Surname	Centre Number	Candidate Number
Other Names		0

GCSE – NEW

3420UB0-1

S18-3420UB0-1

PHYSICS – Unit 2:
Forces, Space and Radioactivity

HIGHER TIER

WEDNESDAY, 23 MAY 2018 – AFTERNOON

1 hour 45 minutes

For Examiner's use only		
Question	**Maximum Mark**	**Mark Awarded**
1.	**7**	
2.	**13**	
3.	**6**	
4.	**17**	
5.	**13**	
6.	**8**	
7.	**16**	
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. Do not use correction fluid.
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.

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)**.

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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	
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 = $\frac{\text{mass} \times \text{velocity}^2}{2}$	$KE = \frac{1}{2}mv^2$
change in potential energy = mass × gravitational field strength × change in height	$PE = mgh$
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	Multiplier
p	1×10^{-12}
n	1×10^{-9}
μ	1×10^{-6}
m	1×10^{-3}

Prefix	Multiplier
k	1×10^{3}
M	1×10^{6}
G	1×10^{9}
T	1×10^{12}

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Answer **all** *questions.*

1. A new timer, in the shape of a ball, has been produced. When it is released it starts a built-in stop clock. When the ball next hits something the timer stops. The time taken is displayed on its screen.

A teacher uses the ball timer for an experiment. He holds the ball out of his third floor classroom window and then carefully releases it. The time taken to fall is recorded in a table. The ball is dropped 5 times during the experiment.

Drop number	1	2	3	4	5
Time (s)	1.48	1.10	1.52	1.54	1.46

(a) Explain how the teacher could find out if the results are reproducible. [2]

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(b) **Circle** the result in the table which is most likely to be anomalous. [1]

(c) Calculate the mean time for the ball timer to fall. [2]

Mean time to fall = ... s

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(d) The mean impact velocity of the ball on the ground is 14.2 m/s.
Use the equation:

$$x = \frac{u + v}{2}\, t$$

to calculate the drop height of the ball. [2]

Drop height = ... m

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2. In 1992 scientists first detected a planet orbiting a star outside our Solar System. Hundreds of these exoplanets have been found since. **Table 1** shows the stars that have been discovered with 6 or more exoplanets in orbit, along with information about our Sun.

Table 1

Name of star	Distance of star from Earth (l-y)	Mass of star (compared to the Sun)	Temperature of star (K)	Number of planets in orbit
Sun	0.00002	1.0	5770	8
HR 8832	21	0.8	4700	7
HD 10180	127	1.1	5910	7
Kepler 90	2500	1.1	5930	7
HD 40307	42	752.0	4980	6
HD 127	206	0.7	870	6
Kepler 20	950	0.9	5470	6
Kepler 11	2000	1.0	5680	6

(a) (i) Tick (✓) the **two** correct statements below. [2]

Four stars have the same mass. ☐

Light travelling from Kepler 90 takes the longest time to reach Earth. ☐

The range of star temperatures is 5060 K. ☐

Hotter stars have more planets in orbit around them. ☐

Star HR 8832 is double the distance of star HD 40307 away from Earth. ☐

(ii) State **two** reasons, using evidence from **Table 1**, why scientists predict that the star Kepler 11 is most likely to have a Solar System similar to ours. [2]

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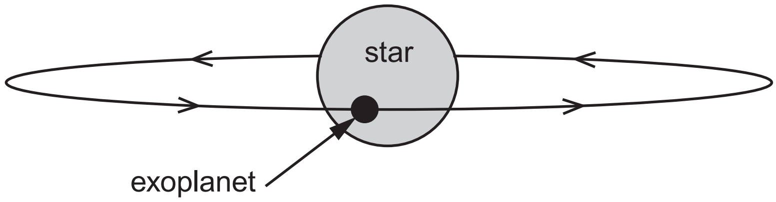
(b) Exoplanets can't be detected directly because they don't give out their own light. One method of detection is to look for a slight dip in the light intensity from the star. This happens when the exoplanet passes in front of the star during its orbit. This is called a transit.



(i) Why does the detected light intensity decrease during a transit? [1]

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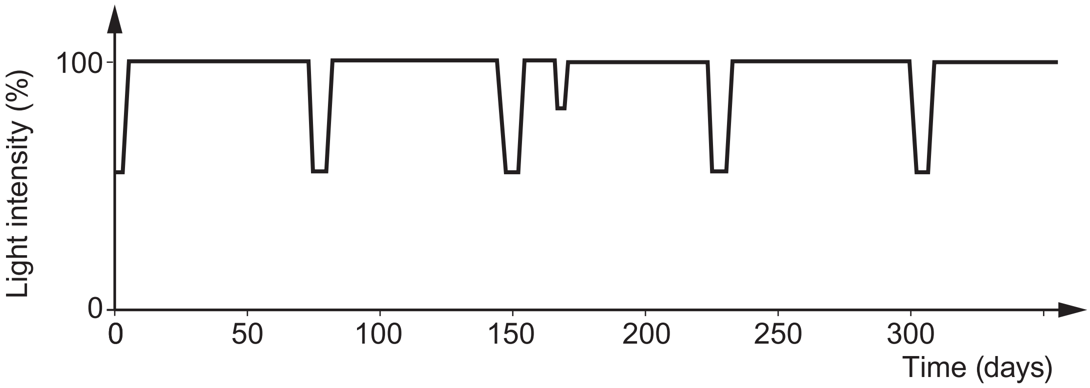
(ii) A pupil finds a graph on the internet that shows the measured light intensity detected from a star against time.



I. Calculate the orbit time, in days, of the exoplanet. [2]

Orbit time = ... days

II. The pupil correctly suggests that there may be two exoplanets in orbit around this star. What evidence is there to back up this claim? [1]

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III. During a transit some of the light from the star passes through the exoplanet's atmosphere. An absorption spectrum is produced. Explain how the absorption spectrum arises and is used to identify gases in its atmosphere. [2]

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 (3420UB0-1) **Turn over.**

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(c) **Table 2** shows data collected for all the exoplanets in orbit around the star called Kepler 11. They are listed in order of increasing distance.

Table 2

Exoplanet	Mass (compared to Earth)	Time for one orbit (days)	Temperature (K)	Orbit radius (AU)
b	1.9	10.3	871	0.09
c	2.9	13.0	807	0.11
d	7.3	22.7	659	0.16
e	8.0	32.0	596	0.20
f	2.0	46.7	525	....
g	25.0	118.4	386	0.47

(i) Compare the **trend** in temperature with orbit radius of the planets around Kepler 11 to the planets in our Solar System where Venus is the hottest. [2]

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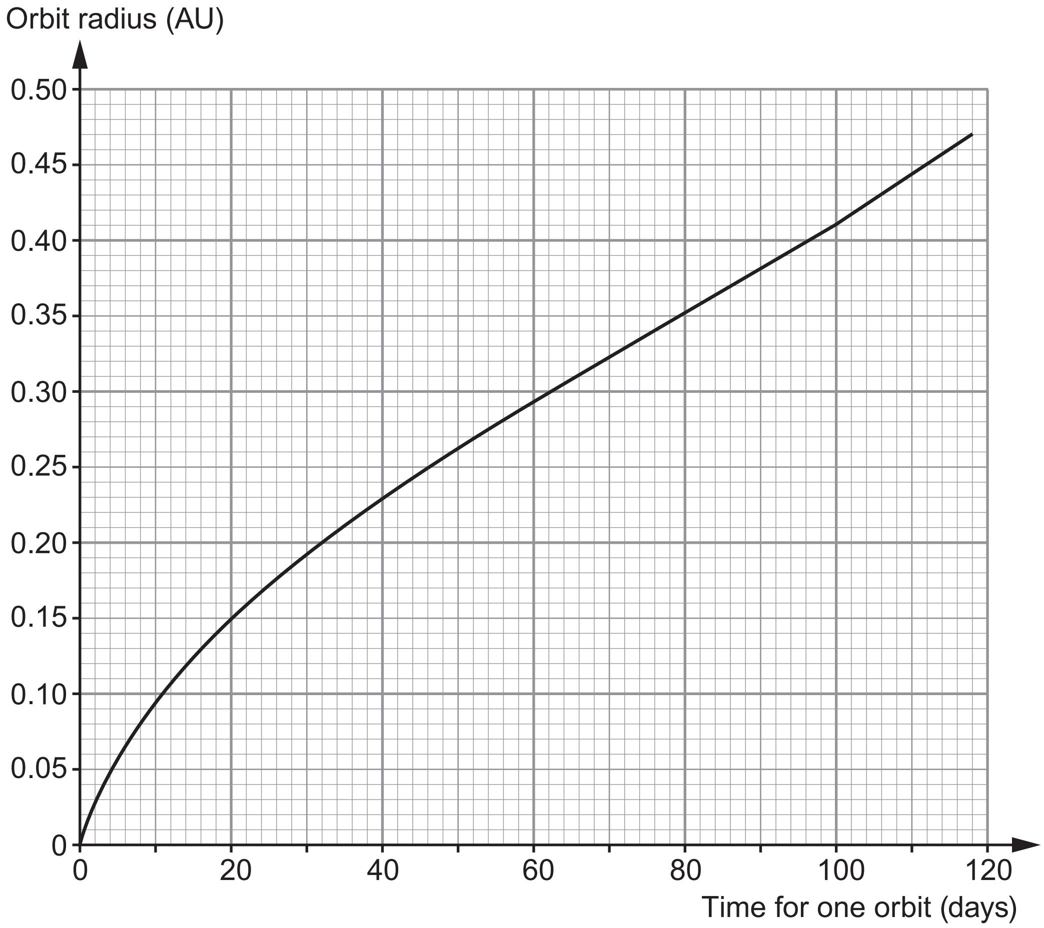
(ii) Some of the data from the table is used to plot a graph.



The orbit time of **exoplanet f** was found using the transit method. Its orbit time was measured as 46.7 days. Use the graph to **complete Table 2** with an estimate of a value for the missing orbit radius. [1]

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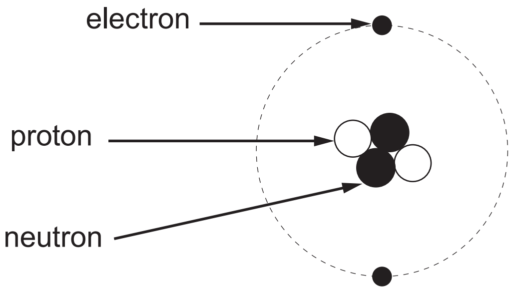
3. A chemistry student correctly draws and labels a helium atom.



(a) An alpha particle is a helium nucleus. State the difference between the structure of an alpha particle and a helium atom. [1]

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(b) A nucleus of polonium-218 ($^{218}_{84}Po$) decays by an alpha (α) emission.

$$^{218}_{84}Po \longrightarrow X + {}^{4}_{2}\alpha$$

A short time later the resulting nucleus X decays by a beta (β) emission.

$$X \longrightarrow Y + {}^{0}_{-1}\beta$$

Nucleus Y then decays by a beta (β) emission.

$$Y \longrightarrow {}^{214}_{84}Z + {}^{0}_{-1}\beta$$

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The following table gives information about some elements, their symbols and proton numbers.

Element	Symbol	Proton number
radium	Ra	88
francium	Fr	87
radon	Rn	86
astatine	At	85
polonium	Po	84
bismuth	Bi	83
lead	Pb	82

(i) Use the information above to complete this table. [4]

	Element	Nucleon number
X	....	....
Y	....	....

(ii) State which of X, Y or Z is an isotope of polonium (Po). .... [1]

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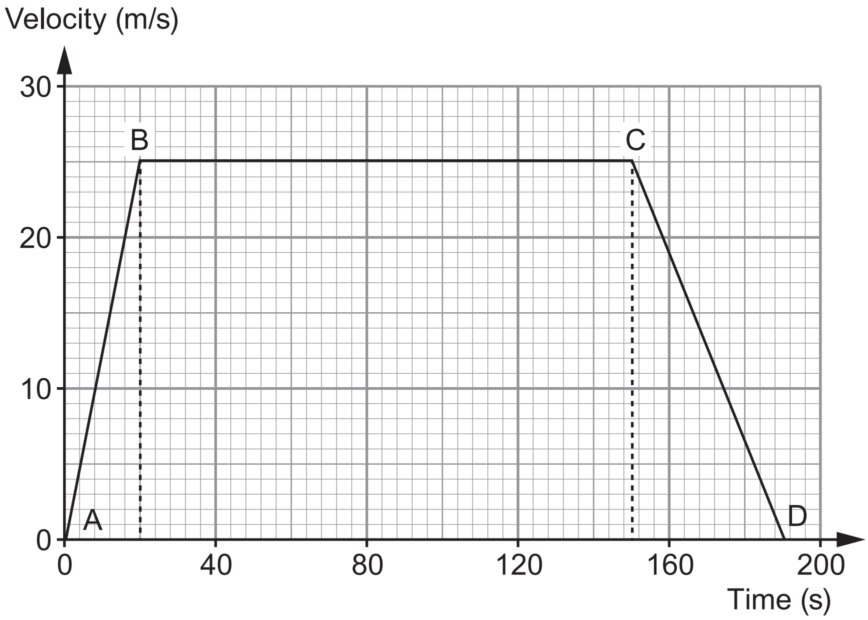
4. An empty school bus takes 190 seconds to travel between two sets of traffic lights. Its journey is shown on the velocity-time graph below.



(a) The bus accelerates uniformly from the first set of traffic lights at A. The resultant force acting on it is 5 000 N. Use the graph and equations from page 2 to calculate the mass of the empty bus. [4]

Mass = ... kg

(b) The same resultant force acts on the bus which is now full of pupils. Explain how the start of the velocity-time graph (between A and B) would change. [2]

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(c) (i) State Newton's first law of motion. [2]

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(ii) Explain how Newton's first law applies to part **B to C** of the journey. [2]

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(d) During its journey from A to D how long is the bus moving at a velocity greater than 12.5 m/s? [2]

Time = ... s

(e) A lorry travels between the same two sets of traffic lights at a constant velocity without stopping. It takes the same time as the school bus. **On the graph opposite** draw the motion of the lorry. You may use equations from page 2 and the space below to show any calculations. [5]

Space for workings:

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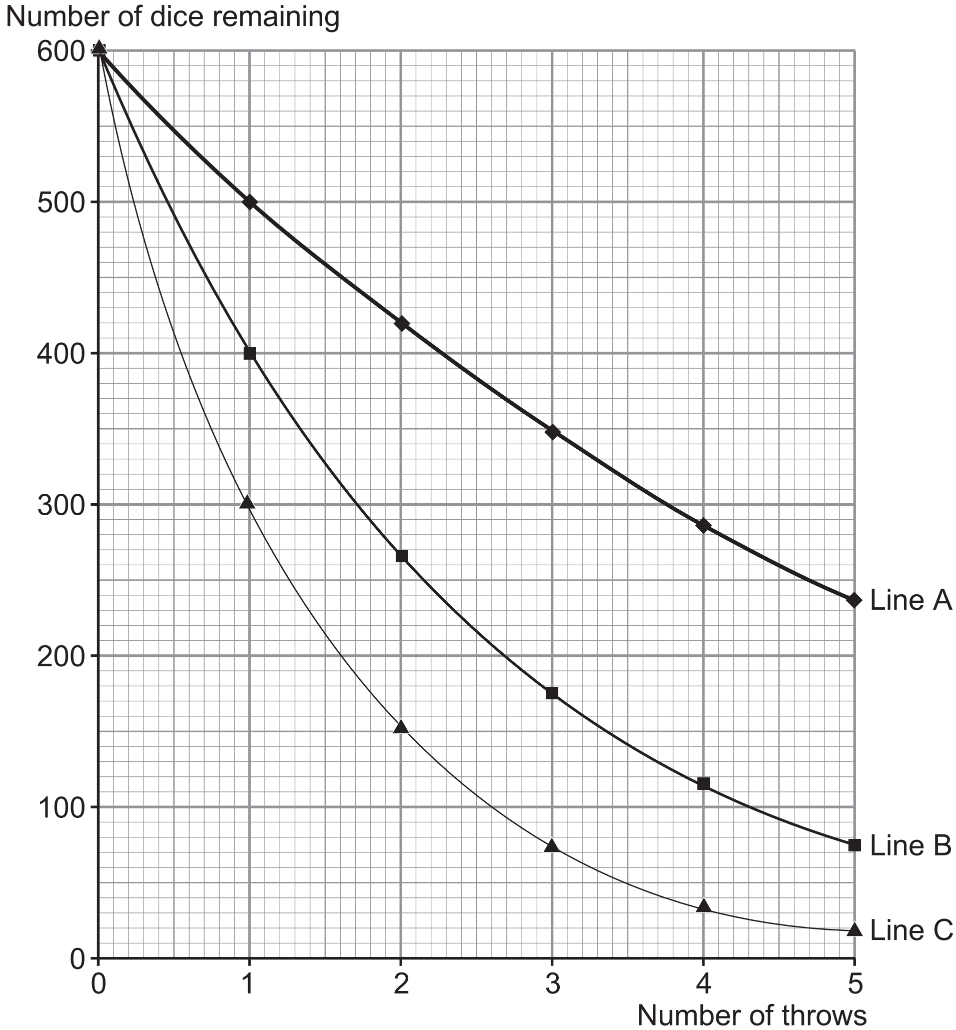
5. A physics teacher uses 600 identical red dice with her class to model the decay of different radioisotopes. To collect her first set of data she throws the 600 dice. She then removes all of the **sixes** that are face up. She then counts the remaining dice and repeats the process for a total of 5 throws.

In her second demonstration she repeats the experiment but removes all of the **fives** and **sixes** that are face up.

In her third demonstration, she removes all of the **fours**, **fives** and **sixes** that are face up.

She records her data on a spreadsheet. This quickly produces a graph for her class to see. The graph is shown below.



(a) (i) Explain why the teacher chooses to use a large number of dice for her demonstration. [2]

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(ii) Using only information from the graph tick (✓) the **three** correct statements. [3]
Space for working:

Line A represents the data from the third demonstration. ☐

Line B shows the equivalent of three half-lives in 5 throws. ☐

Line C could also represent the same demonstration modelled with 600 coins. ☐

Line A represents the radioisotope that decays at the quickest rate. ☐

Line B has an activity that is $\frac{1}{8}$ of its original after 5 throws. ☐

Line C represents the longest half-life. ☐

(iii) The teacher suggests to her class that an improved model of radioactive decay would be to include 20 blue cubes, along with the 600 red dice, at the start. The blue cubes **would not** be removed during the demonstration but would be counted each time.

I. State what physical quantity the blue cubes represent. [1]

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II. State how the presence of the blue cubes affects **line A** on the graph. [1]

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(b) Strontium-93 (Sr-93) is a radioactive source which decays with a half-life of 8 minutes.

(i) A sample of Sr-93 has a mass of 68.0 mg. Calculate the mass of undecayed Sr-93 left after 56 minutes. Show your working and give your answer to **1 significant figure**. [3]

Mass = ... mg

(ii) A scientist works with Sr-93 which decays by beta and gamma emission. When he is not using the Sr-93, explain why, for his own safety, he has to store it in a lead box. [3]

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6. *(a)* Nuclear fusion and nuclear fission reactions both produce heat energy. Describe and compare controlled nuclear fission and nuclear fusion reactions. [6 QER]

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(b) A typical fusion reaction between tritium and deuterium is:

tritium + deuterium $\longrightarrow$ helium + neutron + 2.82×10^{-12} J of energy

Calculate the number of fusion reactions needed each second to provide an energy output of 6.2 MJ every second. [2]

Number of reactions = ...

8

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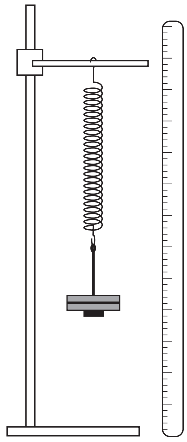
7. A Welsh company has been asked to design a toy that is able to launch a model plastic plane. They decide to use a spring mechanism in its design. Initially they carry out an experiment to investigate whether a spring is suitable for use in the toy.

Slotted masses are added to exert a force on the spring.

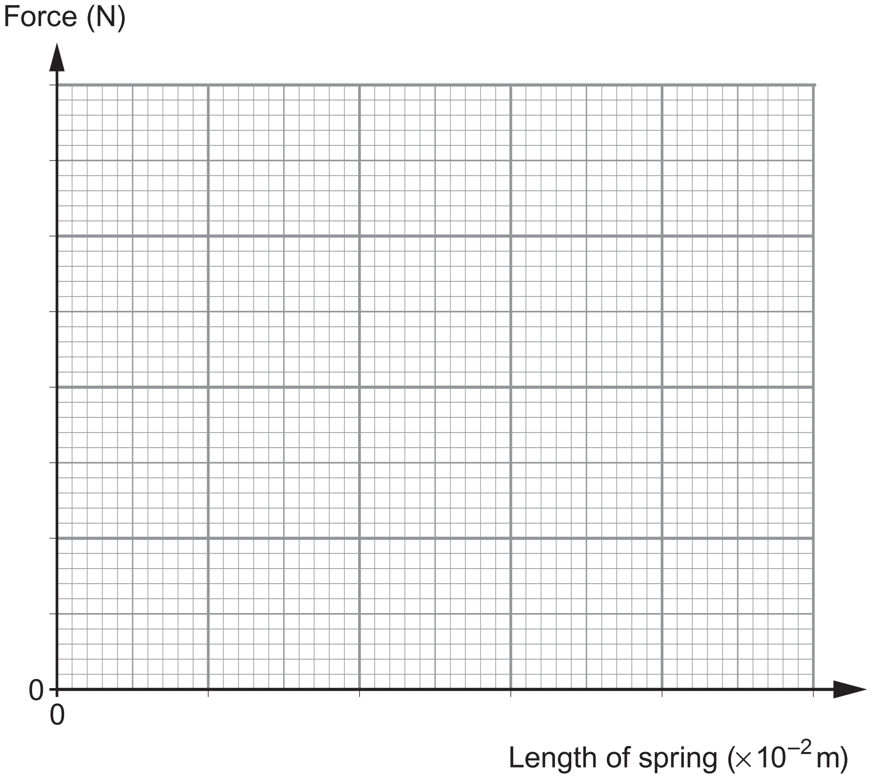
The resulting length of the spring is measured.

The results are shown in the table below.

Mass (g)	Force (N)	Length of spring ($\times 10^{-2}$ m)
100	1.0	7.5
200	2.0	10.0
300	3.0	12.5
600	6.0	20.0
700	7.0	22.5



(a) (i) Plot the data on the grid below and draw a suitable line. [4]



(ii) State the length of the spring when no force is applied. [1]

Length of spring = ... $\times 10^{-2}$ m

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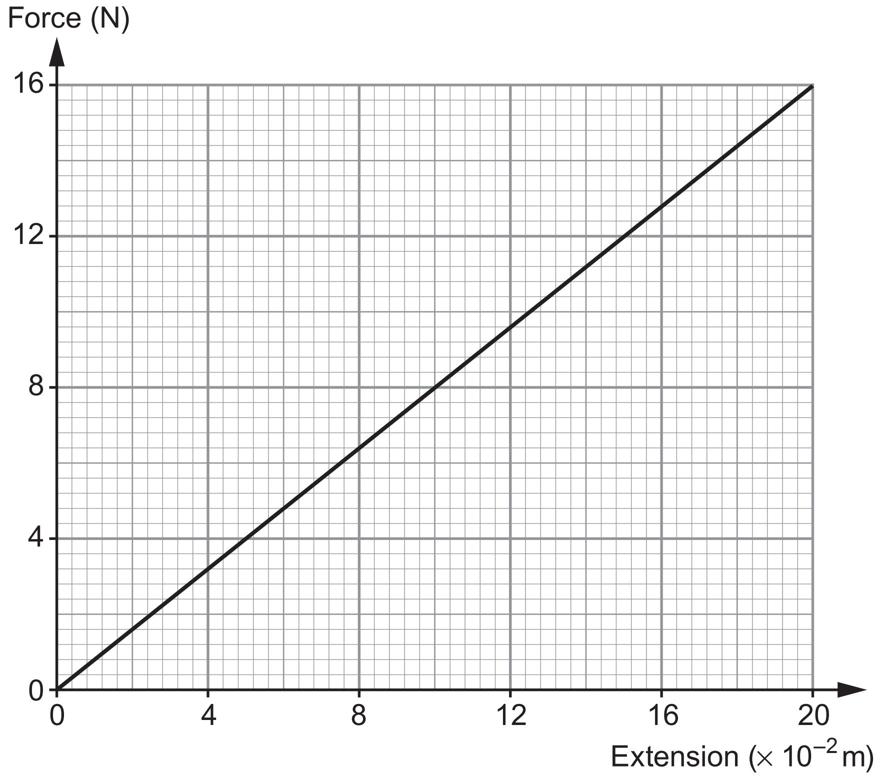
(b) The design company decides to connect two of these springs in parallel with each other in the launch mechanism of the model plastic plane.

The graph shows how the extension of this spring system changes with force.



The two spring system is stretched and a model plastic plane of mass 55×10^{-3} kg is attached. A trigger is pressed, which releases one end of the spring system, and the plane is launched.

(i) The two spring system is stretched to a maximum extension of 15×10^{-2} m. Use the graph and an equation from page 2 to calculate the work done stretching this spring system. Give an appropriate unit with your answer. [4]

Work done = ...

Unit ....

TURN OVER FOR THE REST OF THE QUESTION.

 (3420UB0-1) **Turn over.**

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(ii) Health and safety guidelines limit the launch velocity of the plastic plane to a maximum of 4 m/s. Using an equation from page 2 and your answer from *(b)*(i), calculate the launch velocity of this plane (mass = 55×10^{-3} kg) **and state** whether the launch system design meets this safety guideline. [3]

Launch velocity = ... m/s

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(iii) Explain why the actual launch velocity is always less than your calculated launch velocity. [2]

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(iv) A student suggests that a maximum momentum value would be more appropriate than stating a maximum velocity restriction for the launch. Explain why this would be an improvement to the health and safety guidelines. [2]

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

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