Surname	Centre Number	Candidate Number
First name(s)		0

GCSE

S24-3420UB0-1

3420UB0-1

FRIDAY, 24 MAY 2024 – MORNING

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

1 hour 45 minutes

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**10**	
2.	**10**	
3.	**10**	
4.	**11**	
5.	**11**	
6.	**10**	
7.	**6**	
8.	**12**	
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(s) 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(a)**.

Equations

speed = $\dfrac{\text{distance}}{\text{time}}$	
acceleration [or deceleration] = $\dfrac{\text{change in velocity}}{\text{time}}$	$a = \dfrac{\Delta v}{t}$
acceleration = gradient of a velocity-time graph	
distance travelled = area under a velocity-time graph	
resultant force = mass × acceleration	$F = ma$
weight = mass × gravitational field strength	$W = mg$
work = force × distance	$W = Fd$
kinetic energy = $\dfrac{\text{mass} \times \text{velocity}^2}{2}$	$\text{KE} = \frac{1}{2} mv^2$
change in potential energy = mass × gravitational field strength × change in height	$\text{PE} = mgh$
force = spring constant × extension	$F = kx$
work done in stretching = area under a force-extension graph	$W = \frac{1}{2} Fx$
momentum = mass × velocity	$p = mv$
force = $\dfrac{\text{change in momentum}}{\text{time}}$	$F = \dfrac{\Delta p}{t}$
u = initial velocity v = final velocity t = time a = acceleration x = displacement	$v = u + at$ $x = \dfrac{u + v}{2}\, t$ $x = ut + \frac{1}{2} at^2$ $v^2 = u^2 + 2ax$
moment = force × distance	$M = Fd$

SI multipliers

Prefix	Symbol	Conversion factor	Multiplier
pico	p	divide by 1 000 000 000 000	1×10^{-12}
nano	n	divide by 1 000 000 000	1×10^{-9}
micro	µ	divide by 1 000 000	1×10^{-6}
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}
giga	G	multiply by 1 000 000 000	1×10^{9}
tera	T	multiply by 1 000 000 000 000	1×10^{12}

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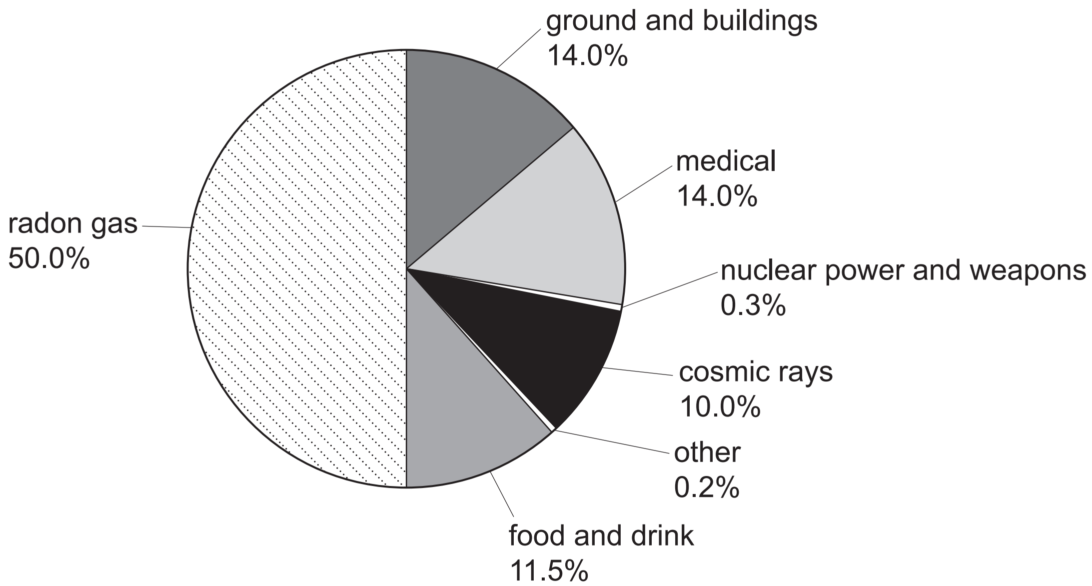
Answer **all** questions.

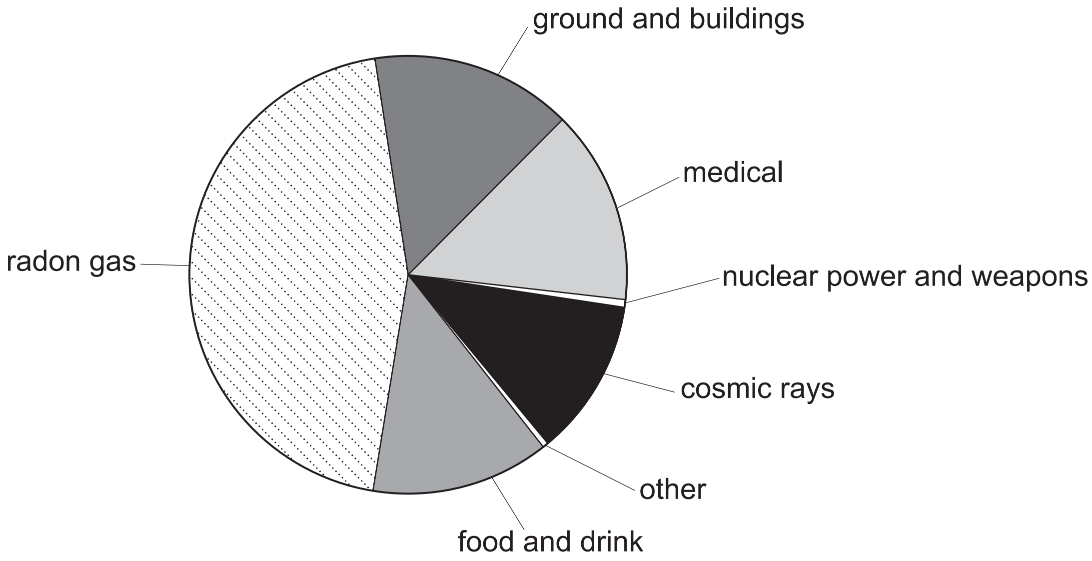
1. A group of students is investigating background radiation.

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

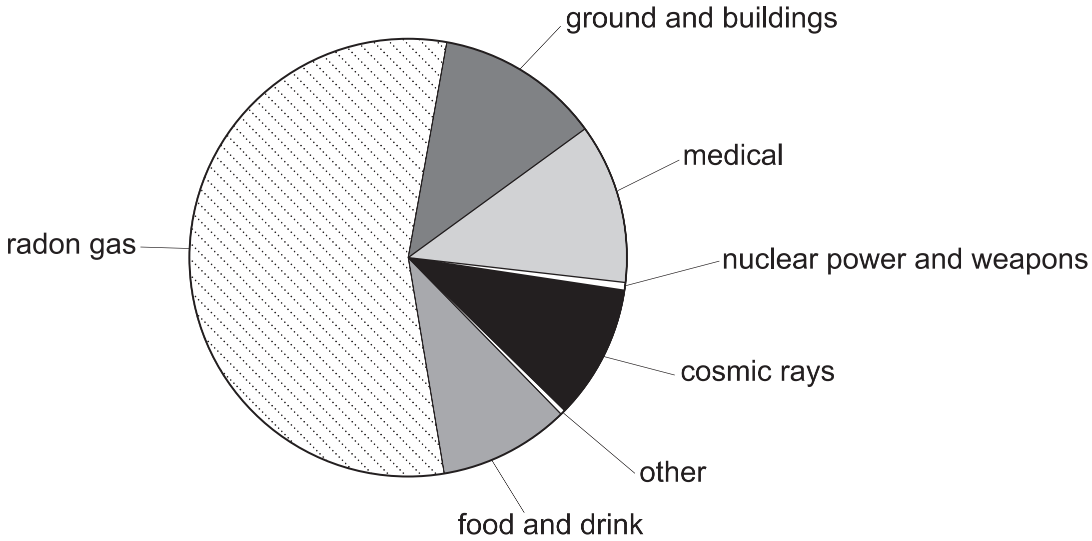
Location A



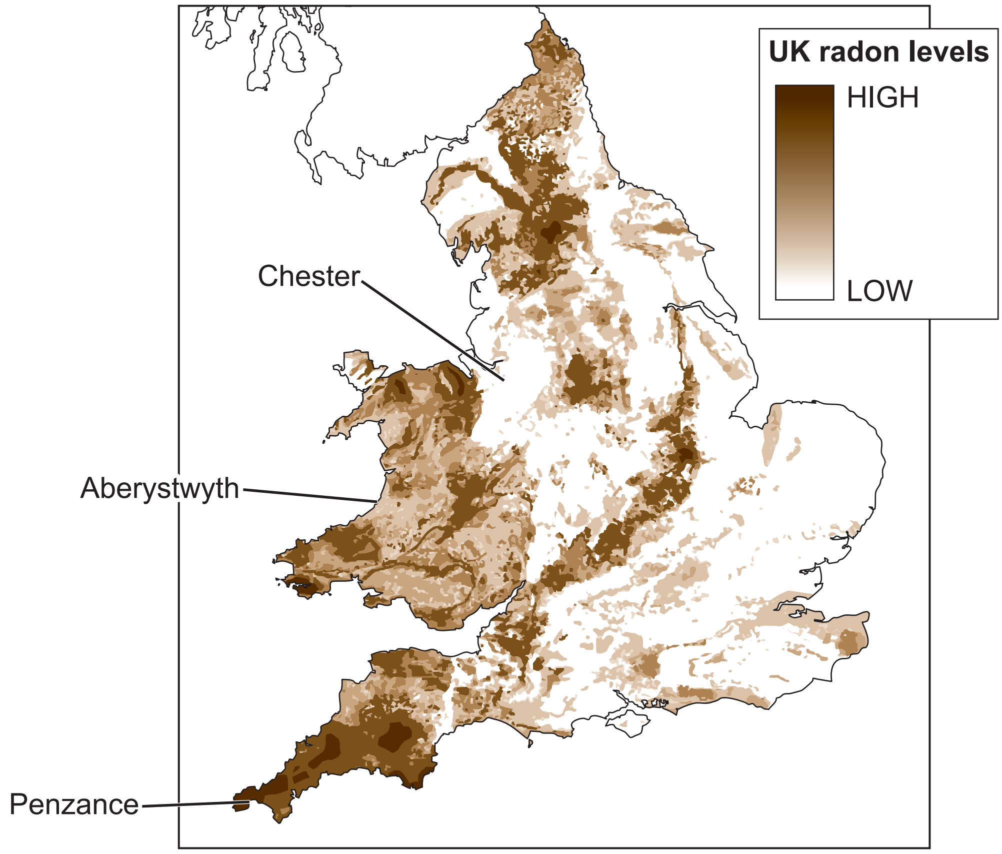
Location B



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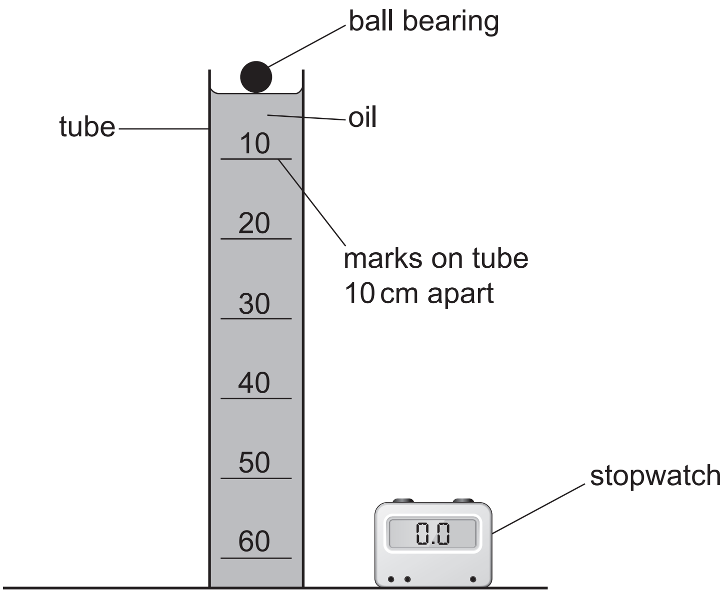
2. Students investigate the terminal speed of a ball bearing in oil.
They measure the time it takes for the ball bearing to drop different distances through the oil.



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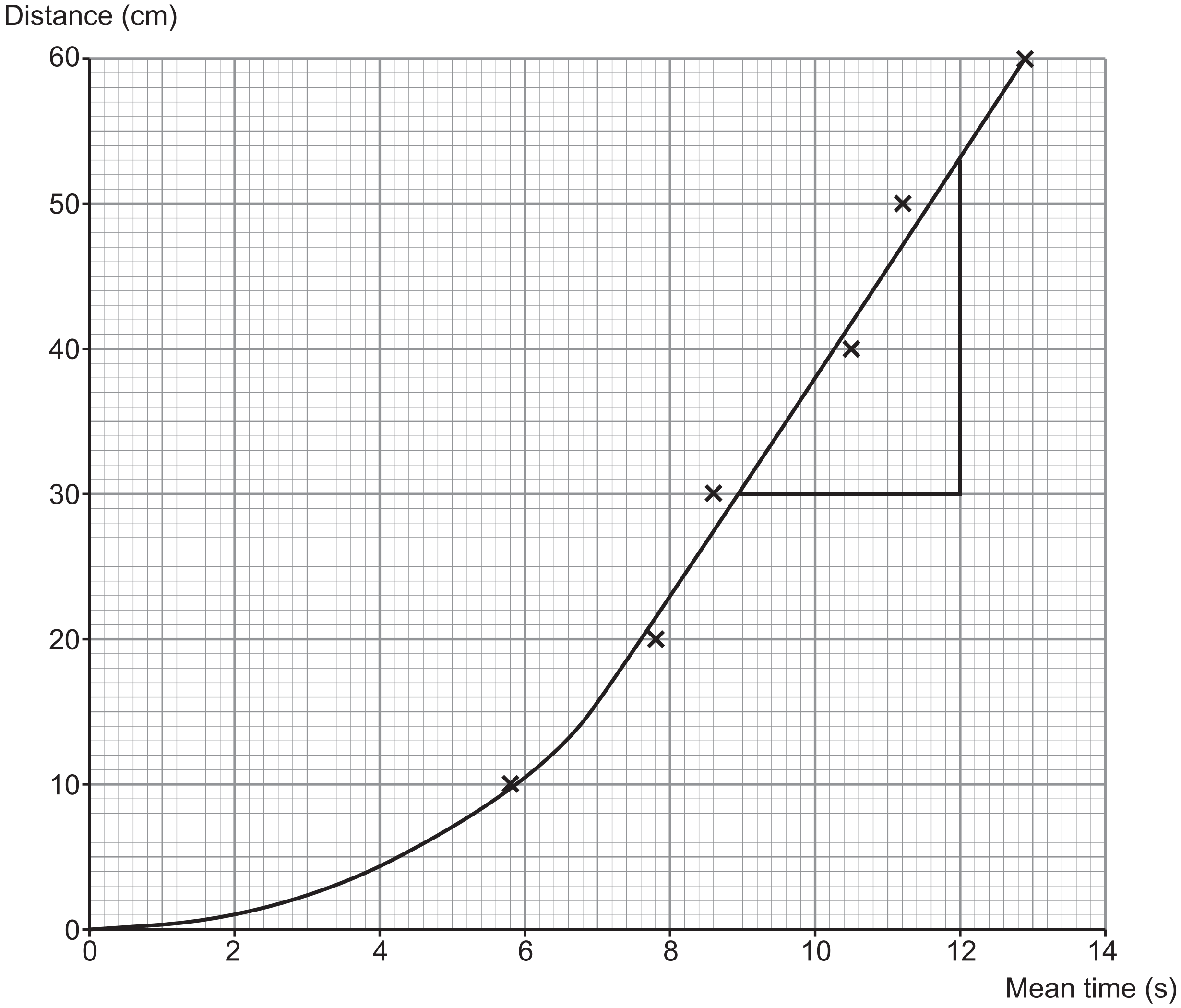
(c) A graph of the students' data is given below.



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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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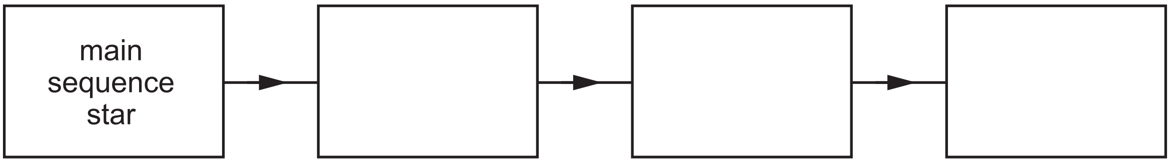
3. Rigel is a high-mass blue star, 870 light-years away from Earth.
Rigel is currently on the main sequence.

(a) Use an equation from page 2 to calculate the distance of Rigel from Earth in metres. [3]
Speed of light, $c = 3 \times 10^8$ m/s
1 year = 31 536 000 s

distance = ... m

(b) (i) Complete the boxes to show the remaining stages in Rigel's life cycle. [3]



(ii) Explain why large mass stars are important in the creation of new solar systems. [2]

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(iii) Describe how a solar system forms. [2]

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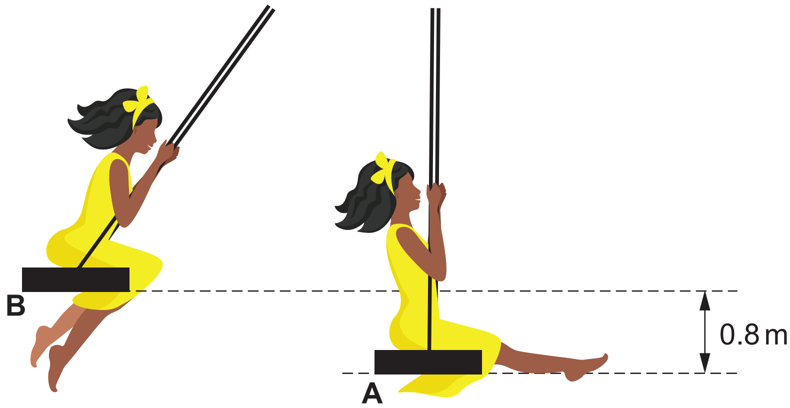
4. A child of mass 35 kg is playing on a swing.



The swing is pulled back to position **B**, 0.8 m above the start point, and released.

(a) (i) Use an equation from page 2 to calculate the potential energy gained by the child when moving from position **A** to position **B**. [2]
[Gravitational field strength, g = 10 N/kg]

potential energy = ... J

(ii) State the kinetic energy of the child as they pass through point **A**.
Assume there are no resistive forces acting. [1]

kinetic energy = ... J

(iii) Use an equation from page 2 to calculate the velocity of the child as they pass through point **A**. [3]

velocity = ... m/s

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(b) (i) At position **B** the child drops a ball which hits the ground time $t = 0.50$ s later. The ball has an initial velocity, $u = 0$ m/s. The downwards acceleration, $a = g = 10$ m/s^2.

Use an equation from page 2 to determine the distance, x, that the ball falls. [3]

$x =$ .... m

(ii) After the collision with the ground, the ball rolls away with initial kinetic energy of 6.4 J and then comes to a halt in 3.0 m.

Use an equation from page 2 to calculate the size of the friction force between the ball and the ground. [2]

friction force = ... N

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5. Radioactive isotopes have a wide variety of uses.

(a) (i) State what is meant by the term 'isotopes'. [2]

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(ii) State why some isotopes are radioactive. [1]

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(b) One use of radiation is in a smoke detector.

The radiation ionises the air inside the detector and causes a current that is detected. If smoke particles are present they block the radiation so that a current is no longer detected.
This sets off the alarm.

The table gives information about different radioisotopes.

isotope	half-life	type of emitter
americium-241	432 years	alpha
radium-224	3.6 days	alpha
caesium-137	30 years	beta and gamma

Explain why americium-241 is suitable for this use but radium-224 and caesium-137 are not. [3]

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(c) Brachytherapy is a form of radiotherapy used in treating prostate cancer.
Pellets containing radioactive material are planted inside the prostate.
One patient has 75 pellets containing iodine-125 planted in his prostate.
Each pellet has an initial activity of 16 MBq.

(i) The iodine-125 has a half-life of 60 days.
Calculate the time taken for the total activity of the iodine-125 in the 75 pellets to drop to 37.5 MBq. [3]

time = ... days

(ii) Iodine-125 is a gamma emitter.
For 60 days after his treatment the patient is warned not to stay too close to people for long periods of time.
Explain why the gamma radiation may pose a risk to other people. [2]

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 (3420UB0-1) Turn over.

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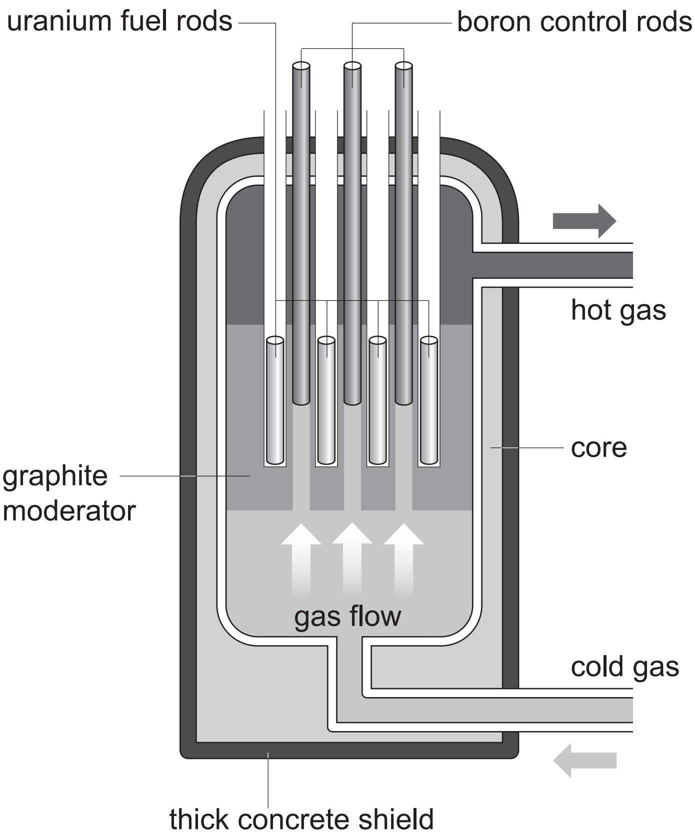
6. Nuclear fission is a nuclear reaction that releases energy.
The diagram shows a nuclear fission reactor.



(a) In each fission reaction, on average three neutrons are released.

Explain how this can lead to an uncontrolled chain reaction **and** how the features of the reactor allow a controlled chain reaction to be achieved. [6 QER]

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(b) Another nuclear reaction is nuclear fusion.

One fusion reaction, which could provide energy on Earth in the future, involves two isotopes of hydrogen, H, deuterium and tritium.

Deuterium and tritium fuse to produce an isotope of helium, He, and one neutron.

(i) Use the information from the table below to complete the nuclear equation for this reaction. [3]

Isotope	Number of protons	Number of neutrons
deuterium	1	1
tritium	1	2

$$^{\cdots}_{\cdots}\text{H} + ^{\cdots}_{\cdots}\text{H} \longrightarrow ^{\cdots}_{\cdots}\text{He} + ^{\cdots}_{\cdots}\text{n}$$

(ii) The main product of this reaction is helium.

Suggest why, if it can be achieved on Earth, nuclear fusion may be better for energy production than nuclear fission. [1]

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7. (a) (i) State the two pieces of evidence that support the Big Bang model of the origin of the Universe. [2]

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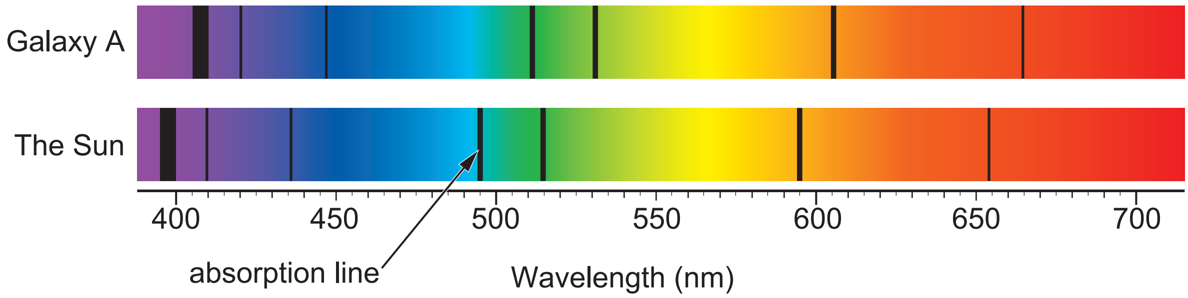
(ii) The diagram below shows the absorption spectrum of a galaxy, A, compared to part of the Sun's absorption spectrum.



One absorption line in the spectrum from the Sun is labelled.
The wavelength of this line is different in galaxy A.
Explain why the wavelength of the line is different in galaxy A. [2]

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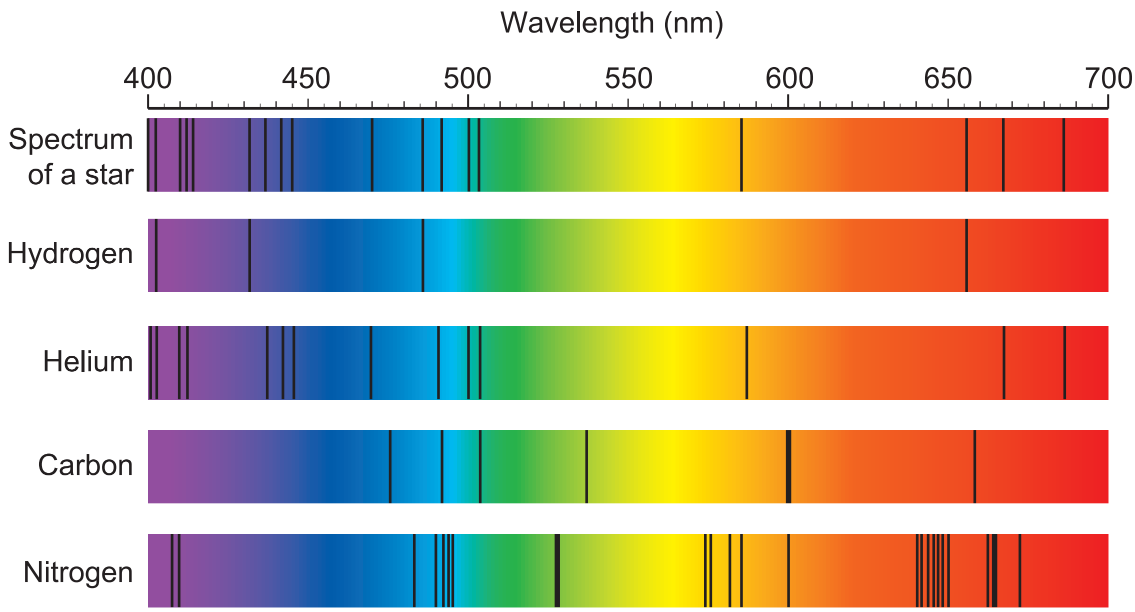
(b) The diagram below shows the absorption spectrum of a star and the absorption spectra of some different elements.



Matthew suggests that the star contains hydrogen and carbon.
Explain whether you agree. [2]

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8. Newton's laws describe the motion of objects.

(a) (i) State what quantity is an expression of the inertia of a body. [1]

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(ii) State Newton's 1st law. [2]

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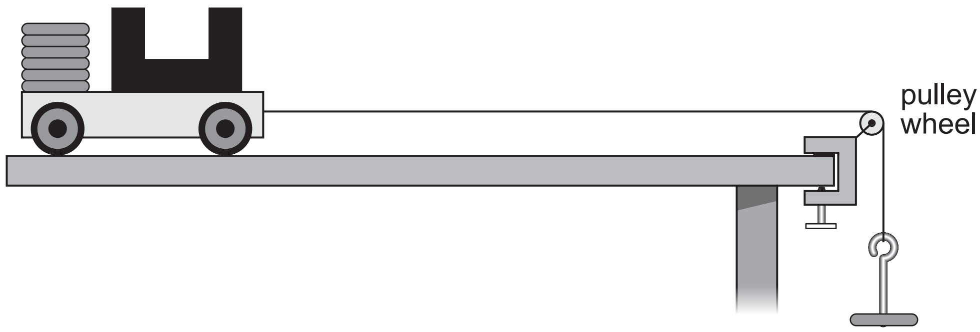
(b) Students investigate Newton's 2nd law.
They measure the acceleration of a trolley for different forces using light gates and a datalogger.
The method they follow is given below.



Method

1. Attach a 50 g mass hanger to the string. This gives an applied force of 0.5 N.
2. Release the trolley and record the acceleration from the datalogger.
3. Repeat step 2 twice more to give 3 results.
4. Remove one of the 50 g slotted masses from the trolley and place it on the mass hanger to increase the applied force by 0.5 N.
5. Repeat steps 2 to 4 until all the slotted masses have been placed on the mass hanger.

(i) State the independent variable. [1]

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(ii) State the dependent variable. [1]

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(iii) The same trolley is used throughout the experiment.
State **one** other controlled variable. [1]

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(iv) Some of the students' results are shown below.

Applied force (N)	Acceleration (m/s^2)			
	Trial 1	Trial 2	Trial 3	Mean
0.5	0.299	0.323	0.309	0.310
1.0	0.618	0.619	0.621	0.619
1.5	0.923	0.936	0.934	0.931

Sara states that the results prove Newton's 2nd law because the acceleration is proportional to the applied force.
Explain whether you agree. [2]

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(v) I. Use the results for an applied force of 0.5 N and an equation from page 2 to calculate the total mass of the trolley and the slotted masses. [3]

mass = ... kg

II. Explain how the students could check the accuracy of this value of the mass. [1]

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END OF PAPER

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