You should try to answer on your own before seeking *H-E-L-P-S*.

TOPIC *opening ....*

Question 1

(a) Define *acceleration*. [2]

(b) A body has an initial velocity u and an acceleration a. After a time t, the body has moved a distance s and has a final velocity v. The motion is summarised by the equations

$$v = u + at,$$

$$s = \tfrac{1}{2}(u+v)t.$$

(i) State the assumption made about the acceleration a in these equations.

(ii) Use the equations to derive an expression for v in terms of u, a and s. [3]

(c) A photographer wishes to check the time for which the shutter on a camera stays open when a photograph is being taken. To do this, a metal ball is photographed as it falls from rest. It is found that before the shutter opens, the ball falls 2.50 m from rest and, during the time that the shutter remains open, the ball falls a further 0.12 m, as illustrated in Fig. 2.1.

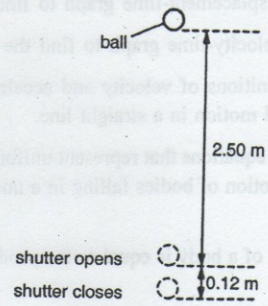


Fig. 2.1

Assuming that air resistance is negligible, calculate

(i) the speed of the ball after falling 2.50 m,

(ii) the time to fall the further 0.12 m.

[You may wish to use an equation of the form $x = \dfrac{-b \pm \sqrt{b^2 - 4ac}}{2a}$].

(iii) The time for which the shutter stays open is marked on the camera as 1/60 s. Comment on whether the test confirms this time. [6]

[D99/P2/Q2]

Suggested Solution:

(a) *Acceleration* is defined as the rate of change of velocity.

(b) (i) The acceleration a is assumed to be constant over the time t.

(ii) $v = u + at \quad \Rightarrow \quad t = \dfrac{v-u}{a}$

$\therefore \quad s = \tfrac{1}{2}(u+v)t = \tfrac{1}{2}(u+v)\left(\dfrac{v-u}{a}\right)$

$\Rightarrow \quad 2as = (u+v)(v-u) \quad \Rightarrow \quad 2as = v^2 - u^2 \quad \Rightarrow \quad v^2 = u^2 + 2as$

(c) (i) $v^2 = u^2 + 2as \Rightarrow v = \sqrt{0^2 + 2(9.81)(2.50)} = 7.00 \text{ ms}^{-1}$

(ii) $v = u + at$

$\therefore \quad s = \frac{1}{2}(u+v)t = \frac{1}{2}(u+u+at)t = \frac{1}{2}(2u+at)t = ut + \frac{1}{2}at^2$

$\Rightarrow \quad \frac{1}{2}at^2 + ut - s = 0$

Solving for t,

$$t = \frac{-u \pm \sqrt{u^2 - 4(\frac{1}{2}a)(-s)}}{2(\frac{1}{2}a)} = \frac{-u \pm \sqrt{u^2 + 2as}}{a} = \frac{-7 \pm \sqrt{7^2 + 2(9.81)(0.12)}}{9.81}$$

$\therefore \quad t = 0.0169$ s (negative answer is inadmissible)

(iii) The time marked on the camera $= \frac{1}{60}$ s $= 0.0167$ s (correct to 3 S.F.)

The value agrees with the value of the time interval between the opening and closing of the shutter that calculated in (c)(ii). Hence the test confirms this time.

(c) (i) Ball falls from rest, $u = 0$. Ball accelerates under the force of gravity, $a = g$.

(ii) For this case where the ball falls a further distance of 0.12 m,

u = speed of ball when shutter opens

$= 7.00 \text{ ms}^{-1}$

Question 2

Statistics for road traffic accidents are sometimes interpreted as showing that many occur as a result of speeding or tiredness of the driver. As a result, some countries have introduced laws to limit the speed at which vehicles may travel and also the length of time a person may drive without a rest.

In order to enforce these laws, some types of vehicle are fitted with tachographs. A tachograph records, on a circular chart, amongst other information, the times at which the vehicle is being driven, together with its speed. One such chart from a lorry tachograph is illustrated in Fig. 9.1.

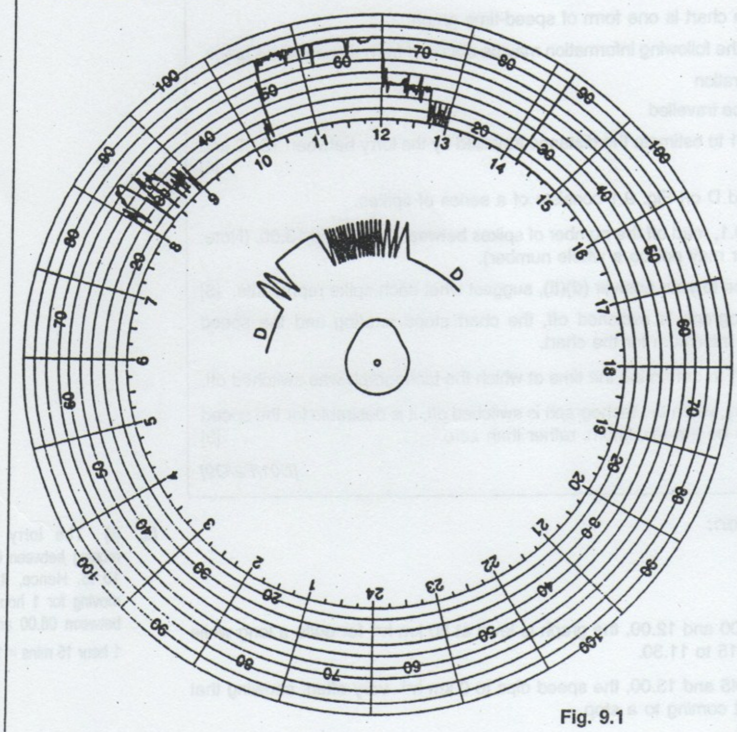


Fig. 9.1

The time of day, using the 24-hour clock, is shown on the inner scale. Each concentric circle represents a speed measured in kilometers per hour (km h⁻¹). For example, at time 12.15, the lorry was travelling at 40 km h⁻¹.

(a) Use Fig. 9.1 to determine

(i) the speed of the lorry at 11.30,

(ii) the length of time for which the lorry was not moving between 08.00 and mid-day (12.00). [2]

(b) Suggest what evidence is provided between the times 08.00 and 13.00 on Fig. 9.1 for

(i) some device on the lorry which limits its maximum speed,

(ii) the lorry being in a congested area with heavy traffic between 12.45 and 13.00. [3]

(c) Fig. 9.2 shows data for a particular journey.

time of day	activity
16.00 – 18.00	resting
18.00	accelerates to 40 km h^{-1}
18.00 – 18.30	continues at 40 km h^{-1}
18.30	accelerates to 65 km h^{-1}
18.30 – 19.10	continues at 65 km h^{-1}
19.10	stops

Fig. 9.2

On Fig. 9.1, draw the trace which would be produced for this journey. [3]

(d) The tachograph chart is one form of speed-time graph.

(i) State how the following information may be obtained from a speed-time graph.

1. acceleration
2. distance travelled

(ii) Use Fig. 9.1 to estimate the distance travelled by the lorry between 12.00 and 13.00. [4]

(e) The line labelled D on Fig. 9.1 consists of a series of spikes.

(i) From Fig. 9.1, read off the number of spikes between 12.00 and 13.00. (Note: this number may not be a whole number).

(ii) By reference to your answer (d)(ii), suggest what each spike represents. [3]

(f) When the tachograph is switched off, the chart stops rotating and the speed recorded is the maximum for the chart.

(i) Use Fig. 9.1 to determine the time at which the tachograph was switched off.

(ii) Suggest why, when the tachograph is switched off, it is desirable for the speed recorded to be the maximum, rather than zero. [3]

[D01/P2/Q9]

Suggested Solution:

(a) (i) 80 km h⁻¹

(ii) 1.25 hours

(b) (i) Between 11.00 and 12.00, the graph is level at 80 km h⁻¹ for quite a long while e.g. from 11.15 to 11.30.

(ii) Between 12.45 and 13.00, the speed dips to 0 km h⁻¹ very often, showing that the lorry kept coming to a stop.

(a) (ii) The lorry was [illegible] moving between 09.00 and 10.15. Hence, it was not moving for 1 hour 15 m[illegible] between 08.00 and 12.0[illegible]

1 hour 15 mins = 1.25 hours

(c)

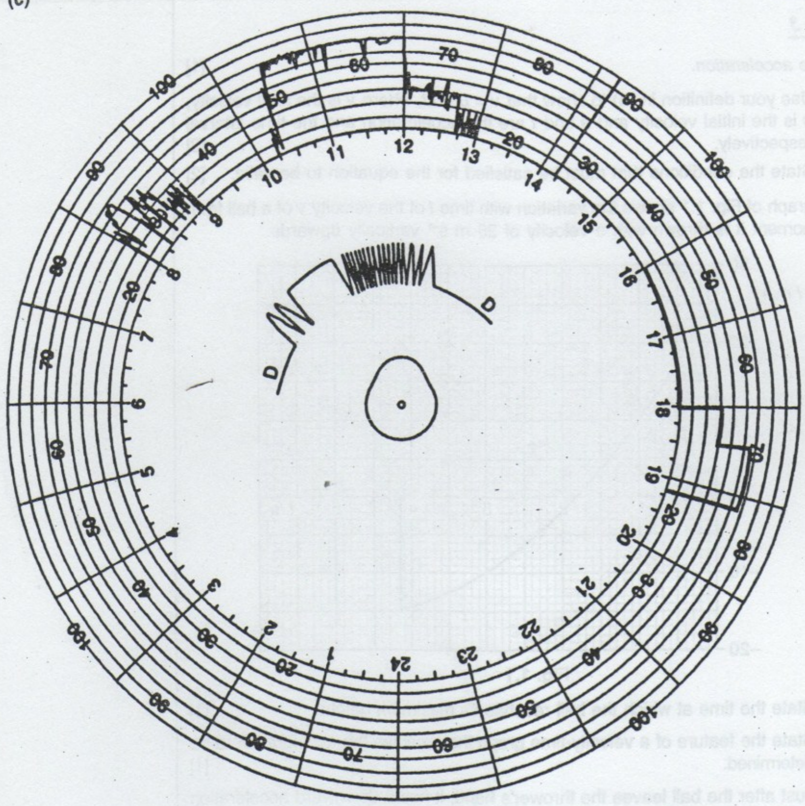


Fig. 9.1

(d) (i) 1. Gradient

2. Area under the speed-time graph.

(ii) Estimated distance travelled = $\frac{3}{4}$hr × 40 km h^{-1} = 30 km

(d) (ii) Between 12.00 and 13.00, the lorry is travelling at speeds close to 40 kmh^{-1} for approximately the first $\frac{3}{4}$ of the hour. For the rest of the hour, it keeps stopping and travelling at low speeds as shown by the spikes on the tachograph.

(e) (i) 3

(ii) Each spike could represent a certain distance being covered by the lorry, eg. 10 km.

(f) (i) 14.13

(ii) It is desirable for the speed recorded to be maximum, rather than zero so that one may know the highest speed at which the lorry was driven, even when the tachograph is switched off.

Question 3

(a) Define *acceleration*. [1]

(b) (i) Use your definition in **(a)** to show that $v = u + at$, where v is the final velocity, u is the initial velocity and a and t are the acceleration and the time interval respectively. [2]

(ii) State the conditions that must be satisfied for the equation to be valid. [2]

(c) The graph of Fig. 1.1 shows the variation with time t of the velocity v of a ball from the moment it is thrown with a velocity of 25 m s^{-1} vertically upwards.

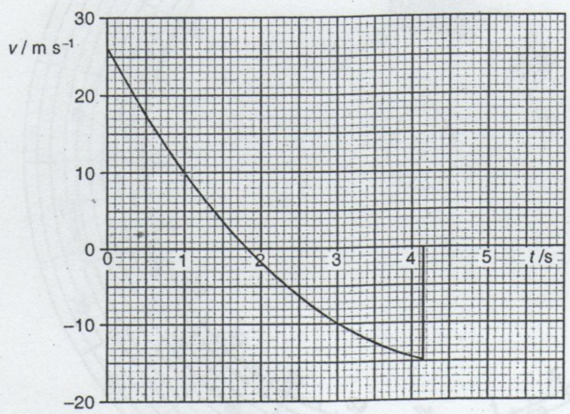


Fig. 1.1

(i) State the time at which the ball reaches its maximum height. [1]

(ii) State the feature of a velocity-time graph that enables the acceleration to be determined. [1]

(iii) Just after the ball leaves the thrower's hand, it has a downward acceleration of approximately 20 ms^{-2}. Explain how this is possible. [2]

(iv) State the time at which the acceleration is g. Explain why the acceleration has this value only at this particular time. [2]

(v) Sketch an acceleration-time graph for the motion. Show the value of g on the acceleration axis. [3]

(d) Explain why, for all real vertical throws, the time taken to reach maximum height must be shorter than the time taken to return to the starting point. [2]

(e) The ball in **(c)** starts with kinetic energy of 54 J.

(i) Calculate the mass of the ball.

(ii) Describe qualitatively how the amount of kinetic energy changes during the motion. [4]

[D03/P3/Q1]

Suggested Solution:

(a) *Acceleration* is defined as the rate of change of velocity.

(b) (i) $a = \frac{\text{change in velocity}}{\text{time interval}} = \frac{v-u}{t}$

$\Rightarrow \quad at = v - u \quad \Rightarrow \quad v = u + at$

(ii) The acceleration must be constant i.e. uniform acceleration. The object moves in a straight line.

learning CORNER

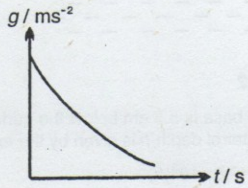
(c) **(i)** 1.8 s

(ii) The gradient of the tangent to the velocity-time graph at a given time.

(iii) This is possible if besides the pull of gravity, there is an additional force acting downward on the ball, such as viscous drag if the ball was thrown in a viscous fluid instead of in a vacuum.

(iv) The acceleration is g when $t = 1.8$ s, the time at which $v = 0$ ms^{-1}. Viscous drag is proportional to velocity. Hence when $v = 0$ ms^{-1}, viscous drag equals zero and the only force acting on the ball would be the pull of gravity (assuming upthrust is negligible).

(v)



(c) (i) The ball reaches its maximum height at its turning point i.e. when the velocity equals zero.

(c) (v) Take the downward direction as positive.

(d) When the ball is travelling upwards, there are two forces acting downwards on the ball - its weight and viscous drag. The net force acts downwards, opposite to the direction of travel. In contrast, when the ball is travelling downwards, the viscous drag acts upwards and the weight acts downwards. The net force acts downwards, in the same direction of travel. This net force is smaller than that when the object is travelling upwards. Hence the time taken to return to the starting point is greater.

(e) **(i)** $\text{K.E} = \frac{1}{2}mv^2$

$\Rightarrow \quad m = \frac{2\text{K.E.}}{v^2} = \frac{2 \times 54}{(26)^2} = 0.16 \text{ kg}$

(ii) As the ball travels upwards, its kinetic energy decreases until it becomes zero momentarily when the ball is at its maximum height. After which it increases when the ball starts to travel downwards.

Question 4

(a) A student throws a ball from point S to a friend at point F. The path of the ball is shown in Fig. 1.1.

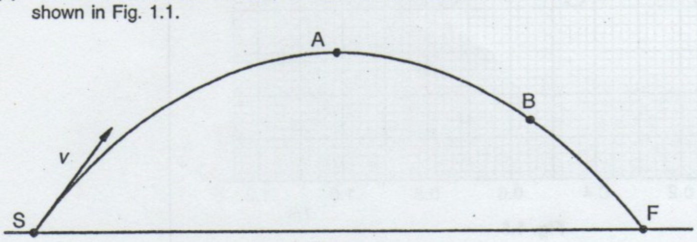


Fig. 1.1

The points S and F are on the same horizontal level. Air resistance is negligible. The ball is thrown from point S with velocity v, represented by the vector arrow shown on Fig. 1.1.

On Fig. 1.1,

(i) draw arrows from point S to represent the initial horizontal and vertical components of the velocity v (label these components v_H and v_V respectively). [1]

(ii) draw arrows at A and at B to represent the horizontal and vertical components of the velocity of the ball at these two points. [3]

(b) A metal tube of uniform cross-sectional area 1.3×10^{-3} m² is sealed at one end. It floats upright in water, as shown in Fig. 1.2.

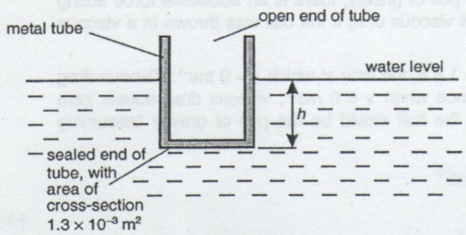


Fig. 1.2

When the tube is stationary, the base is 5.5 cm below the surface of the water. The pressure p due to water of depth h is given by the expression.

$$p = (9.8 \times 10^3)h,$$

where p is in pascals and h is in metres.

(i) 1. Calculate the force acting on the base of the tube due to the pressure of the water.

force = ... N [2]

2. State the direction of the force calculated in **1.** [1]

3. State the weight of the tube. [1]

(ii) The tube is pushed vertically a short distance into the water and then released. Fig. 1.3 shows the variation with time t of the depth h of the base of the tube below the surface.

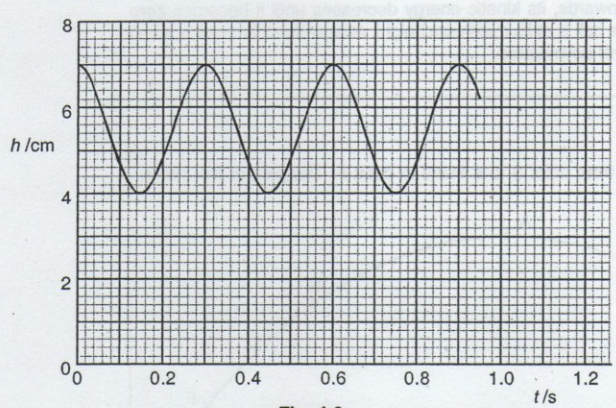


Fig. 1.3

1. Use Fig. 1.3 to determine the amplitude of the oscillations of the tube.

amplitude = ... cm [1]

2. Determine the frequency of the oscillations.

frequency = ... Hz [2]

3. Using your answers to **1.** and **2.**, determine the maximum speed of the tube.

speed = ... ms⁻¹ [2]

[D04/P2/Q1]

Suggested Solution:

(a) (i),(ii)

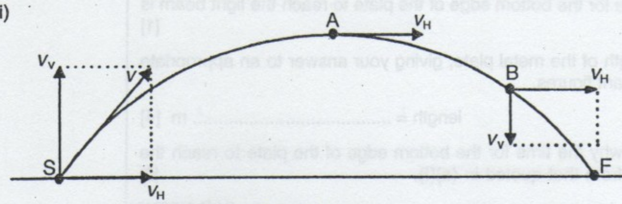


Fig. 1.1

(a) (ii) The horizontal component of the velocity does not change. The vertical component of the velocity changes due to gravity. At the turning point A, the vertical component of the velocity equals zero.

(b) (i) 1. Force acting on base of tube
= Pressure due to water at the base of the tube × Cross-sectional area
$= (9.8 \times 10^3)(5.5 \times 10^{-2})(1.3 \times 10^{-3})$
= 0.70 N

2. Upwards

3. 0.70 N

(b) (i) 3. Since the tube floats, its weight equals to the force acting on its base due to the pressure of the water.

(ii) 1. Amplitude = 1.5 cm

2. Frequency $= \frac{1}{\text{Period}} = \frac{1}{0.3} = 3.33$ Hz

3. Maximum speed, $v_m = \omega r$
$= 2\pi f A$
$= 2\pi \times 3.33 \times (1.5 \times 10^{-2})$
$= 0.314\ \text{ms}^{-1}$

(ii) Amplitude
$= \frac{1}{2} \times$ distance between peak and trough
$= \frac{1}{2} \times (7-4) = 1.5$ cm

Question 5

A student wishes to measure the length of a metal plate. The only equipment available is an electronic timer controlled by a light beam and a rod 1.00m long.

Using the rod, the student positions the plate so that its lower edge is 1.00m above the light beam, as shown in Fig. 1.1.

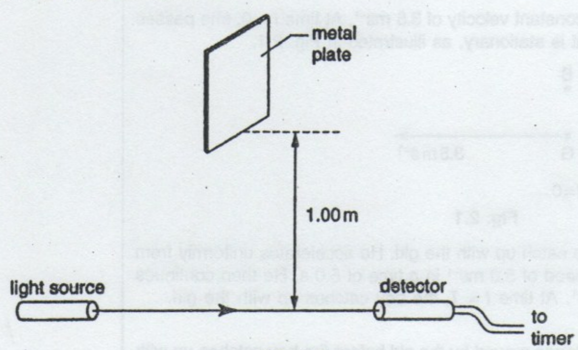


Fig. 1.1

The metal plate is released and the timer starts to record as the light beam is cut. The total time for the plate to pass through the beam is 0.052 s.

The student is told that the local value for the acceleration of free fall is 9.79 ms^{-2}.

(a) **(i)** Show that the time for the bottom edge of the plate to reach the light beam is 0.452 s. [1]

(ii) Calculate the length of the metal plate, giving your answer to an appropriate number of significant figures.

length = ... m [4]

(b) Suggest two reasons why the time for the bottom edge of the plate to reach the light beam may differ from that quoted in **(a)(i)**. [2]

[N05/P2/Q1]

Suggested Solution:

(a) **(i)** Initial velocity, $u = 0\ ms^{-1}$

Displacement, $s = 1.00$ m

Acceleration, $a = 9.79\ ms^{-2}$

Using $s = ut + \frac{1}{2}at^2$

$$1.00 = (0)t + \frac{1}{2}(9.79)(t)^2 \quad \Rightarrow \quad t = 0.452\ s$$

(ii) Let the length of plate be L.

Time taken for the top of the plate to reach light sources is $0.452 + 0.052 = 0.504$s.

Initial velocity, $u = 0\ ms^{-1}$

Displacement, $s = (1 + L)$ m

Acceleration, $a = 9.79\ ms^{-2}$

Using $s = ut + \frac{1}{2}at^2$

$$(1 + L) = (0)t + \frac{1}{2}(9.79)(0.504)^2 \quad \Rightarrow \quad L = 0.243\ m\ (3\ S.F.)$$

(b) 1. The plate may be dropped at an angle to the vertical.

2. There might be rotational motion if the metal plate is not uniform.

Question 6

A girl G is riding a bicycle at a constant velocity of 3.5 ms^{-1}. At time t = 0, she passes a boy B sitting on a bicycle that is stationary, as illustrated in Fig. 2.1.

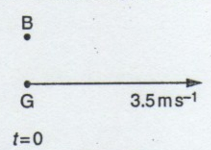


Fig. 2.1

At time t = 0, the boy sets off to catch up with the girl. He accelerates uniformly from time t = 0 until he reaches a speed of 5.6 ms^{-1} in a time of 5.0 s. He then continues at a constant speed of 5.6 ms^{-1}. At time t = T, the boy catches up with the girl. T is measured in seconds.

(a) State, in terms of T, the distance moved by the girl before the boy catches up with her. [1]

(b) For the boy, determine

(i) the distance moved during his acceleration, [2]

(ii) the distance moved during the time that he is moving at constant speed. Give your answer in terms of T. [1]

(c) Use your answers in **(a)** and **(b)** to determine the time T taken for the boy to catch up with the girl. [2]

(d) The boy and the bicycle have a combined mass of 67 kg.

(i) Calculate the force required to cause the acceleration of the boy. [3]

(ii) At a speed of 4.5 ms⁻¹, the total resistive force acting on the boy and bicycle is 23 N.

Determine the output power of the boy's legs at this speed. [2]

[N07/P2/Q2]

Suggested Solution:

(a) distance = $3.5T$ m

(a) Since speed is uniform so
$s = vt$
$= 3.5T$

(b) (i) Distance = (Average speed) × time

$$= \left(\frac{u+v}{2}\right)t$$

$$= \left(\frac{0+5.6}{2}\right)(5.0) = 14 \text{ m}$$

(ii) distance: $s = vt$

$$= (5.6)(T-5) \text{ m}$$

(b) (ii) T is the total time, so time taken to move with constant speed is $(T-5)$ s.

(c) Distance travelled by girl = (Distance travelled by boy with acceleration) + (Distance travelled by boy with uniform velocity)

$$3.5T = 14 + 5.6(T-5)$$

$$3.5T = 14 + 5.6T - 28$$

$$2.1T = 14$$

$$T = \frac{14}{2.1} \Rightarrow T = 6.7 \text{ s}$$

(d) (i) First calculate acceleration,

$$a = \frac{v-u}{t} = \frac{5.6-0}{5} = 1.12 \text{ ms}^{-2}$$

Now

$$F = ma$$

$$= (67)(1.12) = 75 \text{ N}$$

∴ force = 75 N

(ii)

$$P = FV$$

$$= (75+23)(4.5) = (98)(4.5) = 441$$

∴ power = 441 W

Question 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 1.2ms⁻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, [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 1.2ms⁻¹. [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.

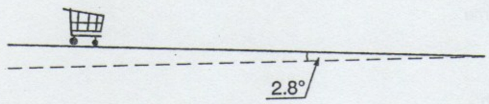


Fig. 3.1

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, [2]

(ii) the time for the trolley to travel from rest a distance of 3.5 m along the length of the slope. [4]

(d) Use your answer to **(c)(ii)** to explain why, for safety reasons, the slope is not made any steeper. [1]

[J08/P2/Q3]

Suggested Solution:

(a) (i)

$$2as = v^2 - u^2$$

$$2(a)(1.9) = (0)^2 - (1.2)^2$$

$$a = -\frac{1.44}{3.8} = -0.379$$

$\therefore$ deceleration = 0.38 ms^{-2}

(a) (i) Since Deceleration = –ve (acceleration), so deceleration must be written with +ve sign.

(ii) By Newton's second law

$F = ma \Rightarrow F = (42)(0.38) = 16$ N

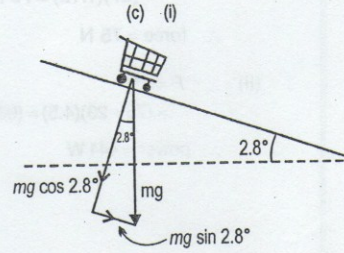
(b) $P = Fv = (16)(1.2) = 19.2$ W

(c) (i) Component of weight down the slope = $mg \sin 2.8°$

$= (42)(9.81)(\sin 2.8°)$

$= 20.1$ N

(c) (i)



(ii) Resultant force along the slope = 20.1 − 16 = 4.1 N

applying Newton's 2nd law

$F = ma$

$4.1 = (42)(a) \Rightarrow a = 0.0976$ ms^{-2}

using $s = ut + \frac{1}{2}at^2$, $3.5 = (0)(t) + \frac{1}{2}(0.0976)t^2 \Rightarrow t = \sqrt{\frac{2(3.5)}{0.0976}} = 8.47$

$\therefore$ required time = 8.5 s

(d) Speed of the trolley increase due to resultant force which increases with steepness.

(d) Component of weight down the slope of weight is $mg \sin\theta$. So if θ increases, since also increases and this increases the resultant force down the slope.

Question 8

A car is travelling along a straight road at speed *v*. A hazard suddenly appears in front of the car. In the time interval between the hazard appearing and the brakes on the car coming into operation, the car moves forward a distance of 29.3 m. With the brakes applied, the front wheels of the car leave skid marks on the road that are 12.8 m long, as illustrated in Fig. 2.1.

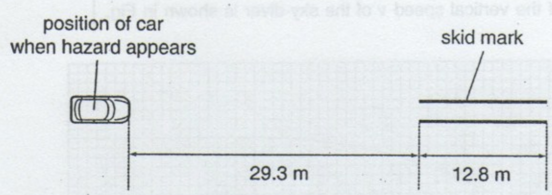


Fig. 2.1

It is estimated that, during the skid, the magnitude of the deceleration of the car is 0.85 *g*, where *g* is the acceleration of free fall.

(a) Determine

(i) the speed *v* of the car before the brakes are applied, [2]

(ii) the time interval between the hazard appearing and the brakes being applied. [2]

(b) The legal speed limit on the road is 60 km per hour.

Use both of your answers in **(a)** to comment on the standard of the driving of the car. [3]

[N08/P2/Q2]

Suggested Solution:

(a) (i) $2aS = v^2 - u^2$

$2(-0.85g)(12.8) = (0)^2 - (v)^2$

$-2(0.85)(9.81)(12.8) = -v^2$

$v^2 = 213$

$v = 14.6\ \text{ms}^{-1}$

(a) (i) Final speed of car = 0 as it comes to rest and deceleration = negative acceleration. So a = – 0.85 g.

(ii) $S = vt$

$29.3 = (14.6)t$

$t = \frac{29.3}{14.6} = 2.0\text{s}$

(ii) The car travel the thinking distance with uniform velocity.

(b) Since $60\ \text{kmh}^{-1} = \frac{60 \times 1000}{60 \times 60} = 16.7\text{ms}^{-1}$.

So speed of car is within the speed limit but the reaction time of driver is too long.

(b) (Driving speed) < (speed limit) i.e.

$14.6\ \text{ms}^{-1} < 16.7\text{ms}^{-1}$ and the reaction time of a normal person is 0.1 to 0.4 s.

Question 9

A sky-diver jumps from a high-altitude balloon.

(a) Explain briefly why the acceleration of the sky-diver

(i) decreases with time, [2]

(ii) is $9.8\ \text{m s}^{-2}$ at the start of the jump. [1]

(b) The variation with time t of the vertical speed v of the sky-diver is shown in Fig. 2.1.

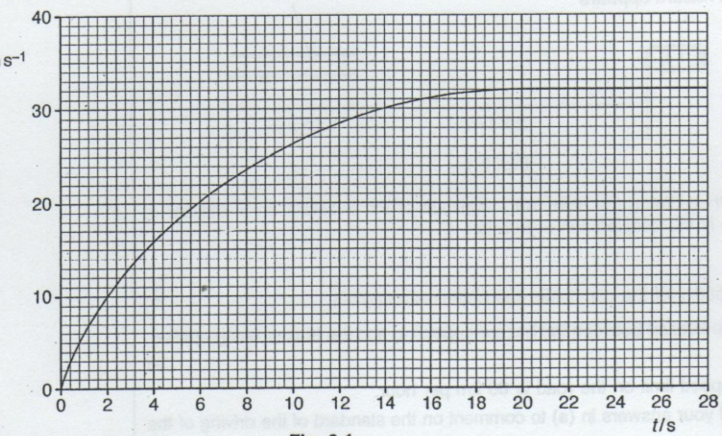


Fig. 2.1

Use Fig. 2.1 to determine the magnitude of the acceleration of the sky-diver at time $t = 6.0$ s. [3]

(c) The sky-diver and his equipment have a total mass of 90 kg.

(i) Calculate, for the sky-diver and his equipment,

1. the total weight, [1]
2. the accelerating force at time $t = 6.0$ s. [1]

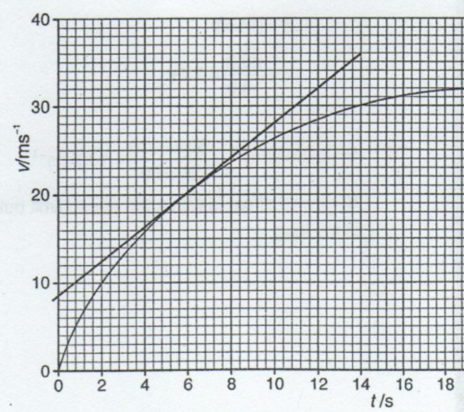
(ii) Use your answers in **(i)** to determine the total resistive force acting on the sky-diver at time $t = 6.0$ s. [1]

[N09/P21/Q2]

Suggested Solution:

(a) (i) Air resistance increases with increase in speed which therefore decreases the resultant force and hence its acceleration with time.

(ii) Air resistance is zero and only force acting is the Gravitational pull of Earth.



(b) Acceleration, a = Gradient of tangent at $t = 6.0$ s

$$a = \frac{35 - 8.5}{13.6 - 0} = 1.95\ \text{ms}^{-2}$$

(c) (i) 1. $W = mg$

$= (90)(9.81) = 882.9 \approx 883\ \text{N}$

2. $F = ma$

$= (90)(1.9) = 171\ \text{N}$

(ii) Resistive force, $R = W - F$

$= 883 - 171 = 712\ \text{N}$