A Level · OCR · Physics

48 mins · 4 questions

Structured Questions

Dynamics

Force & Acceleration / Weight / Tension, Normal force, Upthrust & Friction / Motion in One & Two Dimensions / Drag Forces / Terminal Velocity / Investigating Terminal Velocity

Medium (3 questions)	/35
Hard (1 question)	/13
Total Marks	**/48**

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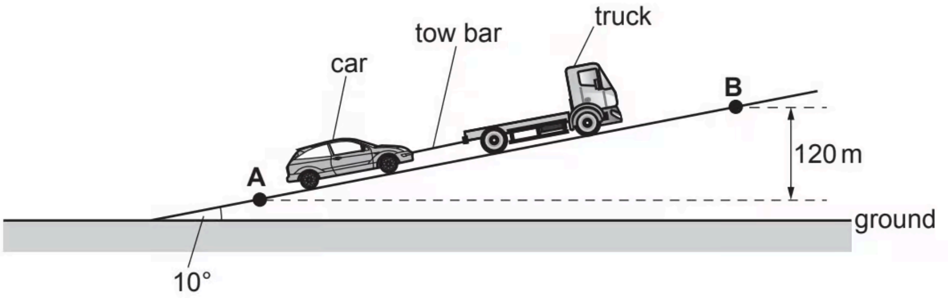
Medium Questions

1 (a) A truck pulls a car up a slope at a **constant** speed.

The truck and the car are joined with a steel tow bar, as shown in the diagram.

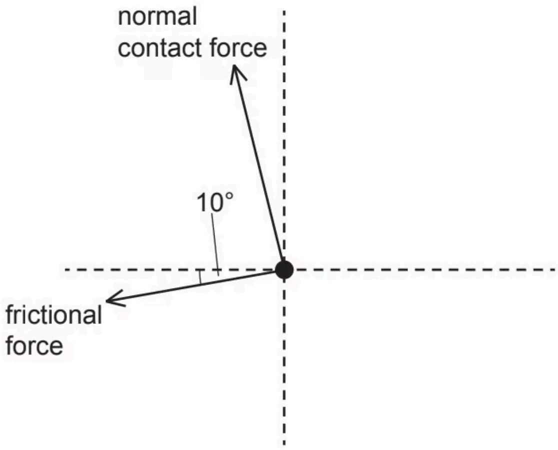


The diagram is **not** drawn to scale.

The slope is 10° to the horizontal ground. The mass of the car is 1100 kg. The car travels from **A** to **B**. The vertical distance between **A** and **B** is 120 m.

There are four forces acting on the **car** travelling up the slope.

Complete the free-body diagram below for the car and label the missing forces.



(2 marks)

(b) Show that the component of the weight of the car W_S acting down the slope is about 1900 N.

(1 mark)

(c) The total frictional force acting on the car as it travels up the slope is 300 N.

Calculate the force provided by the tow bar on the car.

force = ... N

(1 mark)

(d) Calculate the work done by the force provided by the tow bar as the car travels from **A** to **B**.

work done = ... J

(3 marks)

(e) The steel tow bar used to pull the car has length 0.50 m and diameter 1.2×10^{-2} m. The Young modulus of steel is 2.0×10^{11} Pa.

Calculate the extension x of the tow bar as the car travels up the slope.

x = ... m

(3 marks)

2 (a) A student uses a motion-sensor connected to a laptop to investigate the motion of a hollow ball of mass 1.2×10^{-2} kg falling through air.

The ball is dropped from rest. It reaches terminal velocity before it reaches the ground.

The upthrust on the ball is negligible.

Fig. 17 shows the variation with time *t* of the velocity *v* of the ball as it falls towards the ground.

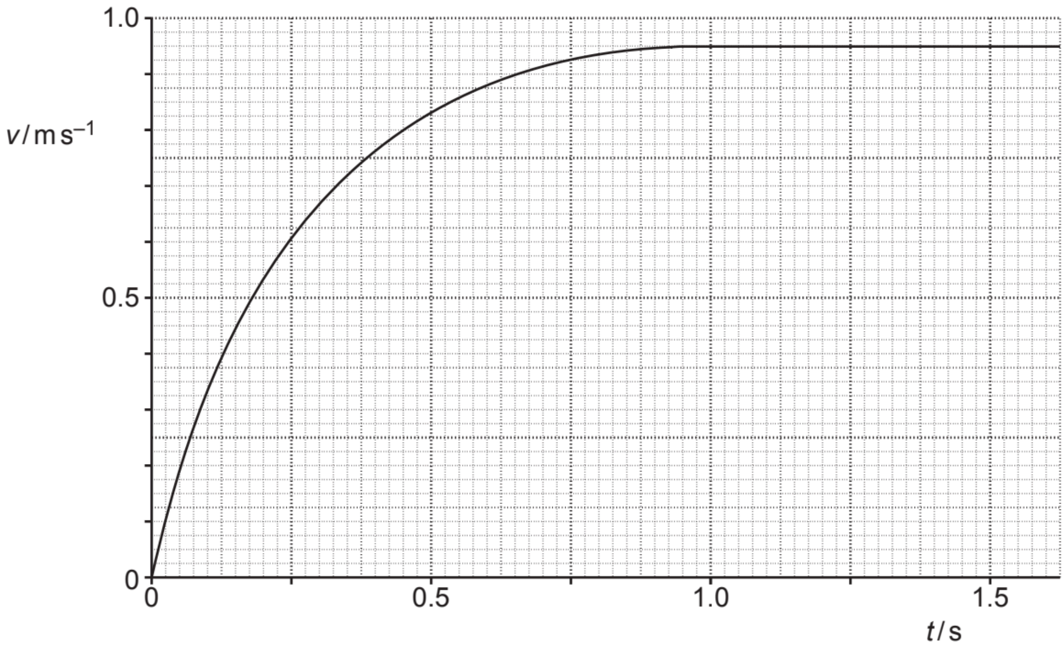


Fig. 17

Draw a tangent to the curve at t = 0.25 s and determine the acceleration of the ball.

acceleration = ... ms^{-2}

....

....

....

(3 marks)

(b) Calculate the resultant force F acting on the ball at t = 0.25 s.

F = ... N

(1 mark)

(c) Use your answer in **(b)** to calculate the drag on the ball at time t = 0.25 s.

drag = ... N

(3 marks)

(d) The student now adds a small amount of sand inside the hollow ball.

As before, the ball is dropped from rest and it also reaches terminal velocity before it reaches the ground.

i) Describe how the forces acting on the sand-filled ball at v = 0.50 ms^{-1} compare with the forces acting on the hollow ball at this speed.

[2]

ii) Explain why the terminal velocity of the sand-filled ball will be greater than the terminal velocity of the hollow ball.

[2]

(4 marks)

3 (a) A swimming pool designer investigates the depth *d* below a water surface reached by a diver when diving from a height *h* above the water surface. The designer models the diver as a uniform wooden cylinder. The experimental arrangement is shown in Fig. 18.1.

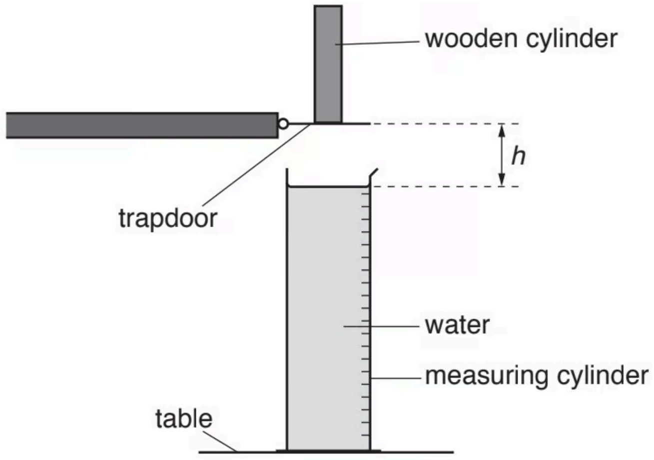


Fig. 18.1

The wooden cylinder has mass 5.0×10^{-3} kg, diameter 1.0×10^{-2} m and length 7.0×10^{-2} m.

i) Calculate the density of the wood.

density = ... kg m^{-3} **[2]**

ii) Suggest why wood is an appropriate material to model the depth reached by a diver.

[2]

....

....

....

....

(4 marks)

(b) The cylinder is released from rest from a trapdoor. The base of the cylinder is at a height h = 0.30 m above the water surface. Calculate the speed of the cylinder just before the base hits the water. Ignore air resistance.

speed = ... m s^{-1}

(2 marks)

(c) Fig. 18.2 shows the cylinder fully submerged under the water surface before it has come to rest. The cylinder is moving vertically **down**.

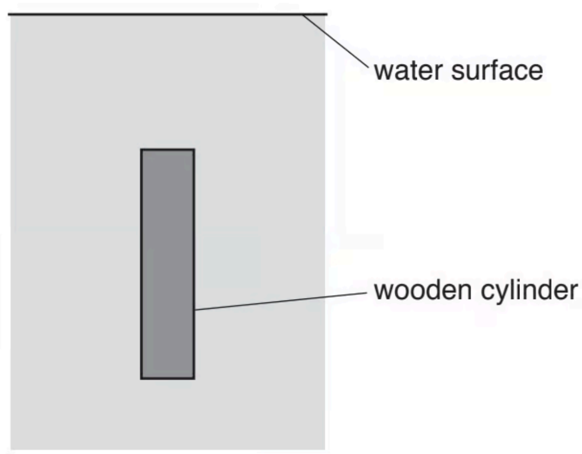


Fig. 18.2

i) Add arrows to Fig. 18.2 to show the **three** forces acting on the wooden cylinder. Label the arrows.

[3]

ii) Describe and explain how the **resultant** force on the wooden cylinder varies from the moment the cylinder is fully submerged until it reaches its deepest point.

[3]

(6 marks)

(d) The graph of Fig. 18.3 shows the depth d reached for different initial drop height h.

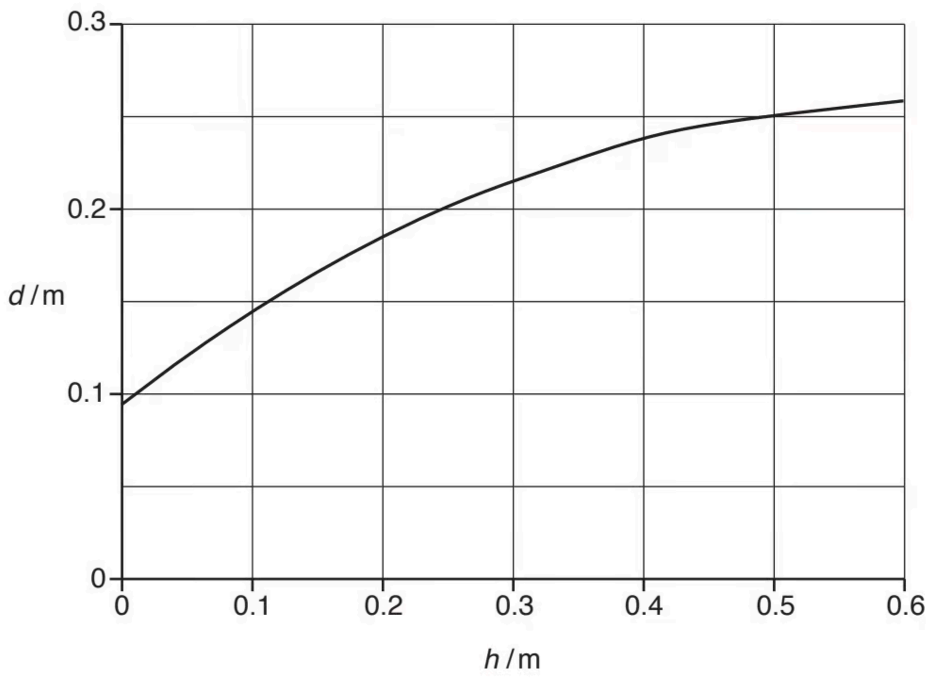


Fig. 18.3

The designer is required to double the height of a diving board for an existing swimming pool.

He suggests that the depth of the pool also needs to be doubled.

Use Fig. 18.3 to explain whether you agree with this suggestion.

(2 marks)

Hard Questions

1 (a) A toy rocket is made from a 1.5 litre plastic bottle with fins attached for stability.

The bottle initially contains 0.30 litres of water, leaving 1.2 litres of trapped air at a temperature of 17°C.

A pump is used to increase the pressure of the air within the plastic bottle to 2.4×10^5 Pa at the start of lift-off.

Fig. 1.1 shows the rocket at the start of lift-off.

1 litre = $10^{-3} m^3$

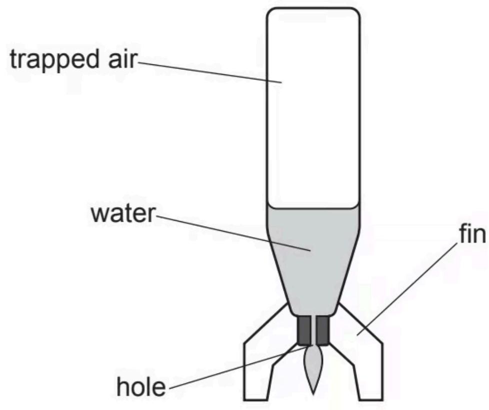


Fig. 1.1

Calculate, in moles, the amount of trapped air in the bottle at the start of lift-off.

amount of air = ... mol

(2 marks)

(b) The trapped air pushes the water downwards out of the hole, causing the rocket to rise.

The temperature of this air remains constant.

Calculate the final pressure of the trapped air just before all the water has been released.

final pressure = ...Pa

(3 marks)

(c) Here is some data on the toy rocket.

mass of empty bottle and fins = 0.050 kg

area of cross-section of hole = 1.1×10^{-4} m^2

initial pressure of trapped air = 2.4×10^5 Pa

atmospheric pressure = 1.0×10^5 Pa

density of water = 1.0×10^3 kgm^{-3}

i) Use the data above to show that the **upwards** force on the rocket at the start of lift-off is about 15 N.

[2]

ii) Hence calculate the initial vertical acceleration of the rocket.

initial acceleration = ... ms^{-2} **[3]**

(5 marks)

(d) Discuss whether adding more water initially would enable the rocket to reach a greater height.

(3 marks)