

Newton's Laws of Motion

Question paper 3

Level	International A Level
Subject	Physics
Exam Board	CIE
Topic	Dynamics
Sub Topic	Newton's Laws of Motion
Paper Type	Theory
Booklet	Question paper 3

Time Allowed: 80 minutes

Score: /66

Percentage: /100

A*	A	B	C	D	E	U
>85%	77.5%	70%	62.5%	57.5%	45%	<45%

1 Two balls X and Y are supported by long strings, as shown in Fig. 3.1.

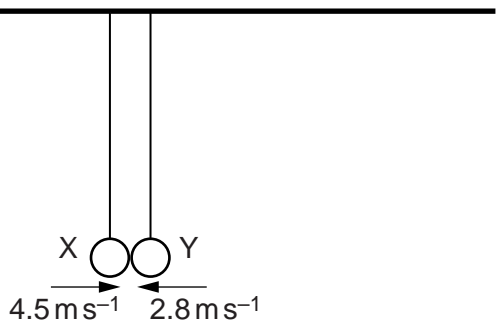


Fig. 3.1

The balls are each pulled back and pushed towards each other. When the balls collide at the position shown in Fig. 3.1, the strings are vertical. The balls rebound in opposite directions.

Fig. 3.2 shows data for X and Y during this collision.

ball	mass	velocity just before collision / ms^{-1}	velocity just after collision / ms^{-1}
X	50g	+4.5	-1.8
Y	M	-2.8	+1.4

Fig. 3.2

The positive direction is horizontal and to the right.

(a) Use the conservation of linear momentum to determine the mass M of Y.

$M = \dots\dots\dots \text{ g [3]}$

(b) State and explain whether the collision is elastic.

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

(c) Use Newton's second and third laws to explain why the magnitude of the change in momentum of each ball is the same.

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.....[3]

2 A trolley moves down a slope, as shown in Fig.

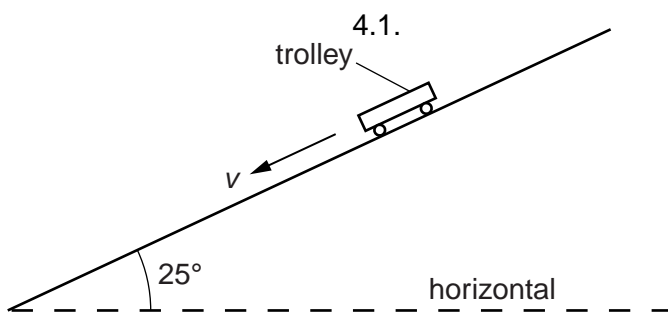


Fig. 4.1

The slope makes an angle of 25° with the horizontal. A constant resistive force F_R acts up the slope on the trolley.

At time $t = 0$, the trolley has velocity $v = 0.50 \text{ m s}^{-1}$ down the slope.

At time $t = 4.0 \text{ s}$, $v = 12 \text{ m s}^{-1}$ down the slope.

(a) (i) Show that the acceleration of the trolley down the slope is approximately 3 m s^{-2} .

[2]

(ii) Calculate the distance x moved by the trolley down the slope from time $t = 0$ to $t = 4.0 \text{ s}$.

$x = \dots\dots\dots \text{ m}$ [2]

(iii) On Fig. 4.2, sketch the variation with time t of distance x moved by the trolley.

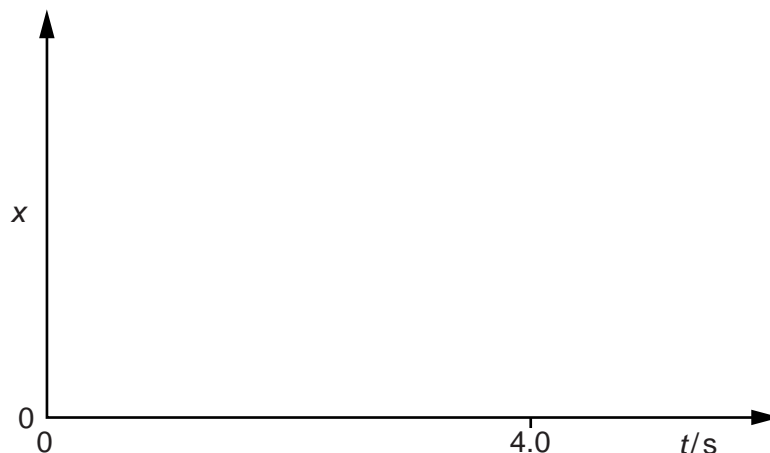


Fig. 4.2

[2]

(b) The mass of the trolley is 2.0 kg.

(i) Show that the component of the weight of the trolley down the slope is 8.3 N.

[1]

(ii) Calculate the resistive force F_R .

$F_R = \dots\dots\dots$ N [2]

3 (a) (i) Define *velocity*.

.....
 [1]

(ii) Distinguish between *speed* and *velocity*.

.....
 [2]

(b) A car of mass 1500 kg moves along a straight, horizontal road. The variation with time t of the velocity v for the car is shown in Fig. 1.1.

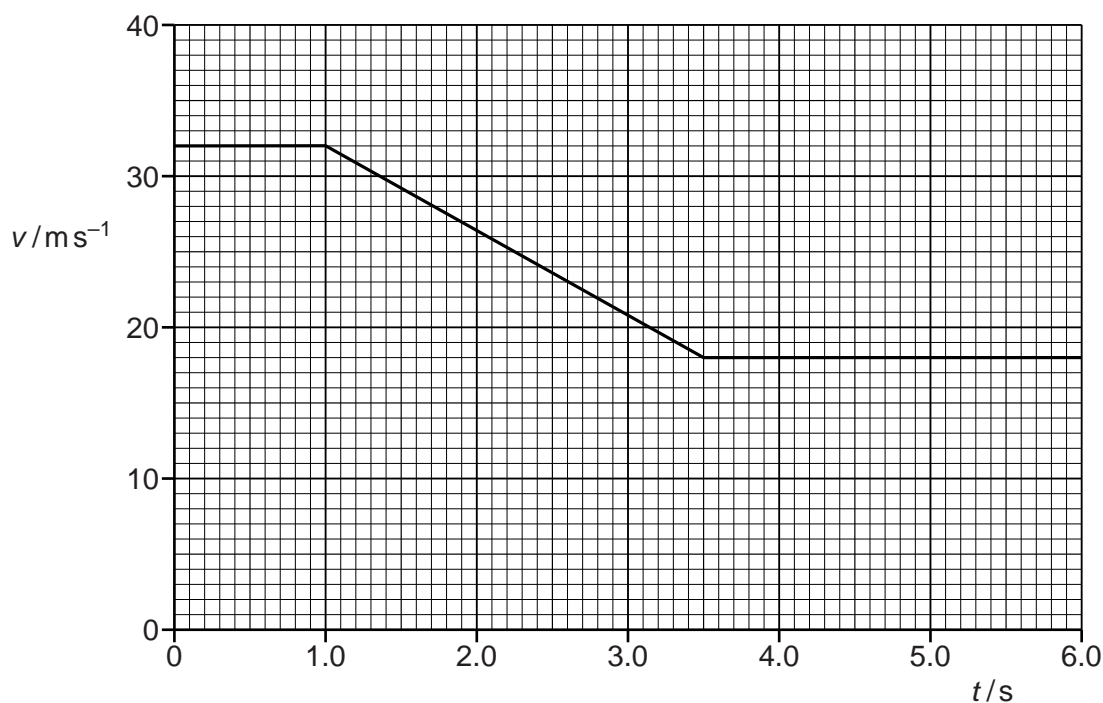


Fig. 1.1

The brakes of the car are applied from $t = 1.0$ s to $t = 3.5$ s.
 For the time when the brakes are applied,

(i) calculate the distance moved by the car,

distance = m [3]

(ii) calculate the magnitude of the resultant force on the car.

resultant force = N [3]

(c) The direction of motion of the car in (b) at time $t = 2.0\text{s}$ is shown in Fig. 1.2.

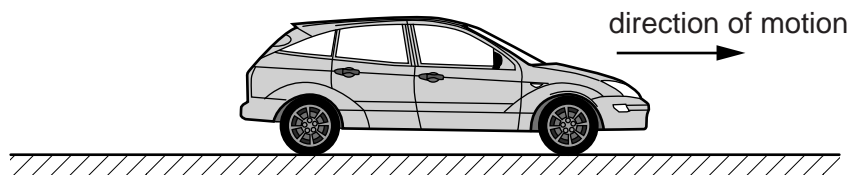


Fig. 1.2

On Fig. 1.2, show with arrows the directions of the acceleration (label this arrow A) and the resultant force (label this arrow F). [1]

- 4 (a) The drag force D on an object of cross-sectional area A , moving with a speed v through a fluid of density ρ , is given by

$$D = \frac{1}{2} C \rho A v^2$$

where C is a constant.

Show that C has no unit.

[2]

- (b) A raindrop falls vertically from rest. Assume that air resistance is negligible.

- (i) On Fig. 1.1, sketch a graph to show the variation with time t of the velocity v of the raindrop for the first 1.0s of the motion.

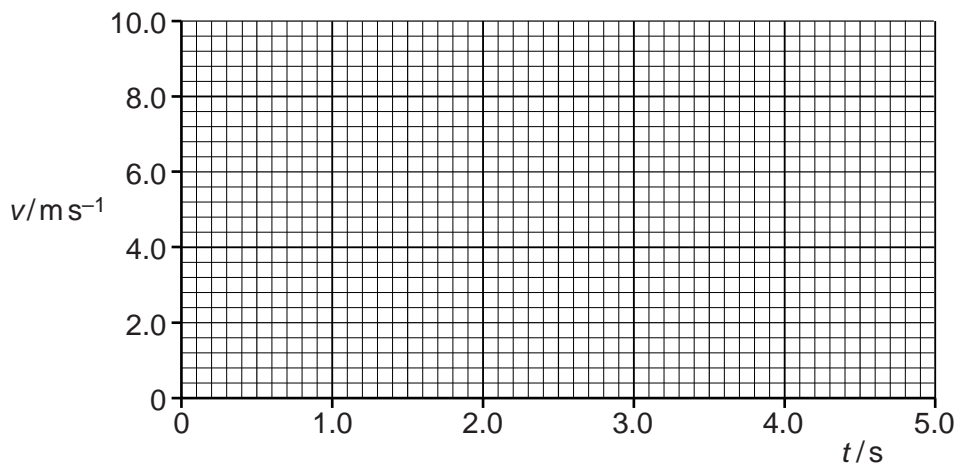


Fig. 1.1

[1]

- (ii) Calculate the velocity of the raindrop after falling 1000m.

velocity = ms^{-1} [2]

(c) In practice, air resistance on raindrops is not negligible because there is a drag force. This drag force is given by the expression in (a).

(i) State an equation relating the forces acting on the raindrop when it is falling at terminal velocity.

[1]

(ii) The raindrop has mass 1.4×10^{-5} kg and cross-sectional area 7.1×10^{-6} m². The density of the air is 1.2 kg m^{-3} and the initial velocity of the raindrop is zero. The value of C is 0.60.

1. Show that the terminal velocity of the raindrop is about 7 m s^{-1} .

[2]

2. The raindrop reaches terminal velocity after falling approximately 10 m. On Fig. 1.1, sketch the variation with time t of velocity v for the raindrop. The sketch should include the first 5 s of the motion.

[2]

- 5 An experiment is conducted on the surface of the planet Mars. A sphere of mass 0.78 kg is projected almost vertically upwards from the surface of the planet. The variation with time t of the vertical velocity v in the upward direction is shown in Fig. 2.1.

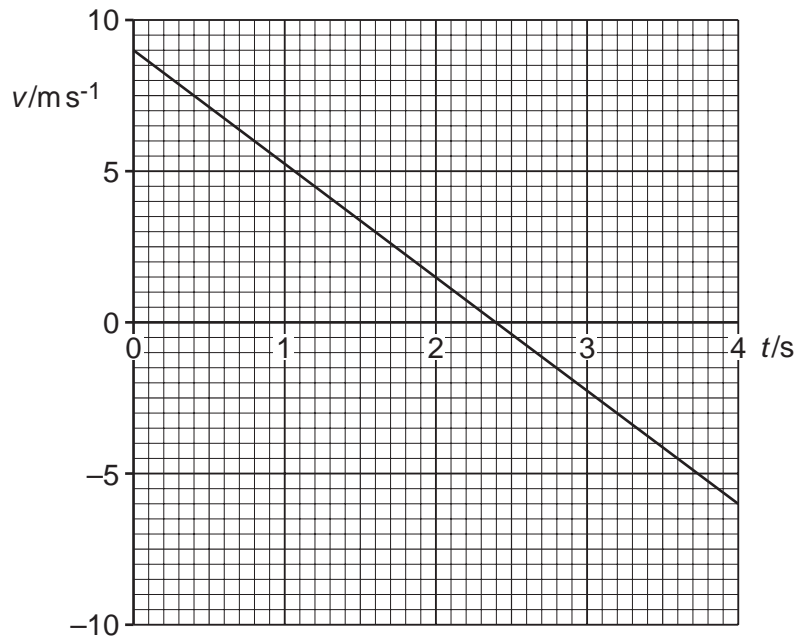


Fig. 2.1

The sphere lands on a small hill at time $t = 4.0$ s.

- (a) State the time t at which the sphere reaches its maximum height above the planet's surface.

$t = \dots\dots\dots$ s [1]

- (b) Determine the vertical height above the point of projection at which the sphere finally comes to rest on the hill.

height = $\dots\dots\dots$ m [3]

(c) Calculate, for the first 3.5 s of the motion of the sphere,

(i) the change in momentum of the sphere,

change in momentum =N s [2]

(ii) the force acting on the sphere.

force =N [2]

(d) Using your answer in (c)(ii),

(i) state the weight of the sphere,

weight =N [1]

(ii) determine the acceleration of free fall on the surface of Mars.

acceleration =ms⁻² [2]

6 (a) Distinguish between the moment of a force and the torque of a couple.

moment of a force

.....

.....

torque of a couple

.....

.....

[4]

(b) One type of weighing machine, known as a steelyard, is illustrated in Fig. 3.1.

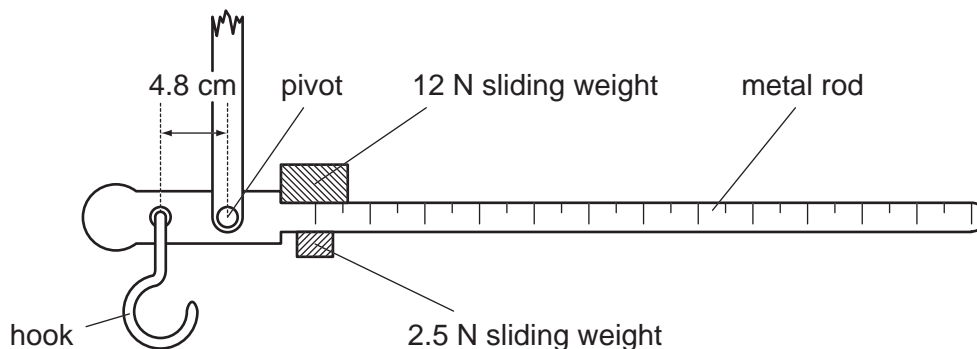


Fig. 3.1

The two sliding weights can be moved independently along the rod.

With no load on the hook and the sliding weights at the zero mark on the metal rod, the metal rod is horizontal. The hook is 4.8 cm from the pivot.

A sack of flour is suspended from the hook. In order to return the metal rod to the horizontal position, the 12 N sliding weight is moved 84 cm along the rod and the 2.5 N weight is moved 72 cm.

(i) Calculate the weight of the sack of flour.

weight =N [2]

(ii) Suggest why this steelyard would be imprecise when weighing objects with a weight of about 25 N.

.....

.....[1]

7 A shopping trolley and its contents have a total mass of 42 kg. The trolley is being pushed along a horizontal surface at a speed of 1.2 m s^{-1} . When the trolley is released, it travels a distance of 1.9 m before coming to rest.

(a) Assuming that the total force opposing the motion of the trolley is constant,

(i) calculate the deceleration of the trolley,

deceleration = m s^{-2} [2]

(ii) show that the total force opposing the motion of the trolley is 16 N.

[1]

(b) Using the answer in (a)(ii), calculate the power required to overcome the total force opposing the motion of the trolley at a speed of 1.2 m s^{-1} .

power = W [2]

- (c) The trolley now moves down a straight slope that is inclined at an angle of 2.8° to the horizontal, as shown in Fig. 3.1.

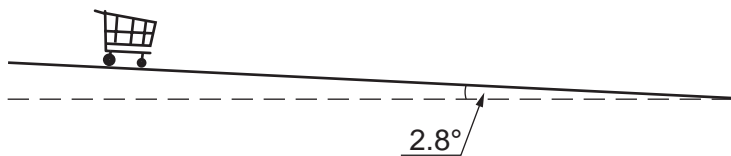


Fig. 3.1

The constant force that opposes the motion of the trolley is 16 N.

Calculate, for the trolley moving down the slope,

- (i) the component down the slope of the trolley's weight,

component of weight = N [2]

- (ii) the time for the trolley to travel from rest a distance of 3.5 m along the length of the slope.

time = s [4]

- (d) Use your answer to (c)(ii) to explain why, for safety reasons, the slope is not made any steeper.

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..... [1]