1)

(a) According to Aristotle (384 – 322 B.C.)

'heavier objects fall faster than lighter ones'.

Explain how one experiment carried out by Galileo (1564 – 1642) overturned Aristotle's ideas of motion.

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..... **[3]**

(b) Fig. 2.1 shows an arrangement used in the laboratory to determine the acceleration *g* of free fall.

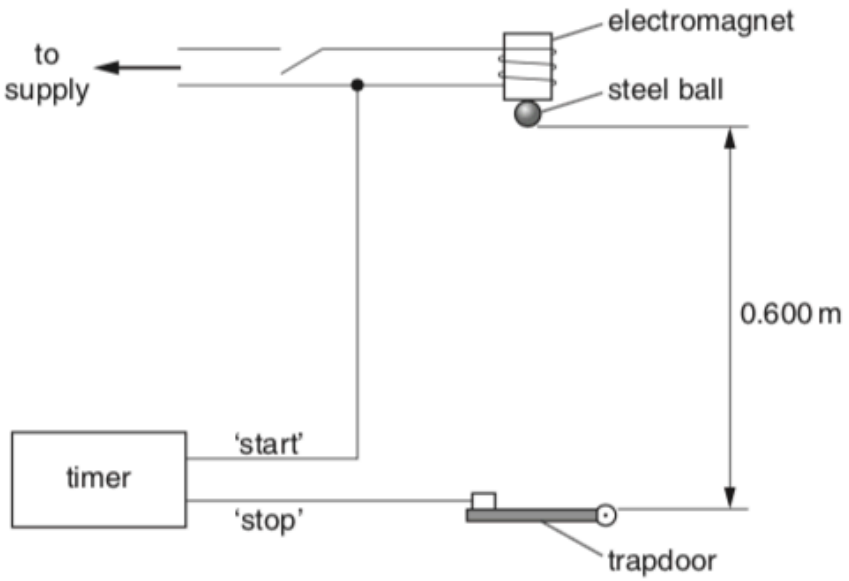

Fig. 2.1

The steel ball is held at rest by an electromagnet. When the electromagnet is switched off, the electronic timer is started and the ball falls. The timer is stopped when the ball opens the trapdoor. The distance between the bottom of the ball and the top of the trapdoor is 0.600 m. The timer records a time of fall of 0.356 s.

(i) Show that the value for the acceleration g of free fall obtained from this experiment is $9.47\,m\,s^{-2}$.

[2]

(ii) State **one** reason why the experimental value in **(i)** is less than $9.81\,m\,s^{-2}$.

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..... **[1]**

(iii) On Fig. 2.2 sketch a graph to show the variation of the vertical distance s fallen by the ball with time t.

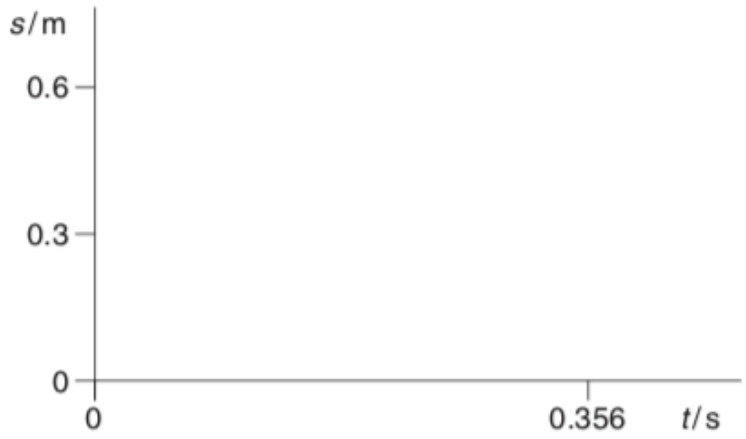

Fig. 2.2

[1]

[Total: 7]

2)

(a) State two factors that affect the magnitude of the drag force acting on an object falling through air.

1. .....

2. ..... **[2]**

(b) Fig. 4.1 shows a skydiver of total mass 75 kg falling vertically towards the ground.

Fig. 4.1

The air resistance, or drag force, D in newtons (N) acting on the skydiver falling through the air is given by the equation

$$D = 0.3v^2$$

where v is the speed in $m\,s^{-1}$ of the skydiver.

(i) On Fig. 4.1, draw arrows to represent the weight (labelled W) and drag force (labelled D). **[1]**

(ii) Calculate the weight of the skydiver.

weight = ... N **[1]**

(iii) At a particular instant, the speed of the skydiver is $20\,m\,s^{-1}$. Calculate the instantaneous acceleration of the skydiver.

acceleration = ... $m\,s^{-2}$ **[3]**

(iv) State the relationship between the forces *W* and *D* when the skydiver reaches terminal velocity.

.....

..... **[1]**

(v) Determine the terminal velocity of the skydiver.

terminal velocity = ... $m\,s^{-1}$ **[2]**

[Total: 10]

3)

(a) A student conducts an experiment to estimate the acceleration g of free fall by dropping a heavy metal ball from a high wall into a sandpit below. Describe how this student can estimate the acceleration g of free fall. Your description should include:

- the measurements taken
- the instruments used to take the measurements
- how the measurements are used to estimate g
- an explanation of why the value for g is only an estimate

In your answer, you should use appropriate technical terms, spelled correctly.

..... **[7]**

4)

A skydiver jumps from a stationary hot-air balloon several kilometres above the ground.

(a) In terms of acceleration and forces, explain the motion of the skydiver

immediately after jumping .....

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at a time **before** terminal velocity is reached .....

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at terminal velocity. .....

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..... **[6]**

(b) In the final stage of the fall, the skydiver is falling through air at a constant speed. The skydiver's kinetic energy does not change even though there is a decrease in the gravitational potential energy. State what happens to this loss of gravitational potential energy.

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..... **[1]**

(c) Fig. 3.1 shows a sketch graph of the variation of the velocity v of the skydiver with time t.

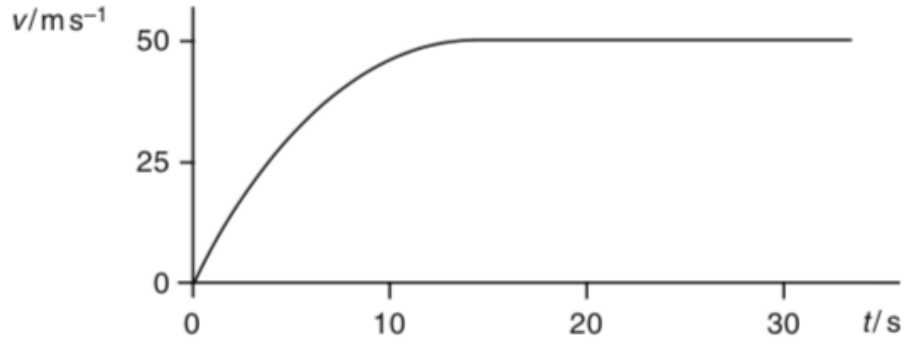

Fig. 3.1

Suggest the changes to the graph of Fig. 3.1, if any, for a more massive (heavier) skydiver of the same shape.

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..... **[2]**

[Total: 9]

5)

Fig. 4.1 shows a metal ball held stationary above a tube containing oil.

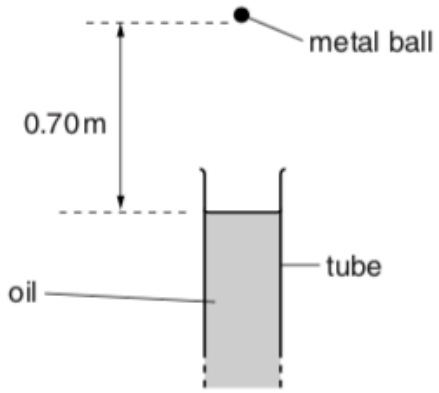
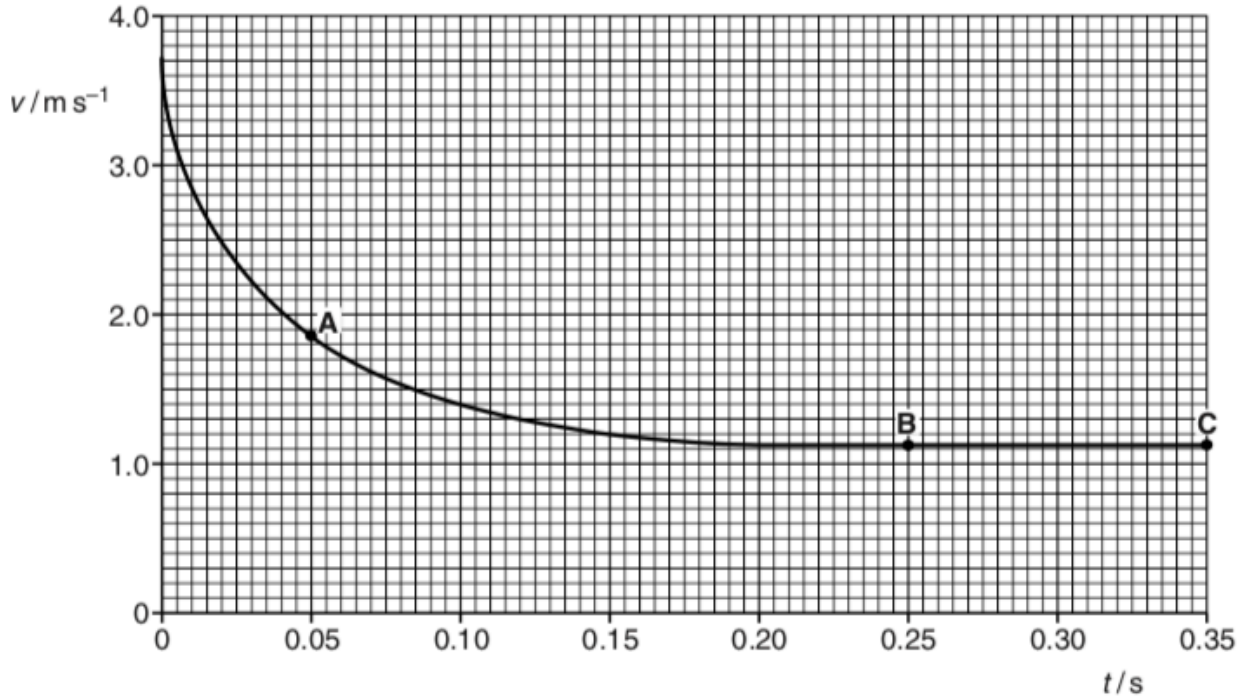


Fig. 4.1

(a) The ball is 0.70 m above the surface of the oil in the tube. Calculate the time taken for the ball to reach the surface of the oil when it is dropped from this height. Assume air resistance has negligible effect on the motion of the ball.

time = ... s **[3]**

(b) Fig. 4.2 shows the graph of velocity v against time t for the ball as it travels through the oil. The ball enters the oil at time $t = 0$.



(i) Complete the sentence below.

The gradient of the graph is equal to the ..... of the ball and

the area under the graph is equal to the ..... . **[1]**

(ii) Use Fig. 4.2 to determine the magnitude of the deceleration of the ball at time $t = 0.05\,s$ (point **A**). Show your working.

deceleration = ... $m\,s^{-2}$ **[3]**

(iii) In terms of the **forces** acting on the ball, describe and explain its motion when

1 time $t = 0.05\,s$ (point **A**)

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2 time $t = 0.25\,s$ (point **B**).

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[4]

(iv) Describe the energy transfers taking place between $t = 0.25\,s$ and $t = 0.35\,s$ (point **B** to **C**).

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..... **[1]**

[Total: 12]

6)

(a) The drag force F acting on a car travelling at a speed v is given by the equation

$$F = kAv^2$$

where A is the area of the front of the car.

Show that a suitable unit for the quantity k is kg m^{-3}.

[2]

(b) A table tennis ball experiences drag as it travels through the air. Fig. 6.1 shows the ball in three different situations, **A**, **B** and **C**.

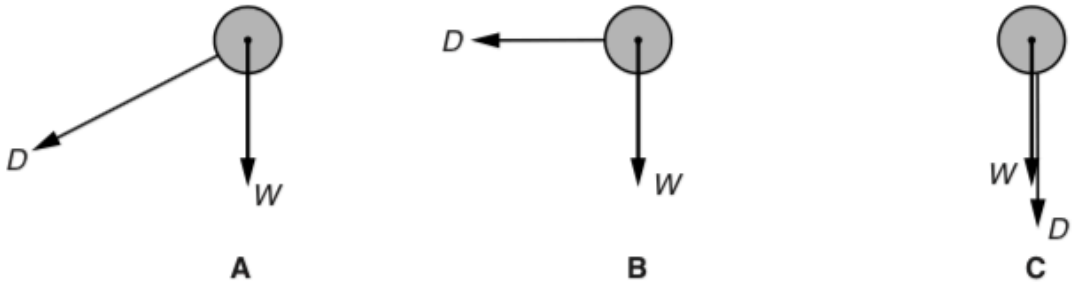

Fig. 6.1

The ball has weight W and the drag force is D.

(i) On Fig. 6.1 draw an arrow to show the **direction** of travel of the ball in situation **A**. **[1]**

(ii) In situation **B** the magnitude of the weight and the drag are the same.

Explain whether or not the ball is travelling at its terminal velocity.

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..... **[1]**

(iii) Describe and explain the motion of the ball in situation **C**.

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..... **[2]**

(c) Fig. 6.2 shows a DVD held above the ground.

Fig. 6.2

The DVD is dropped from rest. The circular face remains horizontal as it falls. The DVD does not reach terminal velocity before it hits the ground.

Describe and explain how the acceleration of the DVD varies from the instant it is dropped until just before it hits the ground.

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..... **[4]**

7)

(a) State how the magnitude of the drag force on an object is affected by its speed.

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..... **[1]**

(b) Describe the experiments Galileo carried out which overturned Aristotle's ideas of motion.

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..... **[3]**

(c) A skydiver is falling towards the ground at a terminal velocity of $50\,m\,s^{-1}$.

(i) State the **two** main forces acting on the skydiver and how they are related at terminal velocity.

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..... **[1]**

(ii) The skydiver opens her parachute. After some time, the skydiver reaches a lower terminal velocity of $4.0\,m\,s^{-1}$. Describe and explain how the magnitude of the deceleration of the skydiver changes as her velocity reduces from $50\,m\,s^{-1}$ to $4.0\,m\,s^{-1}$.

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..... **[4]**

[Total: 9]