Surname	Centre Number	Candidate Number
First name(s)		0

GCSE

3420UB0-1

S23-3420UB0-1

THURSDAY, 25 MAY 2023 – 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.	**7**	
2.	**13**	
3.	**7**	
4.	**6**	
5.	**9**	
6.	**16**	
7.	**22**	
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 **4**.

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	
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 = $\frac{\text{mass} \times \text{velocity}^2}{2}$	$\text{KE} = \frac{1}{2} mv^2$
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 = $\frac{\text{change in momentum}}{\text{time}}$	$F = \frac{\Delta p}{t}$
u = initial velocity v = final velocity t = time a = acceleration x = displacement	$v = u + at$ $x = \frac{u + v}{2} t$ $x = ut + \frac{1}{2} at^2$ $v^2 = u^2 + 2ax$
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}
terra	T	multiply by 1 000 000 000 000	1×10^{12}

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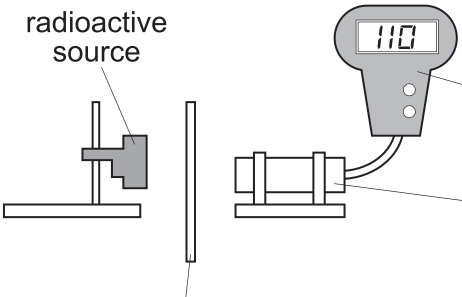
Answer **all** questions.

1. A teacher uses the apparatus below to demonstrate the penetrating properties of alpha, beta and gamma radiation.



(a) The teacher explains that there is a possibility of exposure to radiation from the source. Complete the risk assessment below. [2]

Hazard	Risk	Control measure
Nuclear radiation is ionising	....	....

(b) After the experiment the teacher gives the students some data about the radioactive source, cobalt-60, to analyse. The data are given in the table below.

Absorber	Count rate (counts per second)
no absorber	256
paper	256
aluminium	110
lead	50

Use the data to answer the following questions.

(i) Explain how the data show that cobalt-60 does not emit alpha particles. [1]

....

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(ii) Explain how the data show that cobalt-60 emits beta and gamma radiation. [2]

....

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(iii) The teacher tells the class that counts due to background radiation are included in the results in the table.

I. State **one** cause of background radiation. [1]

....

II. State how the results in the table should be corrected for background radiation. [1]

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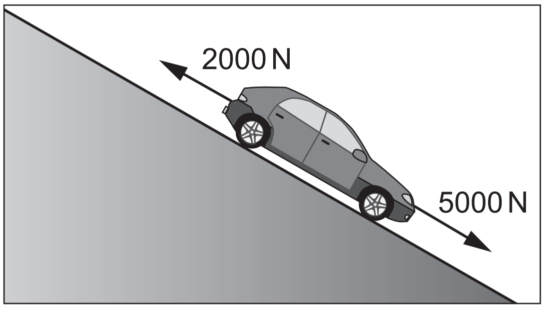
2. The diagram shows a car rolling down a slope. Two of the forces acting on the car are labelled.



(a) The car has a **weight** of 10 000 N. Use the equation:

$$\text{mass} = \frac{\text{weight}}{\text{gravitational field strength}}$$

to calculate the mass of the car. [2]
(Gravitational field strength, g, = 10 N/kg)

mass = ... kg

(b) Use the information in the diagram to answer the following questions.

(i) Calculate the resultant force acting down the slope. [2]

resultant force = ... N

(ii) Use your answers from parts (a) and (b)(i) and the equation:

$$\text{acceleration} = \frac{\text{resultant force}}{\text{mass}}$$

to calculate the acceleration of the car at the instant shown and state the unit. [3]

acceleration = ...

unit = ...

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(iii) I. Explain how the resultant force on the car changes as it speeds up. [2]

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II. State how this change in resultant force affects the acceleration of the car. [1]

....

(c) At the bottom of the slope the car continues horizontally at a constant speed of 12 m/s with a kinetic energy of 72 000 J.

(i) State **one** reason why the potential energy at the top of the hill must have been greater than 72 000 J. [1]

....

(ii) At the bottom of the hill a braking force is applied which stops the car over a distance of 15 m.

Use the equation:

$$\text{force} = \frac{\text{work done}}{\text{distance}}$$

to calculate the braking force. [2]

braking force = ... N

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3. Alpha Centauri is a star of similar size to our Sun.
It is 4.37 light years from Earth.
It is a main sequence star.

(a) State how long light takes to travel from Alpha Centauri to Earth. [1]

time = ...

(b) (i) Explain, in terms of named forces, why Alpha Centauri is currently stable. [2]

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....

....

(ii) Explain, in terms of named forces, the next stage in the life of Alpha Centauri. [2]

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(c) Explain why the mass of hydrogen present in Alpha Centauri will decrease as it gets older. [2]

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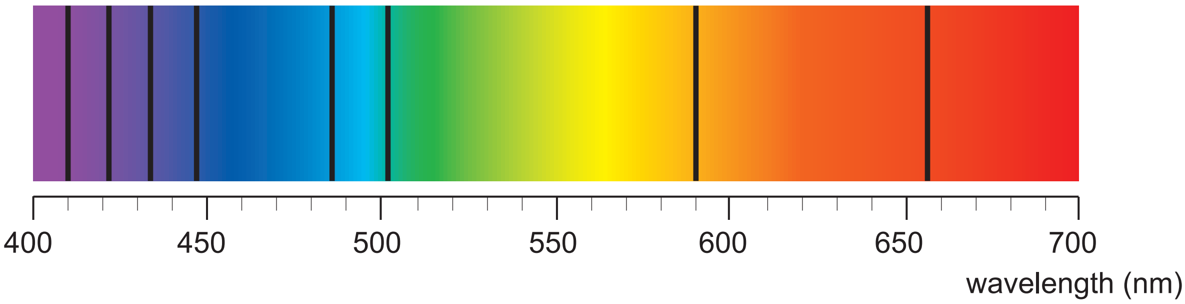
4. The diagram shows a spectrum from a star.
The spectrum is crossed by dark lines.



The table gives information about the wavelengths of lines to be found in a spectrum if the element is present in the atmosphere of the star.

Element	Wavelength (nm)
helium	447, 502
iron	431, 467, 496, 527
hydrogen	410, 434, 486, 656
sodium	590

- Explain how the dark lines arise on the spectrum.
- Explain which elements are present in the star's atmosphere. [6 QER]

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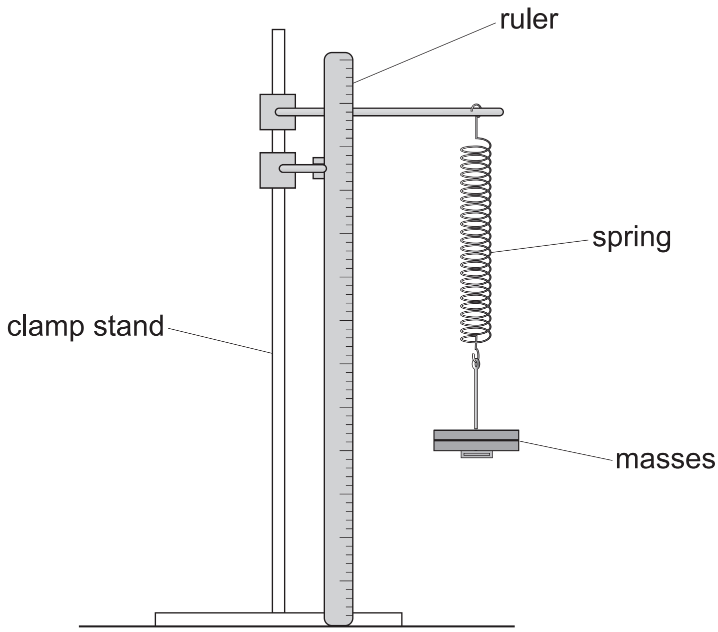
5. Some students carry out an experiment to determine the relationship between the force applied to a spring and its extension.
They use the following apparatus.



They collect data by loading and then unloading the spring. Their results are shown in the table below.

Mass (g)	Force (N)	Extension (cm)	
		Loading	Unloading
0	0	0.0	0.0
100	1	4.4	4.2
200	2	8.9	9.3
300	3	13.6	13.7
400	4	18.2	18.5
500	5	22.5	22.5

(a) The uncertainty in extension is given by:

$$\text{uncertainty in extension} = \frac{\text{maximum value of extension} - \text{minimum value of extension}}{2}$$

(i) State the mass with the greatest uncertainty in extension. [1]

value of mass = ... g

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(ii) Calculate this uncertainty. [2]

uncertainty = ... cm

(b) Suggest how the students could adapt the apparatus to reduce the uncertainty in their results. [1]

....

(c) Explain how they could use **all** of the results to determine a mean value for the spring constant. [3]

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(d) The students determine the spring constant to be 22.3 N/m.
The true value of the spring constant is 22.2 N/m.
Explain what this tells the students about their data. [2]

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6. In one example of the process of nuclear fission of uranium-235, it is suggested that isotopes of caesium and rubidium and a number of neutrons ($^{1}_{0}n$) are produced.

The table gives information about the particles in the nuclei of the isotopes named above.

Element	Symbol	Number of protons in the nucleus	Number of neutrons in the nucleus
uranium	U	92	143
caesium	Cs	55	85
rubidium	Rb	37	55

(a) Write a balanced nuclear equation for the fission decay of uranium into caesium and rubidium. [4]

$$^{\cdots\cdots}_{\cdots\cdots}U + {}^{1}_{0}n \longrightarrow \cdots\cdots\cdots + \cdots\cdots\cdots + \cdots\cdots {}^{1}_{0}n$$

(b) (i) Explain the purpose of the moderator in a fission reactor. [2]

....

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....

(ii) Explain how the rate of reaction can be increased in a nuclear reactor. [3]

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(c) The caesium isotope produced in this fission reaction has a half-life of 64 s.
The rubidium isotope has a half-life of 4 s.
At time, $t = 0$ the mass of caesium present is 131 072 g.
The same mass of rubidium is also present.

(i) Calculate the mass of caesium present after 64 s. [1]

mass of caesium = ... g

(ii) I. Calculate how many half-lives of rubidium occur in 64 s. [1]

number of half-lives = ...

II. After 32 seconds, 512 g of rubidium remains.
Calculate the mass of rubidium remaining after 64 s. [3]

mass = ... g

(iii) Initially the ratio of mass of caesium to mass of rubidium was 1:1.
Explain how this ratio changes with time. [2]

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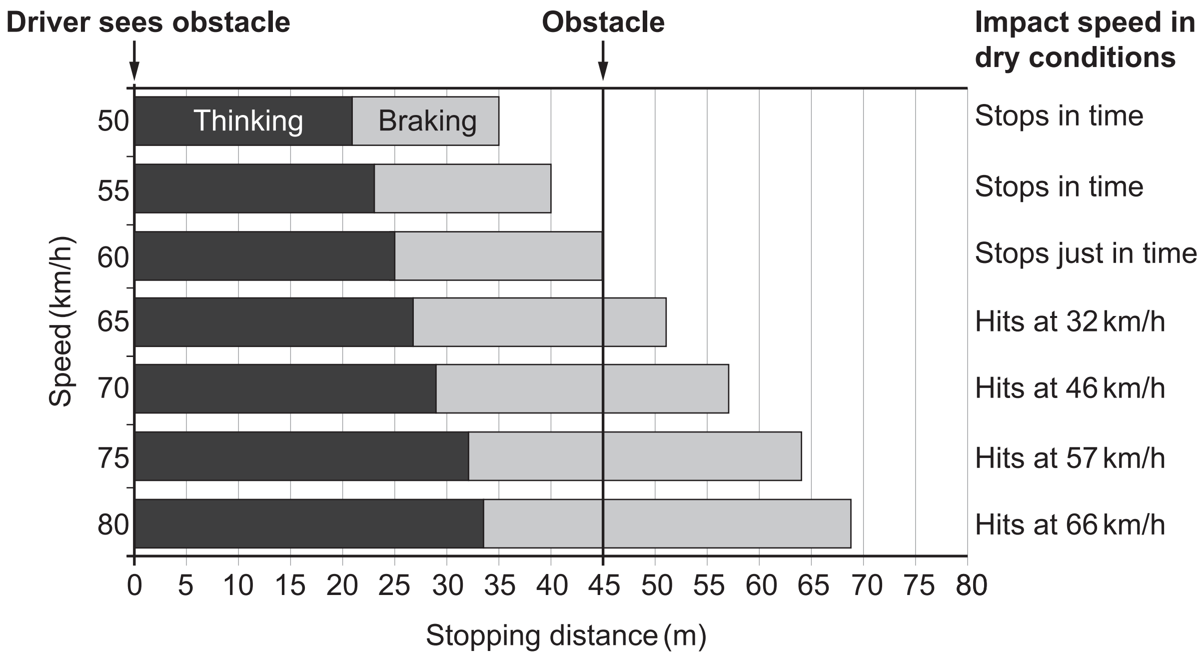
7. The chart below is used by traffic collision investigators. It gives the thinking, braking and stopping distances of cars driven at different speeds by an alert driver on a dry road.

An alert driver notices an obstacle 45 m away on the road ahead. The position of this obstacle is represented by the dark vertical line. If there is a collision, the chart also shows the impact speed with the obstacle.



(a) State how the following information in the chart for a speed of 70 km/h would compare if the tyre treads on the car are worn below the legal limit. [3]

(i) Thinking distance

....

(ii) Braking distance

....

(iii) Impact speed

....

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(b) Use the information opposite to answer the following questions about a car travelling at 60 km/h which **decelerates to a stop**.
(10 km/h = 2.8 m/s)

(i) **Complete** the following table. [4]

Initial speed (km/h)	Initial speed (m/s)	Thinking distance (m)	Braking distance (m)	Stopping distance (m)
60	....	....	....	....

(ii) Using the information in the table, calculate the **thinking time** of the driver. [3]

thinking time = ... s

(iii) Use the equation:

$$v^2 = u^2 + 2ax$$

and the information in the table to calculate the deceleration of the car. [3]

deceleration = ... m/s^2

(c) The chart shows that a car travelling faster than 60 km/h will not stop in time and therefore collides with the obstacle.

(i) Explain, in terms of Newton's 1st Law, how seat belts provide protection during a collision. [2]

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(ii) Explain, in terms of Newton's 3rd law, why the car and the obstacle are damaged during a collision. [2]

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(iii) Explain, in terms of Newton's 2nd law, why cars have crumple zones. [2]

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(d) The Royal Society for the Prevention of Accidents (RoSPA) says that "The majority of pedestrian casualties (in the UK) occur in built-up areas: 22 of the 26 child pedestrians and 264 of the 372 adult pedestrians who were killed in 2017, died on roads in built-up areas."
They strongly feel that reducing the speed limit in built-up areas from 50 km/h to 35 km/h would greatly improve these accident statistics.
Explain whether you agree with RoSPA. [3]

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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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Turn over.

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

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