0.18

Workers in nuclear power stations have their exposure to radiation carefully monitored.

If they receive a total of **20 units** of radiation from all sources including background radiation in one year, they can no longer work with radiation.

(i) Sophia works in a nuclear power station.
In one year, she flies from London to New York and back.
She also has a dental X-ray and a CT scan to her chest.
Sophia is worried about the level of radiation she has been exposed to.

Use data to explain whether it is still safe for her to work with radiation. [2]

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(ii) Jack states that workers in a nuclear power station are exposed to more radiation in one year than airline pilots flying on the London to New York route.

Use data to explain whether he is correct. [2]

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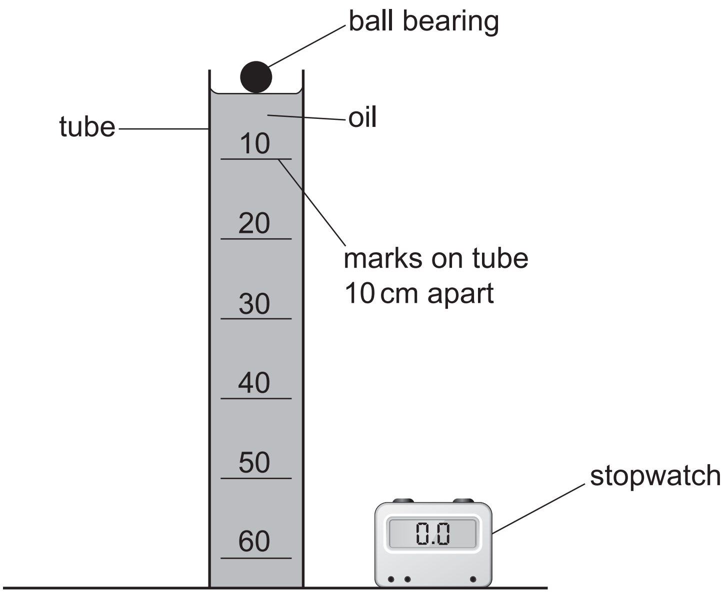
10. Students investigate the terminal speed of a ball bearing in oil.
They measure the time it takes for the ball bearing to drop different distances through the oil.



The results from the experiment are shown in the table below.

Distance (cm)	Time (s)			
	Trial 1	Trial 2	Trial 3	Mean
10	5.4	6.2	5.8	5.8
20	7.6	4.2	8.0	7.8
30	8.4	9.0	8.3	8.6
40	10.9	10.3	10.4	10.5
50	11.5	11.2	10.8	11.2
60	12.5	13.0	13.2	12.9

(a) (i) Freya states that the mean time for 20 cm is incorrect and should be 6.6 s.
Explain whether Freya is correct. [2]

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(ii) Evaluate the repeatability of the data. [1]

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(b) State **one** source of inaccuracy in this method **and** how it could be reduced. [2]

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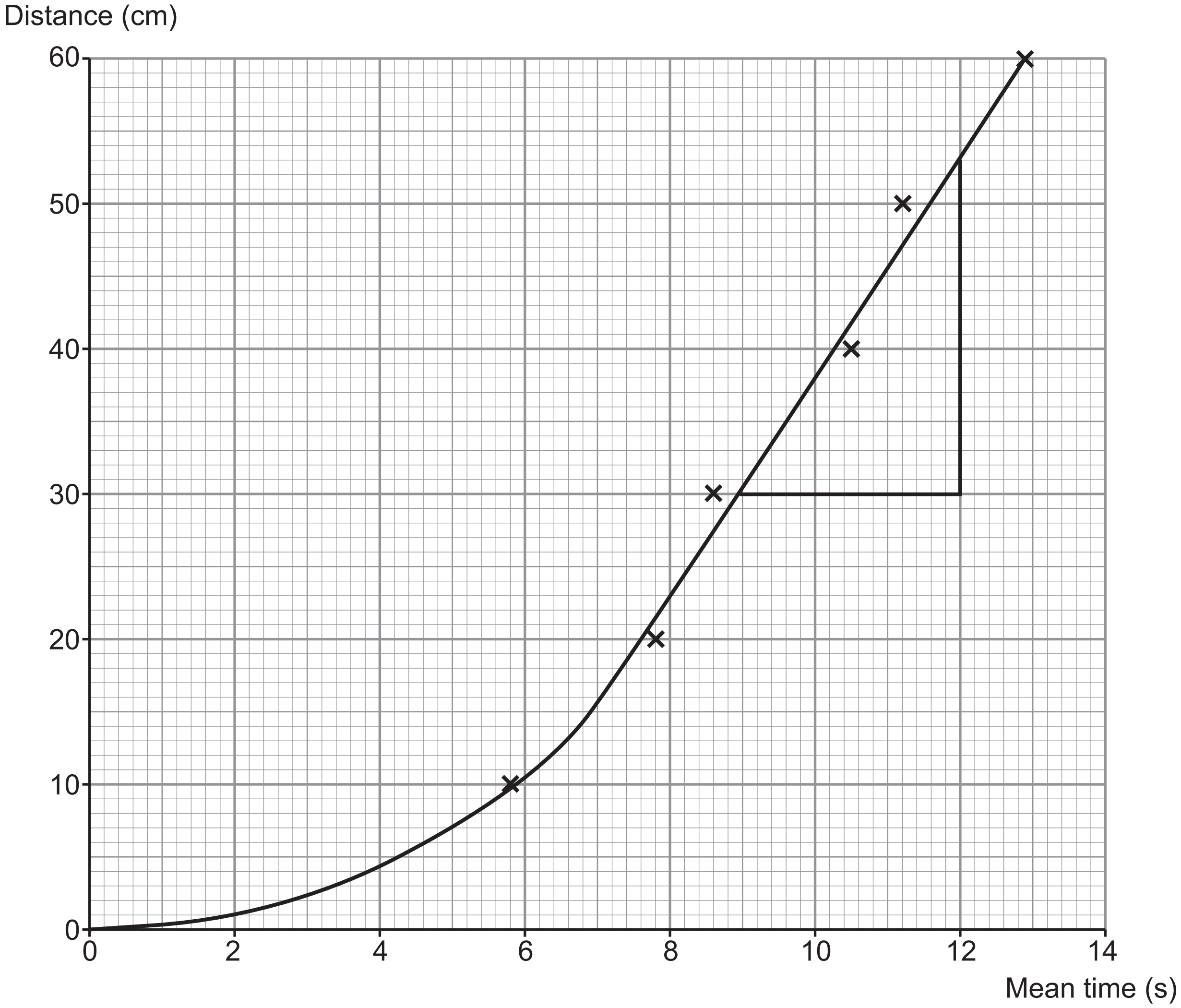
(c) A graph of the students' data is given below.



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The section of the graph where the line is straight represents the ball bearing travelling at terminal speed.

(i) Estimate the time at which the ball bearing reaches terminal speed. [1]

time = ... s

(ii) The gradient of a distance-time graph represents the speed of an object.
Use the equation:

speed = gradient of distance-time graph

and the triangle shown on the graph to calculate the terminal speed of the ball bearing. [2]

terminal speed = ... cm/s

(iii) State how the **acceleration** of the ball bearing changes as it falls through the oil. [2]

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END OF PAPER

Question number	Additional page, if required. Write the question number(s) in the left-hand margin.

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