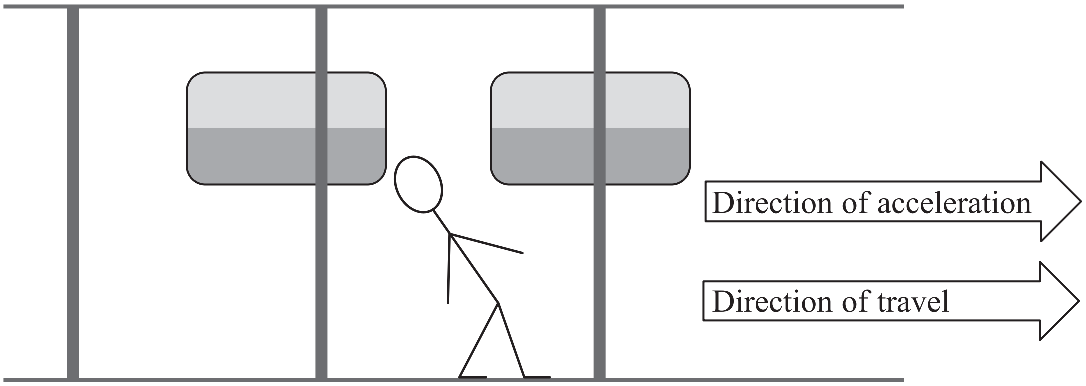
1 A passenger is standing in a train.

(a) The train accelerates and he falls backwards.



Use Newton's first law of motion to explain why he falls backwards.

(3)

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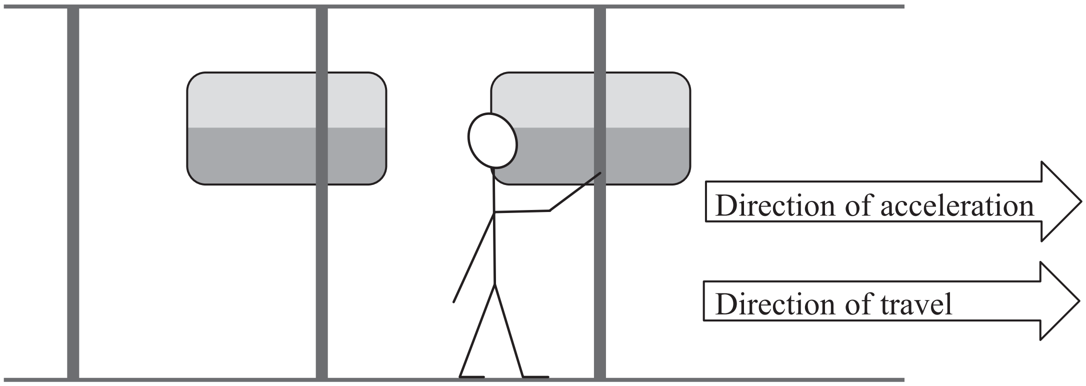
*(b) As the train leaves the next station the passenger holds on to a vertical support as the train accelerates. This prevents the passenger falling backwards.



With reference to Newton's laws of motion, explain why holding on to a vertical support prevents the passenger falling backwards.

(5)

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(Total for Question 8 marks)

2 Metrology is the science of measurement and World Metrology Day is May 20th. In 2010, the day was used to celebrate the 50th anniversary of the SI system.

A metrologist from the National Physical Laboratory said on a radio programme that the SI system uses units that everyone can understand. He stated the following example.

> "If you hold an apple in your hand it's about a *newton*, if you raise it through one metre that's about a *joule* and if you do it in one second that's about a *watt*."

Assuming that the apple has a mass of 100 g, explain and justify the statements made about the three words in italics.

(6)

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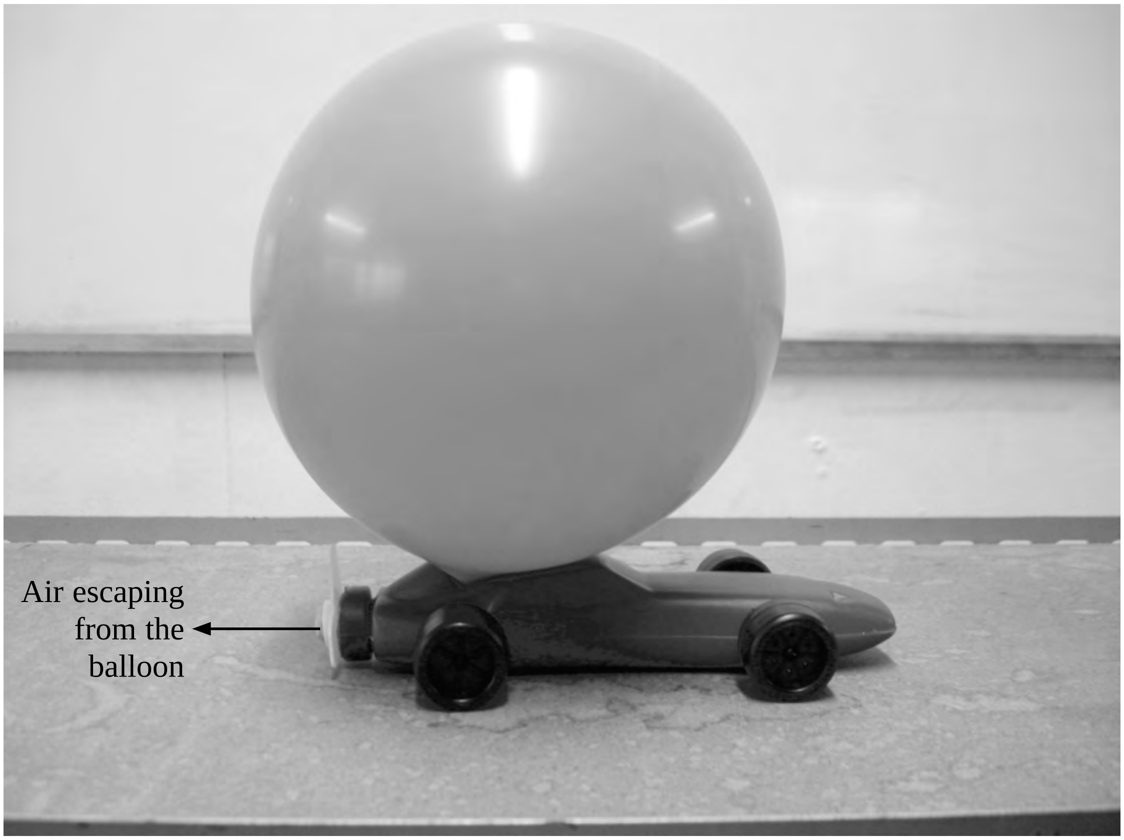
(Total for Question 6 marks)

3 The photograph shows a toy car driven by air from a deflating balloon.

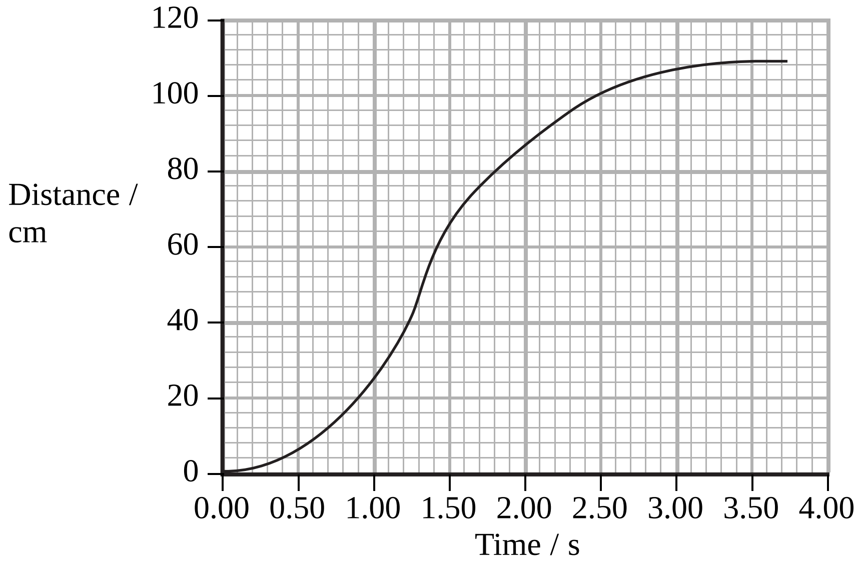


When the air in the inflated balloon is released, the car starts to move forwards.

(a) Use Newton's first and third laws of motion to explain why the air coming out of the balloon causes this.

(3)

(b) The following distance-time graph is obtained for the car.

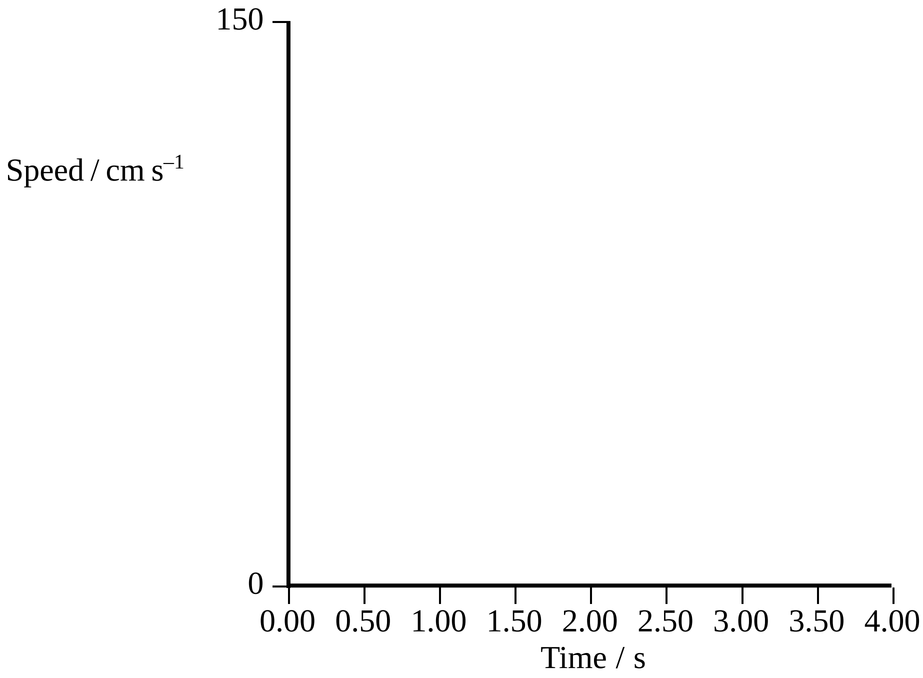


(i) Show that the maximum speed reached is between 100 and 150 cm s^{-1}.

(3)

(ii) Sketch the shape of the corresponding speed-time graph on the axes below.

(3)

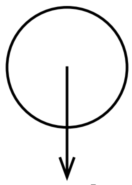


(Total for Question = 9 marks)

4 A science centre houses a display with tall, transparent tubes of different liquids.
Visitors can pump air into the bottom of the tubes to create bubbles that rise to the top at different steady speeds.

(a) (i) Add labelled arrows to the diagram to show the other two forces acting on a bubble as it rises through a liquid.

(2)



(ii) With reference to the forces on the bubble, explain why the bubble initially accelerates and then reaches a steady upwards speed.

(4)

(iii) Write an expression which relates these forces for a bubble moving at a steady upwards speed.

(1)

(b) If the weight of the air in the bubble is ignored, the steady upwards speed is given by

$$v \quad \frac{2\rho r^2 g}{9\eta}$$

Where ρ is the density of liquid, r is the radius of the sphere and η is the coefficient of viscosity of the liquid.

(i) Explain why it is reasonable to ignore the weight of the air.

(2)

(ii) Explain what happens to the speeds of the observed bubbles if the temperature of the liquid increases.

(2)

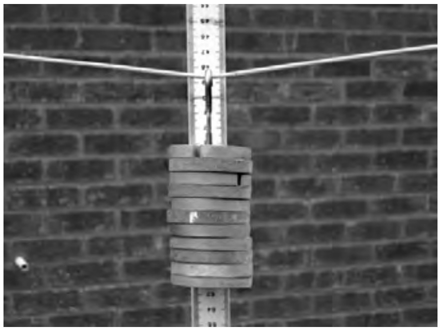
(iii) It is possible to create a small bubble followed by a larger bubble.

Use the expression to explain why the larger bubble catches up with the smaller one.

(1)

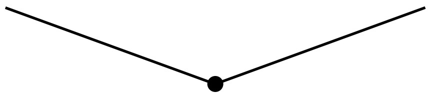
(Total for Question = 12 marks)

5 A washing line has a negligible mass and is initially horizontal. A student investigates the effect of hanging masses from the midpoint of the washing line.



(a) Add to the diagram to show the forces acting at the midpoint of the line when a mass is hung from its midpoint.

(2)



(b) A mass of 1.10 kg is hung from the midpoint of the line.

(i) Show that the downward vertical force on the line is about 11 N.

(1)

(ii) This force pulls the midpoint down a distance of 48.5 cm.

Show that the line is at an angle of about 84° to the vertical.

length of washing line when horizontal = 9.600 m

(2)

(iii) Show that the tension in the line is less than 60 N.

(2)

(iv) The washing line stretches so that the total length of the line is now 9.847 m.

Calculate the strain for the line.

(2)

Strain =

(c) Calculate the value of the Young modulus for the line material.

cross-sectional area of the line = $6.6 \times 10^{-6}\,m^2$

(3)

Young modulus =

(Total for Question = 12 marks)

6 A student carried out an experiment to obtain a value for the acceleration of free fall g.

A small ball was dropped from rest and the motion of the ball was captured using a digital camera. The student counted the frames from the recording to measure the time t for the ball to fall to the ground.

A ruler was visible on the recording to enable the student to measure the distance s fallen by the ball.

(a) Use Newton's second law of motion to show that the acceleration of the ball is independent of its mass.

(1)

(b) (i) State the equation that the student should use to calculate the value of g.

(1)

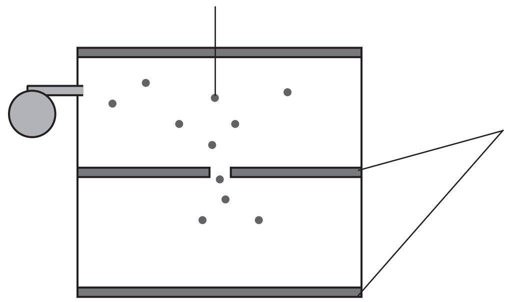
(ii) A value for g was obtained and was greater than expected.

Explain **one** possible source of error that would have produced a greater than expected value.

(2)

(Total for Question = 4 marks)

7 In 1909 Robert Millikan did an experiment to find the charge on an electron. Tiny charged oil drops were dropped between two charged plates.



The radius of an oil drop had to be determined so that its weight could be calculated.

Before the plates were charged, Millikan observed how long it took for an oil drop to fall through the air between two fixed points. The terminal velocity and hence the radius could then be calculated.

(a) (i) Complete the free-body force diagram below for an oil drop falling freely through the air.

(2)

(ii) Explain why the oil drop reaches a terminal velocity.

(2)

(b) An oil drop is travelling at terminal velocity.

(i) The oil drop takes 11.9 s to fall a distance of 10.2 mm.
Show that the terminal velocity of the oil drop is about 0.001 m s^{-1}.

(2)

(ii) Assuming that the upthrust is negligible, show that the radius of the oil drop is about 3 μm.

density of oil = 920 kg m^{-3}
viscosity of air = 1.82×10^{-5} Pa s

(4)

(iii) It is very difficult to measure the radius of such an oil drop directly.
Suggest why.

(2)

(c) Explain why it was necessary for Millikan to maintain the air between the plates at a constant temperature.

(2)

(d) A student tried to model Millikan's method for finding the radius of the oil drop. The student dropped a ball bearing and recorded the time it took to pass between two light gates, a known distance apart.

Explain why this is **not** a good model for Millikan's method.

(2)

(Total for Question = 16 marks)