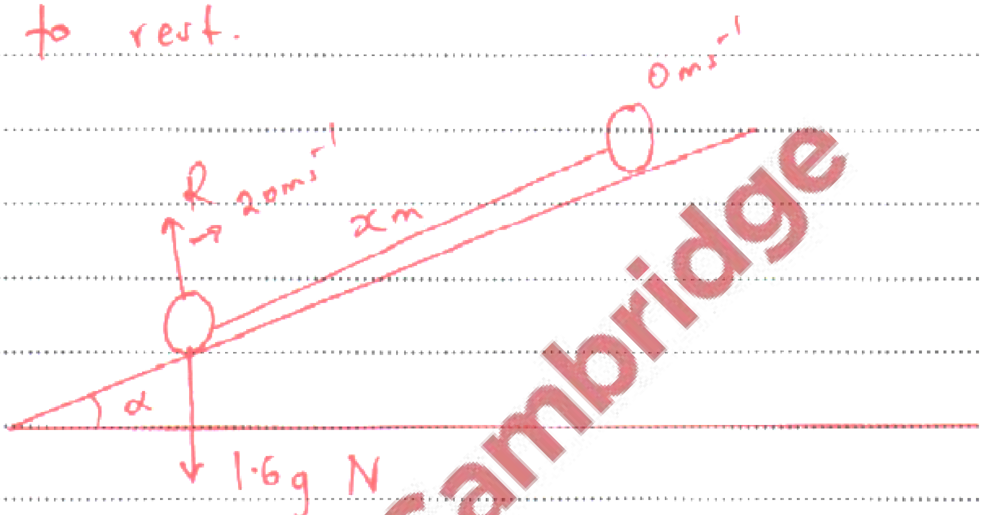
1. Nov/2023/Paper_9709/41/No.1

A particle of mass 1.6 kg is projected with a speed of 20 m s^{-1} up a line of greatest slope of a smooth plane inclined at α to the horizontal, where $\tan\alpha = \frac{3}{4}$.

Use an energy method to find the distance the particle moves up the plane before coming to instantaneous rest. [3]

Let x be the distance the particle moves before coming to rest.



KE lost = PE gained

$\frac{1}{2}mu^2 - \frac{1}{2}mv^2 = mgh$

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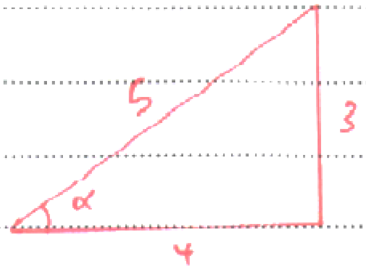
$\left(\frac{1}{2} \times 1.6 \times 20^2\right) - \left(\frac{1}{2} \times 1.6 \times 0\right) = 1.6 \times g \times x \sin\alpha$

But $g = 10\ ms^{-2}$

Given $\tan\alpha = \frac{3}{4}$,



Hypotenuse $= \sqrt{3^2 + 4^2} = 5$

$\Rightarrow \sin\alpha = \frac{3}{5}$

$\Rightarrow \quad 320 = 1.6 \times 10 \times x \times \frac{3}{5}$

$320 = 9.6x \Rightarrow x = \frac{320}{9.6} = \frac{100}{3}$ m

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2. Nov/2023/Paper_9709/41/No.6

A car of mass 1300 kg is moving on a straight road.

(a) On a horizontal section of the road, the car has a constant speed of $30\,\text{m s}^{-1}$ and there is a constant force of 650 N resisting the motion.

(i) Calculate, in kW, the power developed by the engine of the car. [2]

Since the car is moving at a constant speed

Driving force = Resistance force = 650 N

Power = F V

$= 650 \times 30$

$= 19\,500$ W

1 kW = 1000 W

Power $= \dfrac{19\,500}{1000} = 19.5$ kW

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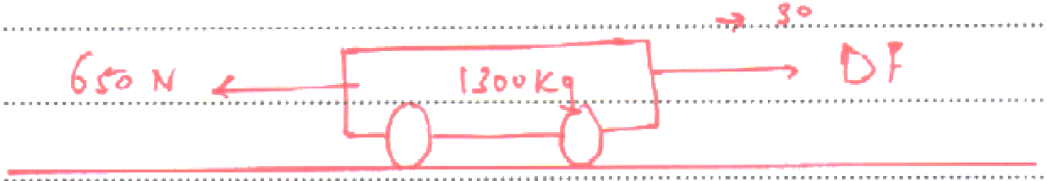
(ii) Given that this power is suddenly increased by 9 kW, find the instantaneous acceleration of the car. [3]



Power $= 19.5 + 9 = 28.5$ kW $= 28\,500$ kW

Power $= DF \times v \Rightarrow DF = \dfrac{P}{v} = \dfrac{28\,500}{30}$

$= 950$ N

Resolving horizontally using Newton's second law of motion, $F = ma$

$DF - 650 = 1300a$

$950 - 650 = 1300a \Rightarrow \dfrac{300}{1300} = \dfrac{1300a}{1300}$

$\therefore a = \dfrac{3}{13}$ m s^{-2}

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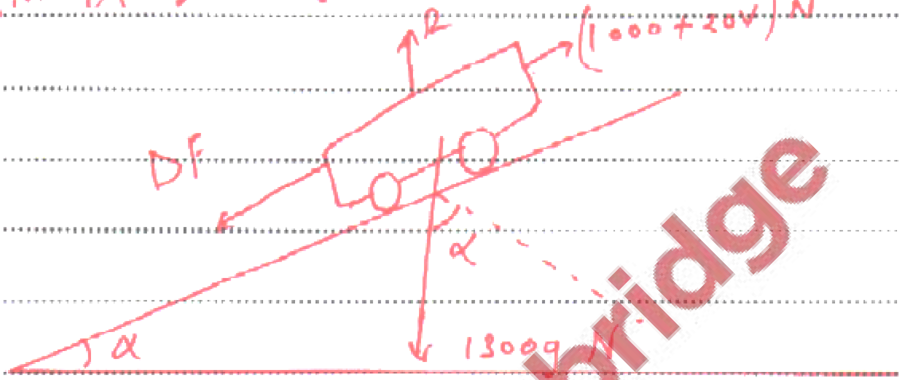
(b) On a section of the road inclined at $\sin^{-1} 0.08$ to the horizontal, the resistance to the motion of the car is $(1000 + 20v)$ N when the speed of the car is $v \text{ m s}^{-1}$. The car travels downwards along this section of the road at constant speed with the engine working at 11.5 kW.

Find this constant speed. [4]

Let α be the angle the road makes with the horizontal.

$\Rightarrow \sin\alpha = 0.08$



$DF : \dfrac{P}{v} = \dfrac{11500}{v}$

Resolving parallel to the plane using Newton's second law of motion, $F = ma$

$DF + 1300g\sin\alpha - (1000 + 20v) = 0$ (No acceleration down the slope)

$\dfrac{11500}{v} + (1300 \times 10 \times 0.08) - 1000 - 20v = 0$

$\dfrac{11500}{v} + 1040 - 1000 - 20v = 0$

$\left(\dfrac{11500}{v} + 40 - 20v = 0\right) \times v$

$11500 + 40v - 20v^2 = 0$

$-20(-575 - 2v + v^2) = 0 \Rightarrow v^2 - 2v - 575 = 0$

$(v - 25)(v + 23) = 0 \Rightarrow v = 25, -23$

But $v > 0$, so $v = 25 \text{ m s}^{-1}$

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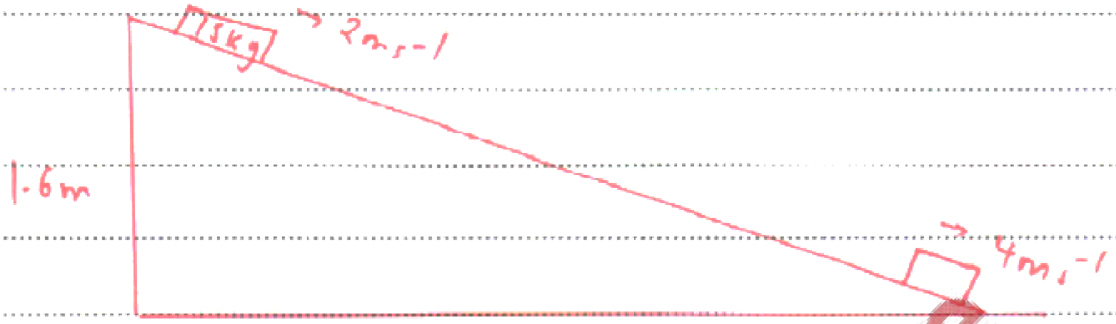
3. Nov/2023/Paper_9709/42/No.1

A block of mass 15 kg slides down a line of greatest slope of an inclined plane. The top of the plane is at a vertical height of 1.6 m above the level of the bottom of the plane. The speed of the block at the top of the plane is $2\,\text{m}\,\text{s}^{-1}$ and the speed of the block at the bottom of the plane is $4\,\text{m}\,\text{s}^{-1}$.

Find the work done against the resistance to motion of the block. [4]



By Conservation of energy:

Work done against resistance = PE lost − KE gained

PE lost = mgh, but $g = 10\,\text{ms}^{-2}$

$= 15 \times 10 \times 1.6$

$= 240\ \text{J}$

KE gained $= \frac{1}{2}mv^2 - \frac{1}{2}mu^2$

$= \left(\frac{1}{2} \times 15 \times 4^2\right) - \left(\frac{1}{2} \times 15 \times 2^2\right)$

$= 120 - 30$

$= 90\ \text{J}$

$\therefore$ Work done against resistance $= 240 - 90$

$= 150\ \text{J}$

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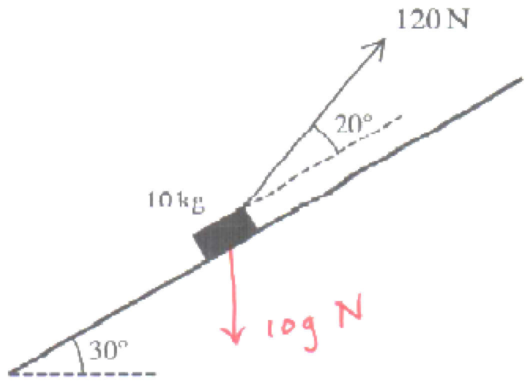
4. Nov/2023/Paper_9709/42/No.3



A block of mass 10 kg is at rest on a rough plane inclined at an angle of 30° to the horizontal. A force of 120 N is applied to the block at an angle of 20° above a line of greatest slope (see diagram). There is a force resisting the motion of the block and 200 J of work is done against this force when the block has moved a distance of 5 m up the plane from rest.

Find the speed of the block when it has moved a distance of 5 m up the plane from rest. [5]

By conservation of energy

Work done by an external force = Change in PE + Change in KE + Work done against resistance.

Work done by 120N force $= f \times d$

$= 120 \times 5\cos 20° = 563.8$ J

Change in PE $= mgh$

$= 10 \times 10 \times 5\sin 30° = 250$

Change in KE $= \frac{1}{2}mv^2 = \frac{1}{2} \times 10 \times v^2 = 5v^2$

Work done against resistance $= 200$ J

$\Rightarrow 563.8 = 250 + 5v^2 + 200$

$563.8 - 250 - 200 = 5v^2$

$\frac{113.8}{5} = \frac{\cancel{5}v^2}{\cancel{5}} \Rightarrow v^2 = 22.76$

$v = \sqrt{22.76}$ $\therefore v = 4.77\ ms^{-1}$ (3s.f)

5. Nov/2023/Paper_9709/43/No.4

A car has mass 1600 kg.

(a) The car is moving along a straight horizontal road at a constant speed of $24\,\mathrm{m\,s^{-1}}$ and is subject to a constant resistance of magnitude 480 N.

Find, in kW, the rate at which the engine of the car is working. [2]

Constant V => Driving force = resistance force = 480N

Power = DF X V = 480 X 24 = 11 520 W

= 11.52 kW

The car now moves down a hill inclined at an angle of θ to the horizontal, where $\sin\theta = 0.09$. The engine of the car is working at a constant rate of 12 kW. The speed of the car is $24\,\mathrm{m\,s^{-1}}$ at the top of the hill. Ten seconds later the car has travelled 280 m down the hill and has speed $32\,\mathrm{m\,s^{-1}}$.

(b) Given that the resistance is not constant, use an energy method to find the total work done against the resistance during the ten seconds. [5]

By Conservation of energy

Work done = Gain in KE - Loss in PE + Work done against resistance (W_r)

Work done = P X t = 12 000 X 10 = 120 000 J

Gain in KE = $\left(\frac{1}{2}mv^2 - \frac{1}{2}mu^2\right) = \left(\frac{1}{2} \times 1600 \times 32^2\right) - \left(\frac{1}{2} \times 1600 \times 24^2\right)$

= 819 200 - 460 800 = 358 400 J

Loss in PE = mgh = 1600 × g × 280 sin θ

= 1600 × 10 × 280 × 0.09

= 403 200

$\Rightarrow$ 120 000 = 358 400 − 403 200 + W_r

120 000 = −44 800 + W_r

$\Rightarrow$ W_r = 120 000 + 44 800 = 164 800

∴ Work done against resistance = 164 800 J

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