Newton's Laws

Higher Tier

Past paper Questions

Equations

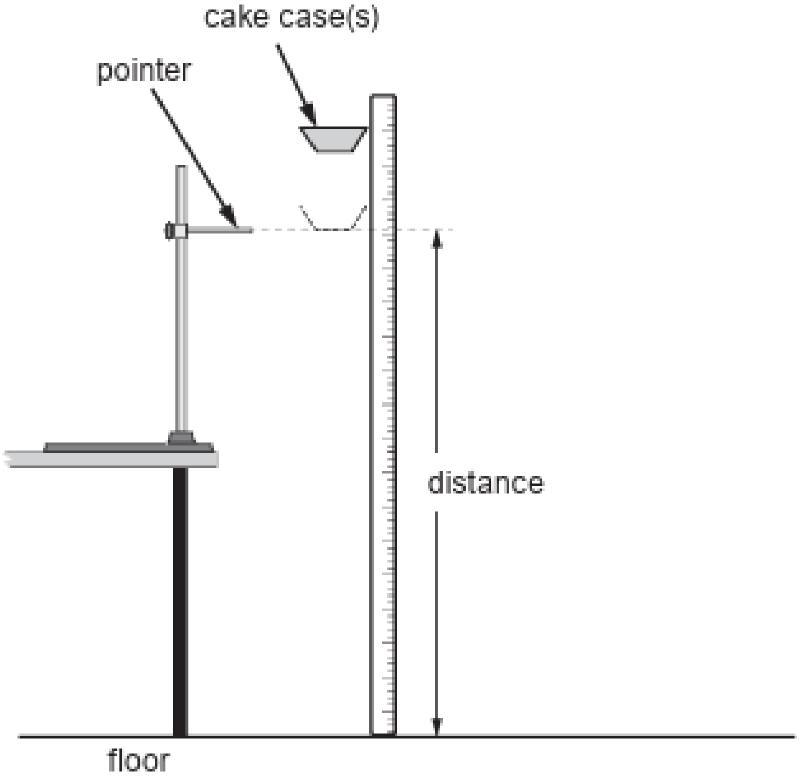
speed = $\frac{\text{distance}}{\text{time}}$	
acceleration [or deceleration] = $\frac{\text{change in velocity}}{\text{time}}$	$a = \frac{\Delta v}{t}$
acceleration = gradient of a velocity-time graph	
distance travelled = area under a velocity-time graph	
resultant force = mass × acceleration	$F = ma$
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	$W = \frac{1}{2}Fx$

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}

A group of students investigate if the terminal speed of falling paper cake cases depends on their mass. They follow the method given below.



1. Set up a pointer in the clamp stand and set it 1.50 m above the ground.
2. Take a single cake case and record its mass using a balance.
3. Drop the cake case from 20 cm above the pointer.
4. Use a stopwatch to record the time it takes to fall from the level of the pointer to the floor.
5. Repeat steps 3 and 4 another four times.
6. Repeat steps 3-5 with extra cake cases in a stack.

(a) (i) Give **one** reason why the students let the cake case fall for 20 cm before starting the stopwatch. [1]

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(ii) Give **two** reasons why the students take more than one repeat reading. [2]

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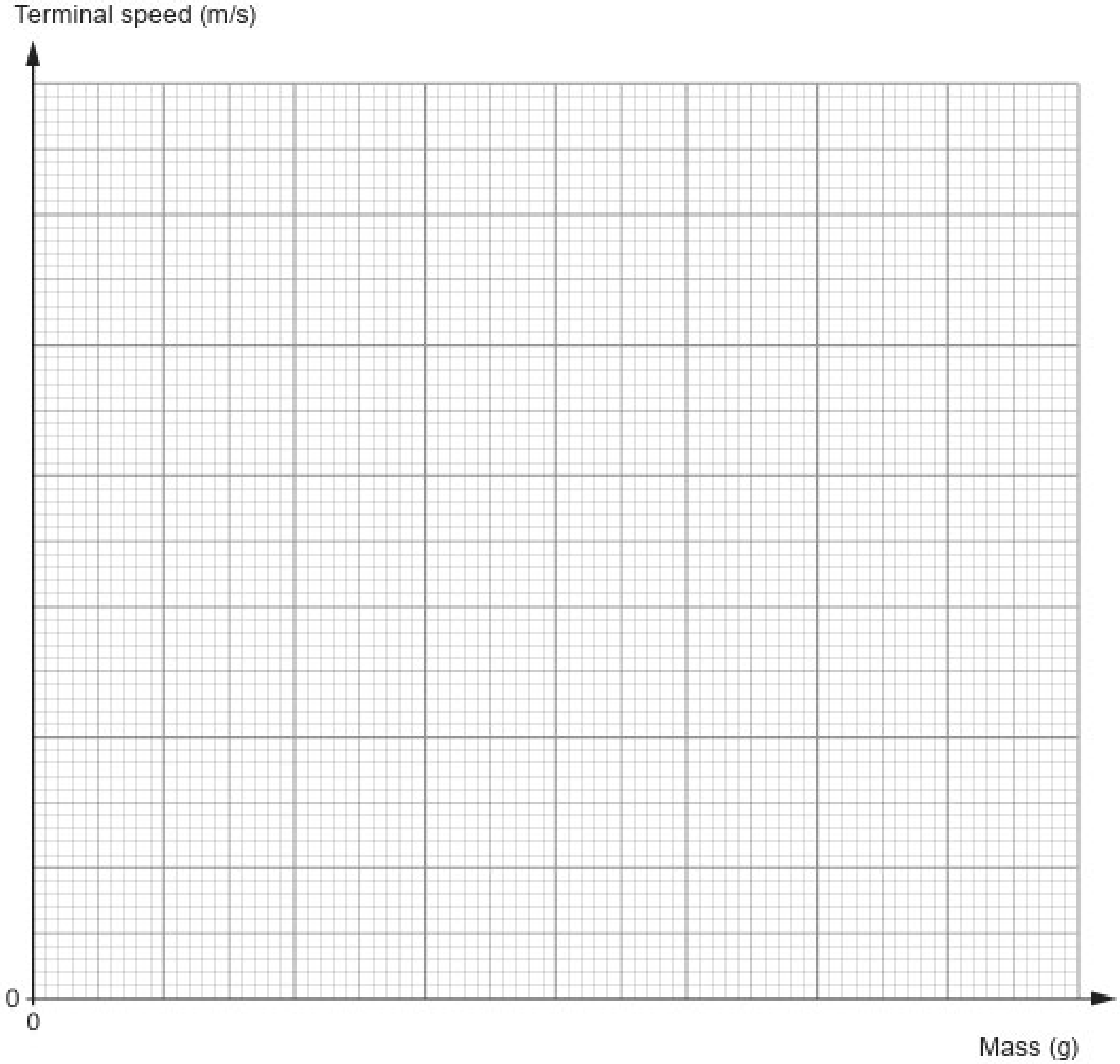
(b) The following data are collected. The students assume that each of the cake cases has a mass of 0.5 g.

Number of cake cases	Mass of cake cases (g)	Mean time taken for cake cases to fall 1.50 m (s)	Terminal speed (m/s)
0	0		0
1	0.5	0.94	1.60
2	1.0	0.67	2.24
3	1.5	0.59	2.54
5	2.5	....	2.88
6	3.0	0.51	2.94

(i) **Complete the table.** Use an equation from page 2 to calculate the missing value of the mean time. *Space for workings.* [2]

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



(iii) One of the students suggests that the terminal speed will always increase by a factor of 1.4 if the mass is doubled. The student finds that when the mass doubles from 0.5 g to 1.0 g this suggestion is true. Explain if this is true for the other masses. [3]

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(c) Apart from taking more repeat readings, suggest one way in which the method could be improved to collect better quality data **and** explain how the improvement would give better data. [2]

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(d) Explaining your reasoning and using an equation from page 2, calculate the size of the air resistance force acting on a stack of 5 cake cases when travelling at terminal speed. (Gravitational field strength, g = 10 N/kg). *Space for workings.* [3]

Air resistance = ... N

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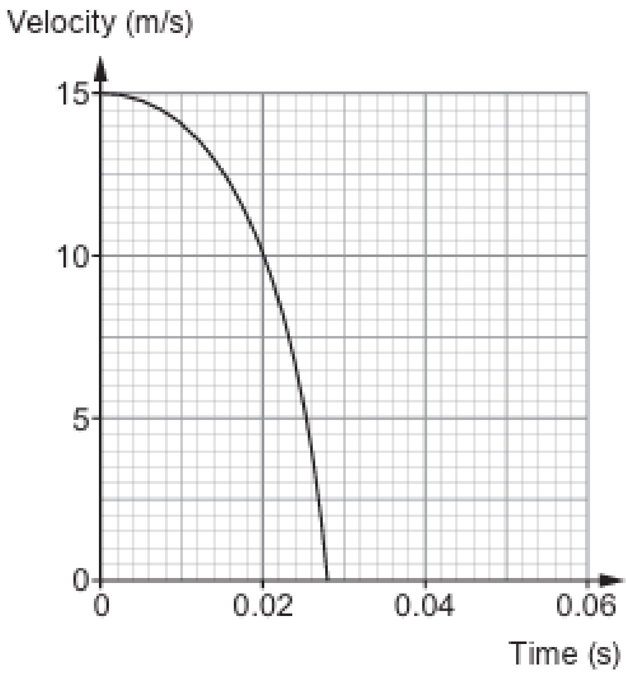
The safety of car drivers and passengers in the event of a collision has been the subject of an enormous amount of research in the last 50 years. As a result, the design of cars has developed to improve the safety of the occupants in the event of a head-on collision.

A crash dummy is positioned in the driving seat of a car, which is directed, under test conditions, into a solid concrete wall. The graph below shows the velocity of the dummy from the moment the car makes contact with the wall.



(a) State Newton's third law of motion and explain how it applies to the car and the wall in this collision. [3]

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(b) (i) Use the graph opposite and equations from page 2 to calculate the mean resultant force on the dummy of mass 85 kg during the collision.
Give your answer to two significant figures. [3]

Mean resultant force = ... N

(ii) Use the graph opposite to explain whether the resultant force is constant during the collision. [2]

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(c) Explain, **in terms of the work done**, how a crumple zone at the front of the car would improve the safety of the driver in a head-on collision. [2]

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Duel award -physics 2022 Q5

An experiment was carried out by students to investigate the mean speed of a stack of 6 cake cases falling from different heights.
The weight of 6 identical cake cases was measured 5 times.
Their results are shown below in **Table 1** and there were no anomalies.

Table 1

Measurement	1	2	3	4	5
Weight of 6 cake cases (N)	0.036	0.032	0.033	0.034	0.030

(a) (i) Calculate the mean weight of the 6 cake cases. [1]

Mean weight = ... N

(ii) Use the equation:

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

to calculate the uncertainty in the mean weight of the 6 cake cases. [1]

Uncertainty in the mean = ... N

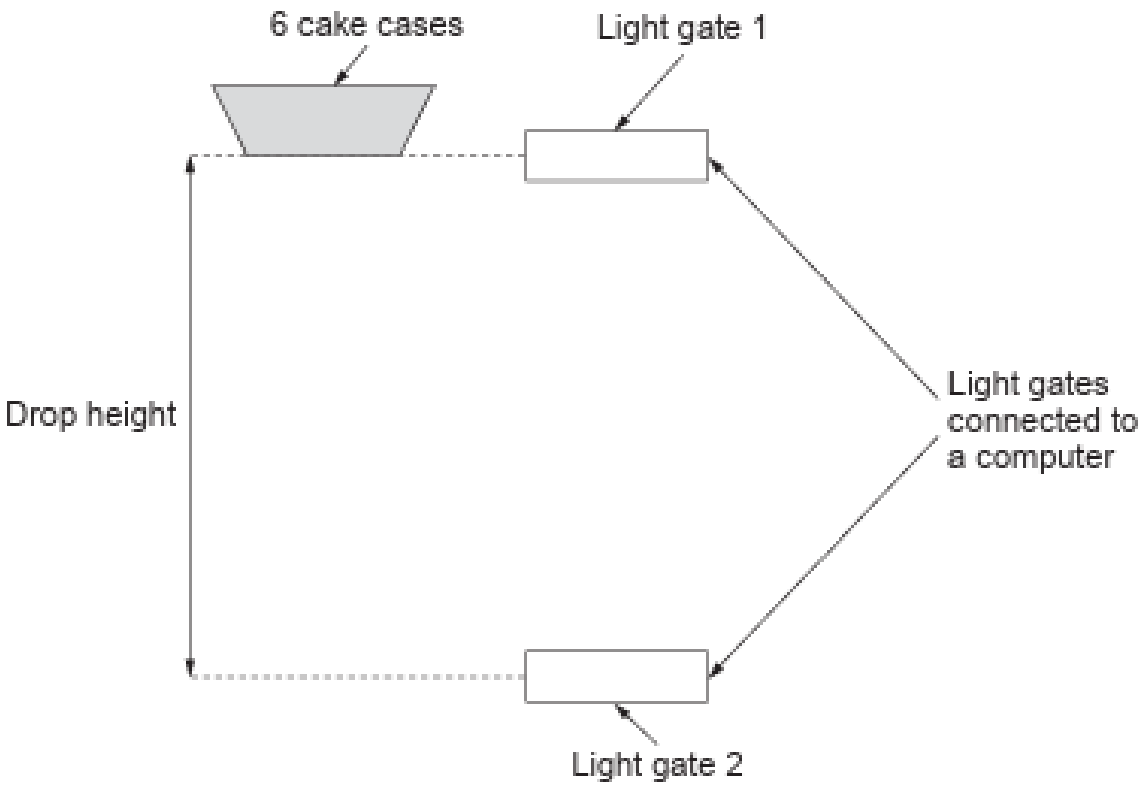
(iii) The teacher states if the percentage uncertainty in the mean is **less than 10%** the data is repeatable.

Use the equation:

$$\text{percentage uncertainty} = \frac{\text{uncertainty in the mean}}{\text{mean weight}} \times 100\%$$

to determine if the data collected is repeatable. [2]

(b) Light gates were used to time the falling cake cases.
The vertical distance between the two light gates was adjusted so that different drop heights could be investigated.
The apparatus is shown below.



Their results are shown in **Table 2** below.

Table 2

Drop height (m)	Time taken for the stack of 6 cake cases to fall (s)			Mean speed (m/s)
	Trial 1	Trial 2	Mean	
0.00				0.00
0.20	0.365	0.366	0.366	0.55
0.60	0.698	0.697	0.698	0.86
0.90	0.916	0.920	0.918	0.98
1.20	1.133	1.131	1.132	1.06
1.60	1.455	1.454	1.455	1.10
2.00	1.816	1.820	1.818	1.10
2.50	2.270	2.274	2.272	1.10
3.00	2.729	2.725	2.727	1.10

(i) Give a reason why light gates, rather than a stopwatch, are used to measure the time taken for the stack of cake cases to fall. [1]

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(ii) A student correctly notices that the mean speed of the cake cases at a drop height of 1.60 m is **double** the mean speed at a drop height of 0.20 m.
The student states that the cake cases have **4 times** more kinetic energy after falling 1.60 m compared to 0.20 m.

Use an equation from page 2 to investigate whether the claim is correct.
The total mass of the 6 cake cases is 3.3×10^{-3} kg. [3]
Space for calculations.

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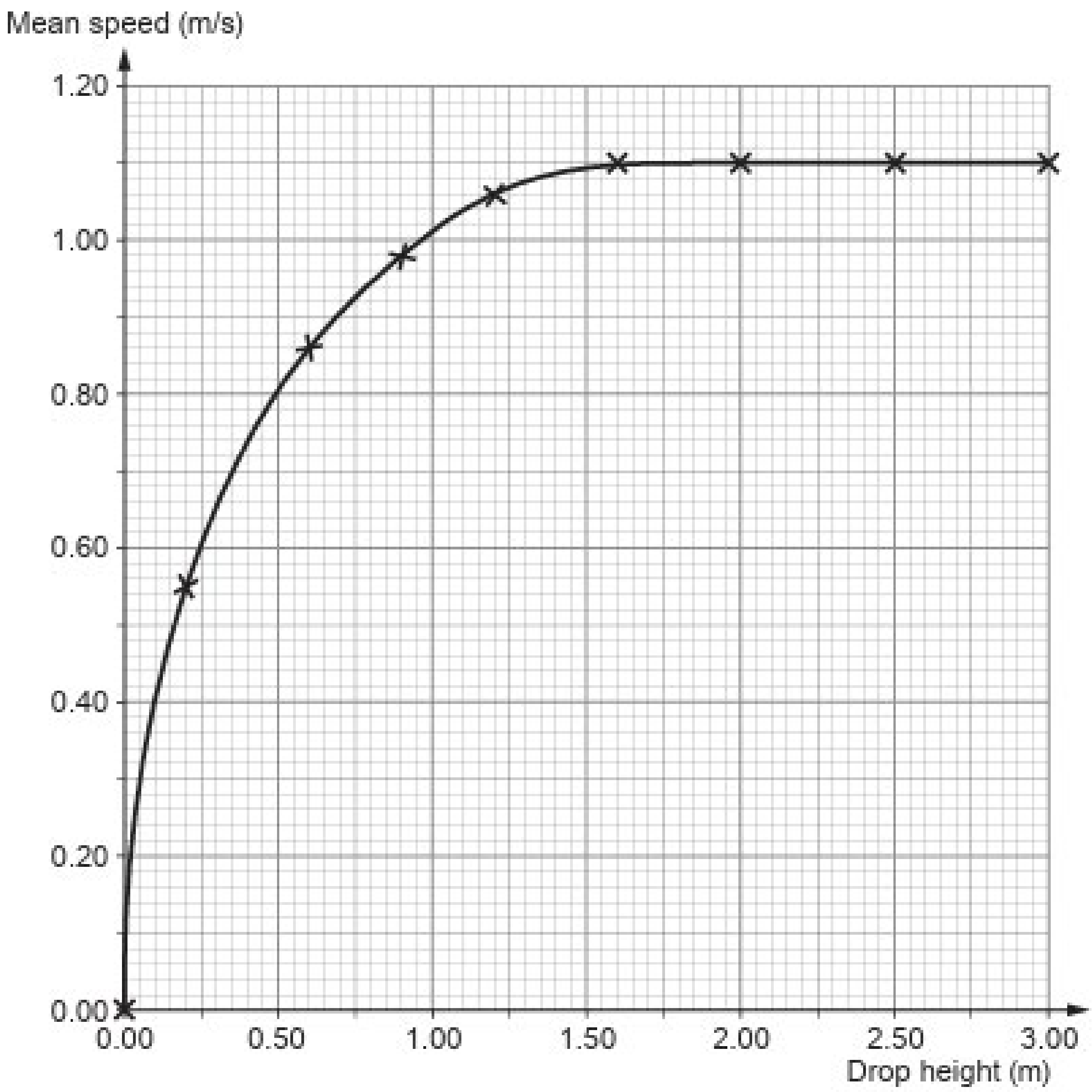

(i) Describe how the mean speed varies with drop height between **0.00 m and 1.50 m**. [2]

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(ii) Use the graph to state the value of terminal speed for the cake cases. [1]

Terminal speed = ... m/s

(iii) I. Name the **two** forces acting on the falling cake cases. [1]

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II. Compare the size of these two forces when the cake cases fall at terminal speed. [1]

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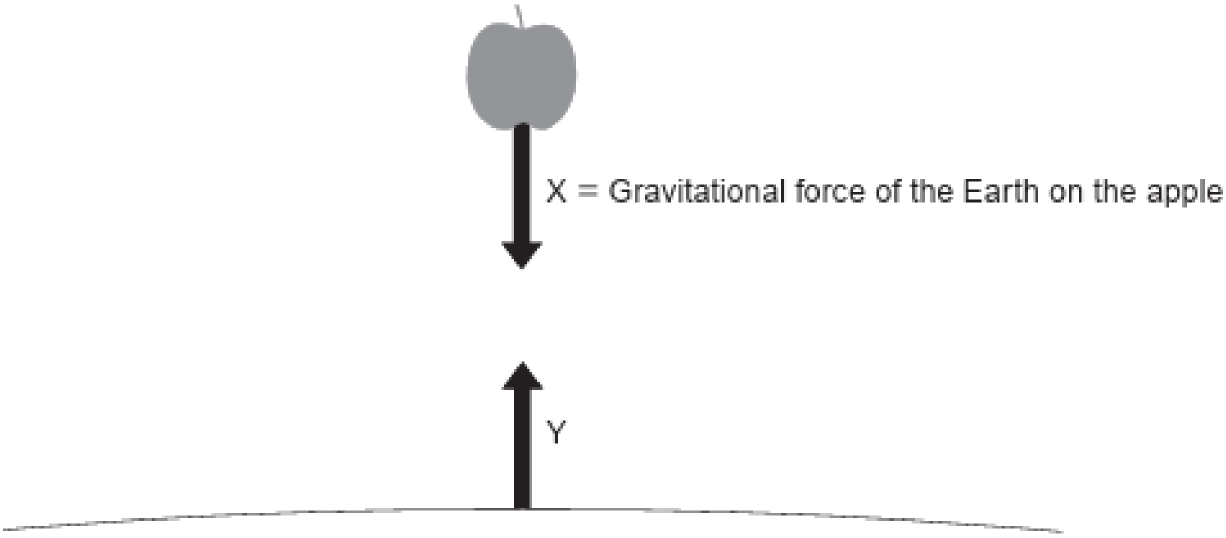
Newton's third law states that if a body A exerts a force on body B, body B exerts an equal and opposite force on body A.

(a) The diagram (not to scale) shows an apple of weight 1.5 N falling to the Earth.



(i) Underline the correct word in the brackets to describe force Y. [2]

Force Y is the (**gravitational / magnetic / mass**) force of the apple on the (**air / Earth / Moon**).

(ii) State how the two forces, X and Y, compare. [1]

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(iii) Use an equation from page 2 to calculate the mass of the apple. [2]
(g = 10 N/kg = 10 m/s^2)

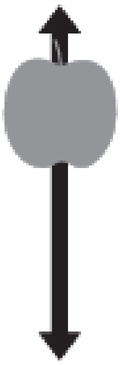
mass = ... kg

(b) The apple is dropped from rest.

(i) State the initial acceleration of the apple. [1]

acceleration = ... m/s^2

(ii) At some time later in the fall, the air resistance acting on the apple is 0.25 N.



Determine the size of the resultant force acting on the apple. [1]

resultant force = ... N

(iii) Use the equation:

resultant force = mass × acceleration

to calculate the new acceleration of the apple. [3]

acceleration = ... m/s^2

c) The Apollo 15 astronaut David Scott performed an experiment on the Moon, where there is no air.
He predicted that if a hammer and a feather were dropped together from the same height, they would hit the Moon's surface at the same time.
Explain whether you agree with this prediction. [2]

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Separate – Physics 2022 Q7 part a

(a) State Newton's **three** laws of motion **and** explain how they each apply to the motion of skydivers from when they first jump from a plane until they first reach terminal speed. [6 QER]

End of Questions