PROSPERITY ACADEMY

AS PHYSCIS 9702
Crash Course

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WORK, ENERGY AND POWER

COMPLETE NOTES

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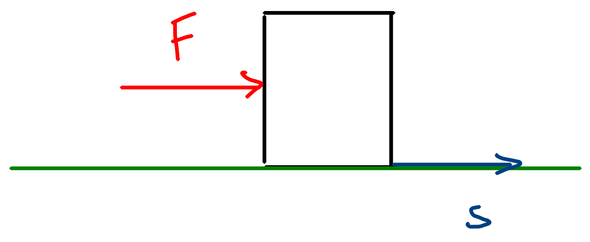
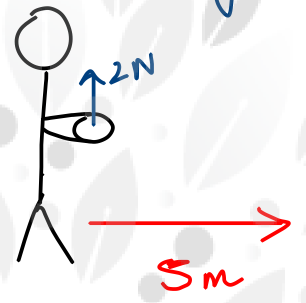
Work, Energy, Power:-

Work done:- Force × the distance moved along the line of action of the force. Scalar, measured in Joules (J)

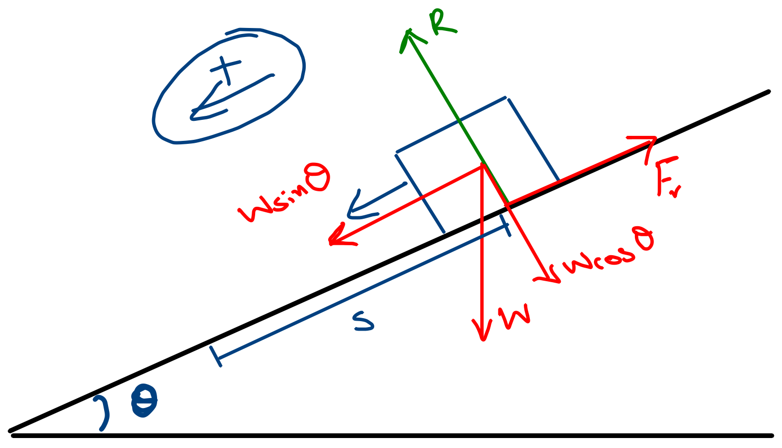


$$W = F \times s$$

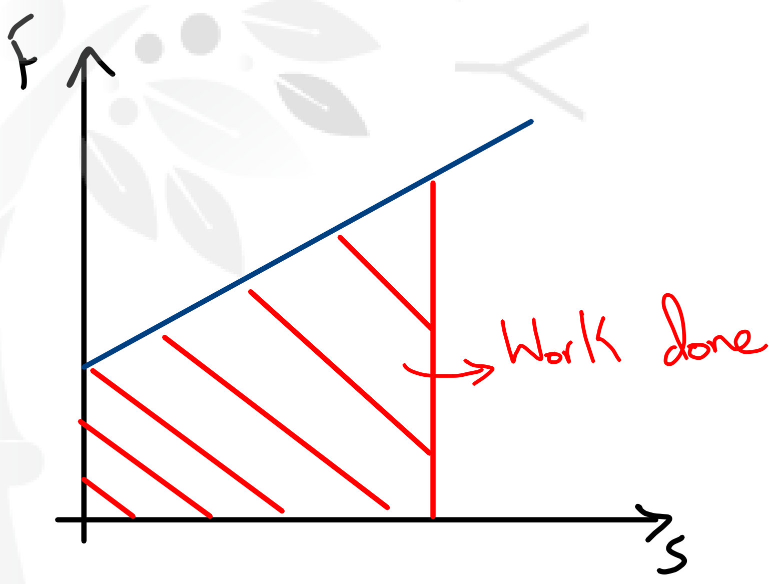


W = zero work done by 2N force

Work is done whenever an energy converts from one form to the other



- Surface is rough
- Block moves downwards



What is the work done by the weight?

$$W = W\sin\theta \times s$$

What is the work done against the friction?

$W = F_r \times s$ (loss of energy)

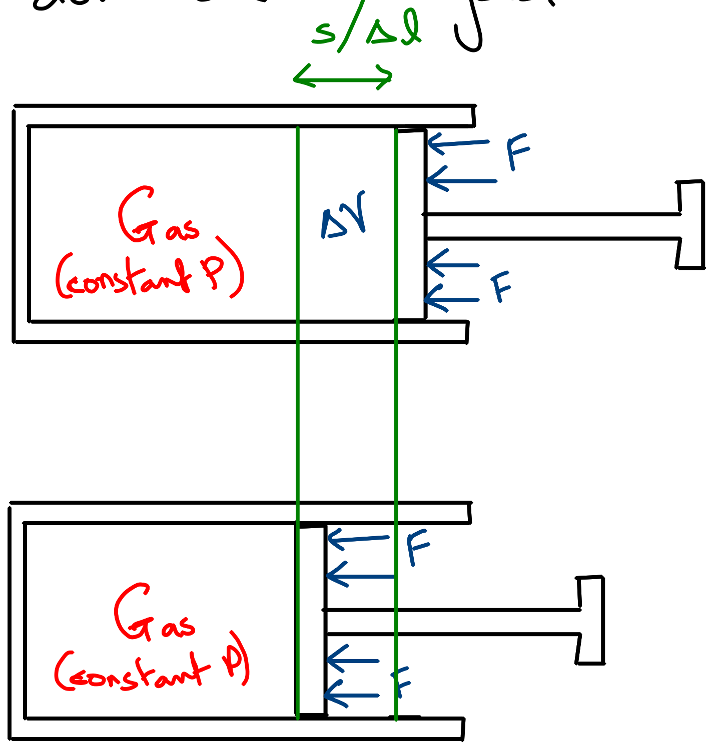
What is the net work done?

$$\Sigma W = \Sigma F \times s = (W\sin\theta - F_r)s$$

$$\Sigma W = W\sin\theta \times s - (F_r \times s)$$

Work done by / on a gas under constant pressure:-

Work done on the gas:-

① 

$$W = F \times s$$

$$W = P \times A \times \Delta l$$

($A \times \Delta l = \Delta V$)

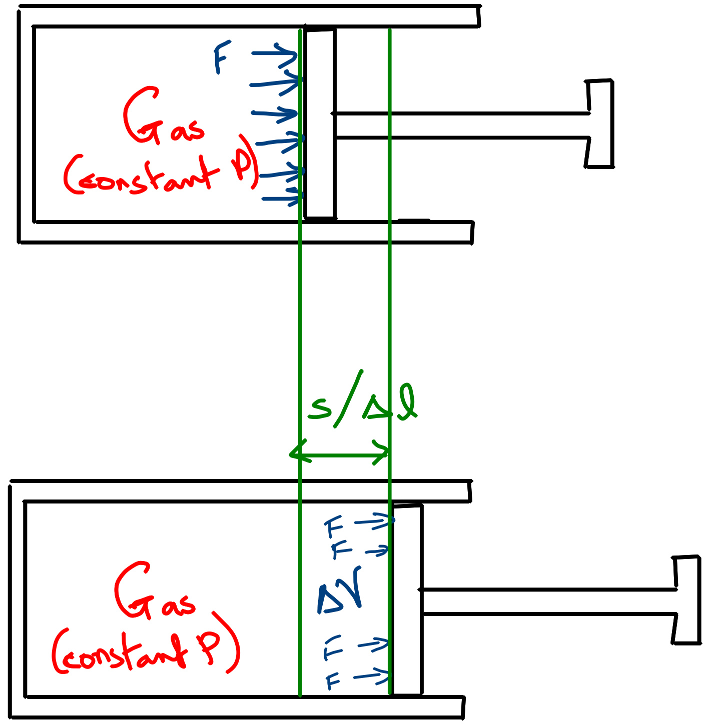
$$W = P \times \Delta V$$

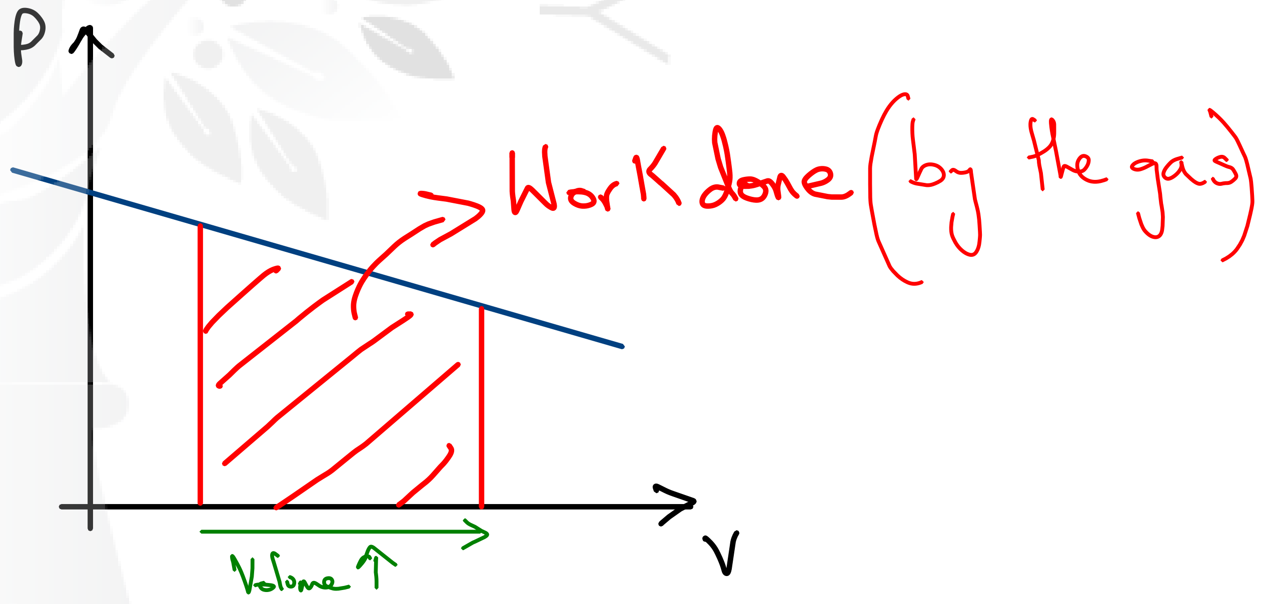
(P = constant pressure)

$$P = \frac{F}{A}$$

$$F = P \times A$$

Work done by the gas:-

② 



Energy:- Ability to do work. Scalar, measured in Joules (J).

Principle of conservation of energy:-

For a closed system, the total energy remains constant.

$$E_{input} = E_{output} + (\text{losses})$$

Types of energies:-

Potential energy:- Energy an object possesses by virtue of its state (position in a field, deformation)

1) * Gravitational potential energy:- Energy an object possesses by virtue of its position in a gravitational field.

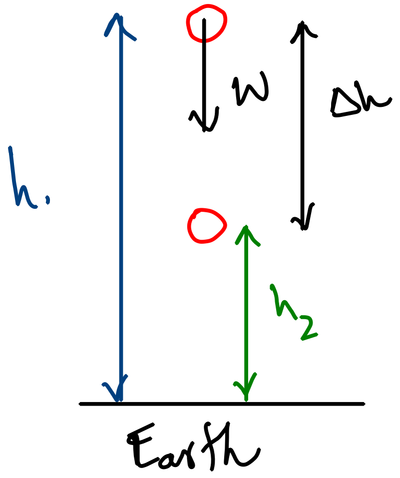
or

Energy an object possesses by virtue of its height above the Earth's surface.

2) * Elastic potential energy:- Energy an object possesses by virtue of its deformation

3) Electric potential energy:- Energy an object possesses by virtue of its position in an electric field.

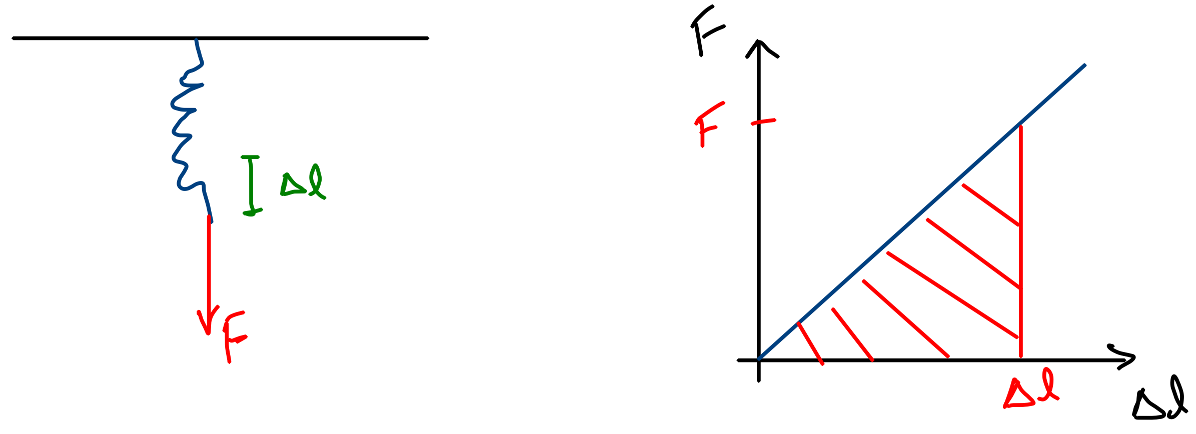
Gravitational potential energy:-



$$W = F \times s$$
$$= W \times s$$
$$= mg(h_1 - h_2)$$

$G.P.E = mg\,\Delta h$ (take height vertically only)

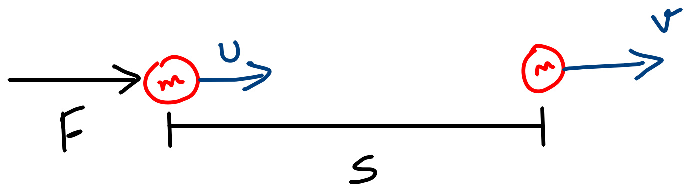
Elastic potential energy:-



W = Area under curve

$$E.P.E = \frac{1}{2} \times F \times \Delta l$$

Kinetic Energy:- The energy an object possesses by virtue of its motion.



$$W = F \times s$$

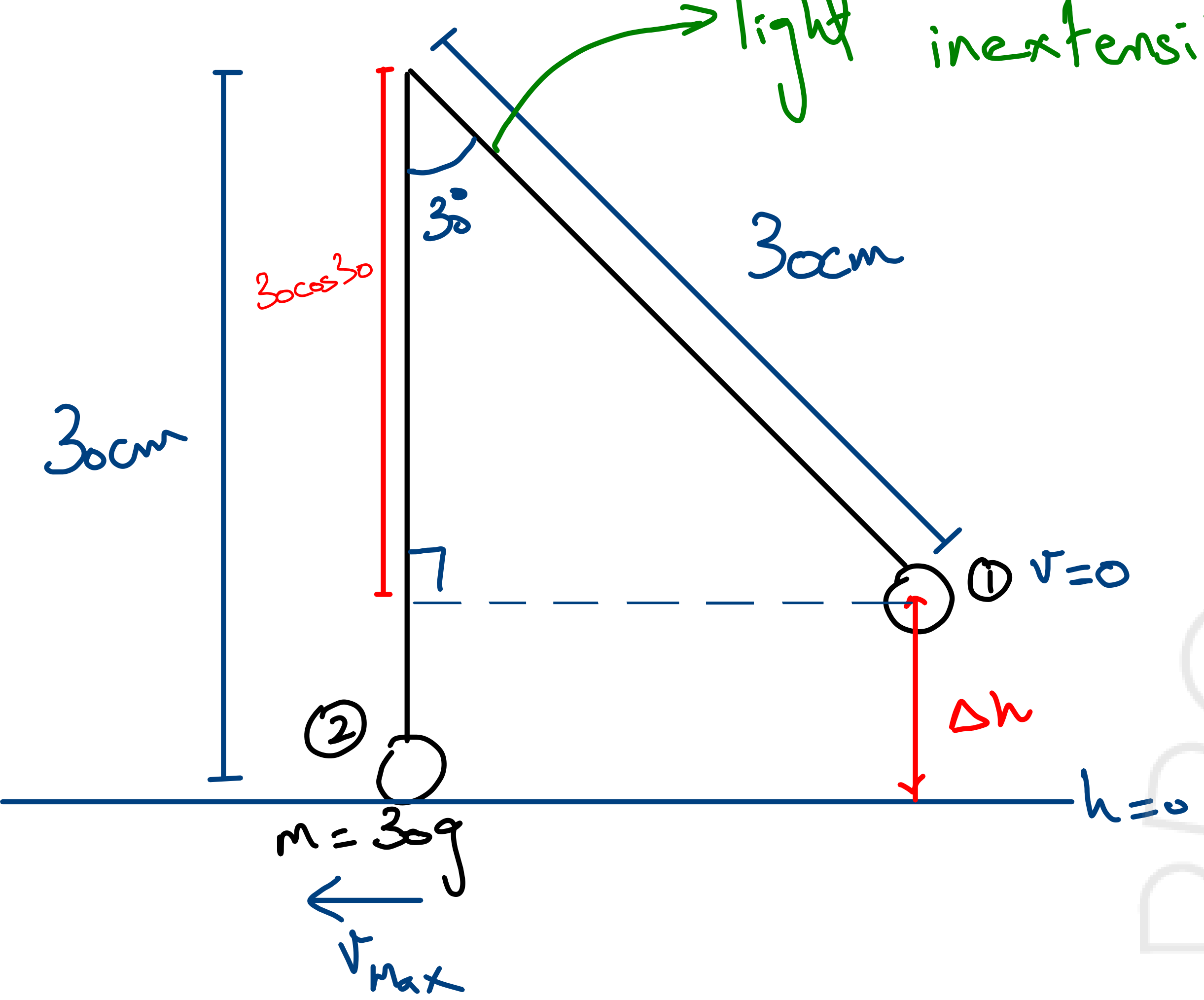
③ $v^2 = u^2 + 2as$

$$\frac{v^2 - u^2}{2s} = a$$

$$W = m \times a \times s$$

$$= m \times \frac{v^2 - u^2}{2s} \times s$$

$$K.E = \frac{1}{2} m \left(v^2 - u^2\right) \Rightarrow \text{if } u = 0 \Rightarrow \frac{1}{2} m v^2$$



Q1) What kinds of energies are posesed by the pendulum at ①

Ans) G.P.E

Q2) Calculate the ΔG.P.E at ①

Ans) $G.P.E = mg\Delta h$

$$= (30\times10^{-3})(9.81)\{[30 - 30\cos30]\times10^{-2}\}$$

$$= 0.0118 \simeq 0.01\ J$$

Q3) Calculate the max speed of the pendulum?

$G.P.E = K.E$

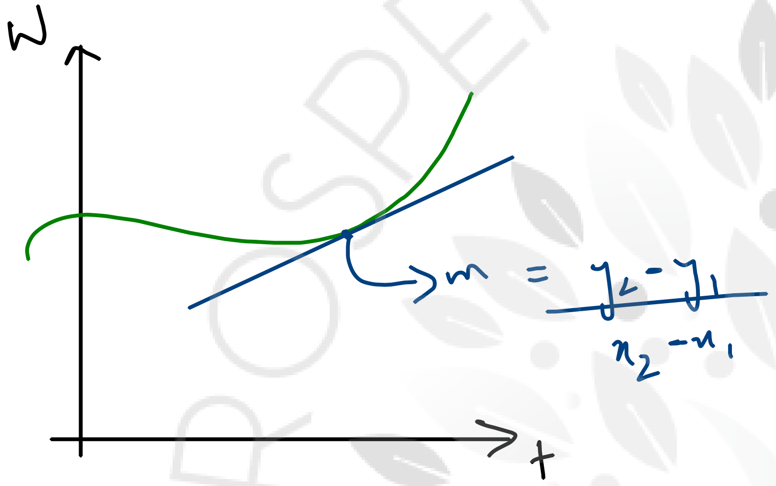
$$0.01 = \frac{1}{2}(30\times10^{-3})v^2$$

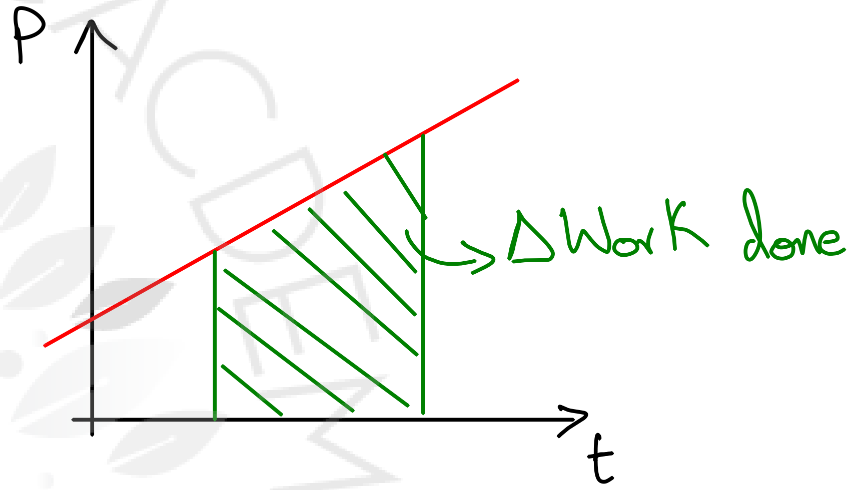
$$v = \sqrt{\frac{2(0.01)}{30\times10^{-3}}} = 0.816 \simeq 0.8\ ms^{-1}$$

Power:-

Rate at which work is being done. Scalar, measured in Watts (W)

1) $P = \dfrac{dW}{dt} = \dfrac{\Delta W}{\Delta t}$



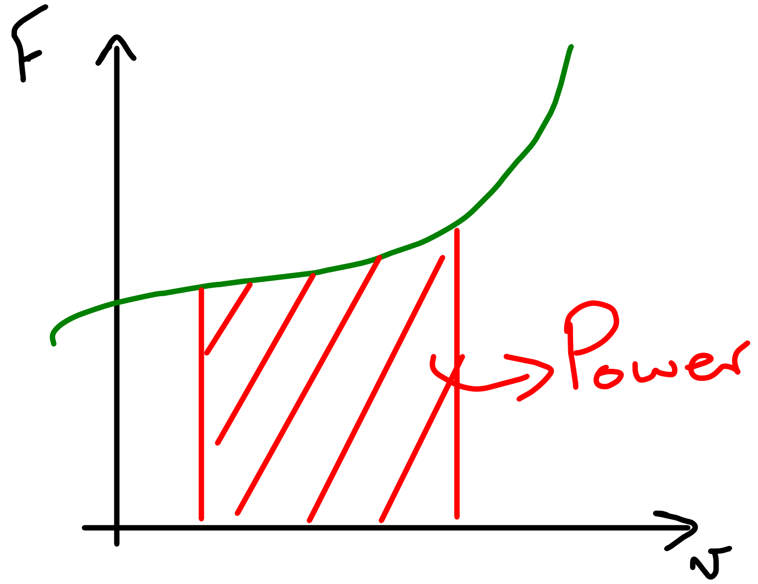


$P \times \Delta t = \Delta W$

2) $P = \dfrac{dW}{dt} = \dfrac{d(F \times s)}{dt}$

if force is constant:-

$P = F \times \dfrac{ds}{dt} \Rightarrow \boxed{P = F \times v}$ (only constant force)



*Power is the rate at which energy is converted from one to the other.

Efficiency:-

$$\eta = \frac{\text{useful energy output}}{\text{total energy input}} \times 100$$

$$\eta = \frac{\text{useful power output}}{\text{total power input}} \times 100$$

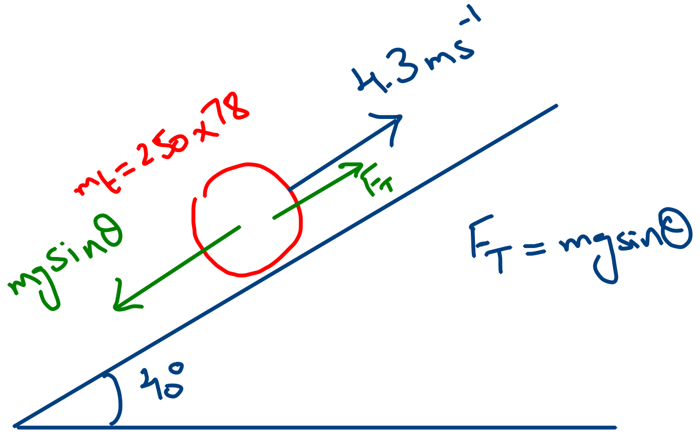
- Nothing in the universe is 100% efficient

s16 qp12 q18

18 An escalator in an underground station has 250 people standing on it and is moving with a velocity of 4.3 m s^{-1}. The average mass of a person is 78 kg and the angle of the escalator to the horizontal is 40°. const v

What is the minimum power required to lift these people?

A 54 kW **B** 64 kW **C** 530 kW **D** 630 kW



$P = F_T \times v$

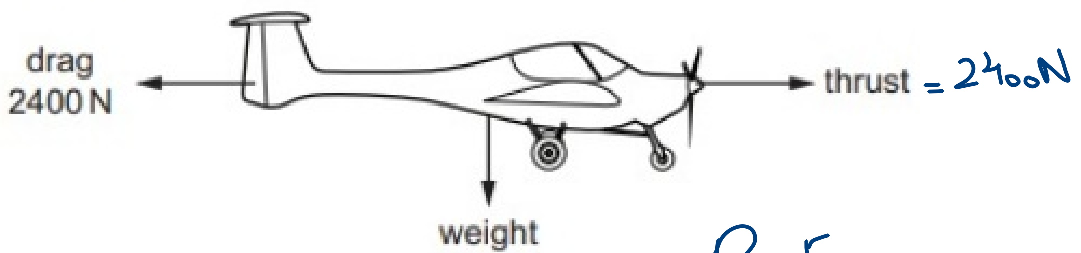
$= 250 \times 78 \times 9.81 \times \sin 40 \times 4.3 \simeq 530\ kW$

$\Sigma F = 0 \Rightarrow \Sigma F_y = 0 \quad \Sigma F_x = 0$

s18 qp11 q16

equilibrium

16 An aircraft travels at a constant velocity of 90 m s^{-1} in horizontal flight. The diagram shows some of the forces acting on the aircraft.



$P = F \times v$

$2400 \times 90 =$

The mass of the aircraft is 2000 kg.

What is the power produced by the thrust force?

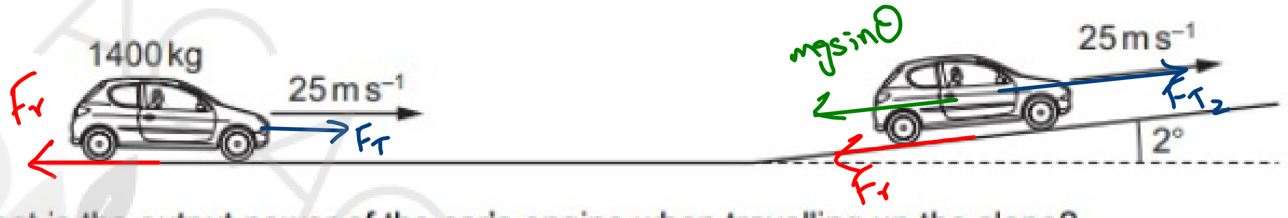
A 1.8×10^5 W **B** 2.2×10^5 W **C** 1.8×10^6 W **D** 2.0×10^6 W

m17 qp12 q19

equilibrium

19 A car of mass 1400 kg is travelling on a straight, horizontal road at a constant speed of 25 m s^{-1}. The output power from the car's engine is 30 kW.

The car then travels up a slope at 2° to the horizontal, maintaining the same constant speed.



What is the output power of the car's engine when travelling up the slope?

A 12 kW **B** 31 kW **C** 42 kW **D** 65 kW

$F_T = F_r$

$P = F_T \times v$

$30000 = F_T \times 25$

$F_T = 1200\ N$

$F_{T_2} = mg\sin\theta + F_r$

$F_{T_2} = 1400 \times 9.81 \times \sin 2 + 1200$

$P = F_{T_2} \times v$

$P = (1400 \times 9.81 \times \sin 2 + 1200) \times 25$

3 A cyclist is moving up a slope that has a constant gradient. The cyclist takes 8.0 s to climb the slope.
The variation with time *t* of the speed *v* of the cyclist is shown in Fig. 3.1.

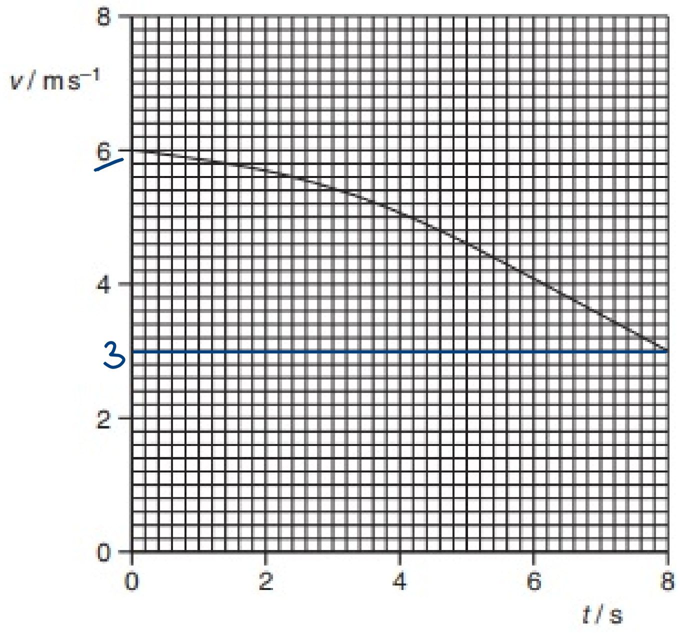


Fig. 3.1

(a) Use Fig. 3.1 to determine the total distance moved up the slope.

Area under graph
(count boxes)

distance = 39 m [3]

(b) The bicycle and cyclist have a combined mass of 92 kg.
The vertical height through which the cyclist moves is 1.3 m.

(i) For the movement of the bicycle and cyclist between $t = 0$ and $t = 8.0$ s,

1. use Fig. 3.1 to calculate the change in kinetic energy,

$\Delta = f - i$

$\Delta K.E = \frac{1}{2} m (v^2 - u^2)$

$= \frac{1}{2} \times 92 \times (3^2 - 6^2)$

$= -1242$ → loss

change = 1240 J [2]

2. calculate the change in gravitational potential energy.

$\Delta G.P.E = mg\Delta h$

$= (92)(9.81)(1.3)$

$= 1173$

change = +1170 J [2]

(ii) The cyclist pedals continuously so that the useful power delivered to the bicycle is 75 W.
Calculate the useful work done by the cyclist climbing up the slope.

$P = \frac{\Delta W}{\Delta t} \Rightarrow 75 \times 8 = \Delta W$

$600 = \Delta W$

work done = 600 J [2]

(c) Some energy is used in overcoming frictional forces.

(i) Use your answers in **(b)** to show that the total energy converted in overcoming frictional forces is approximately 670 J.

$E_{input} = E_{output}$

$\Delta K.E + W_p = \Delta G.P.E + W_{Fr}$

$1240 + 600 = 1170 + W_{Fr}$

$W_{Fr} = 670$

[1]

(ii) Determine the average magnitude of the frictional forces.

$W_{Fr} = F_r \times s$

$670 = F_r \times 39$

$\frac{670}{39} = F_r = 17.2$

average force = 17 N [1]

(d) Suggest why the magnitude of the total resistive force would not be constant.

The velocity is decreasing and so the drag force also decreases

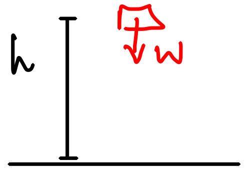
[2]

4 **(a)** Distinguish between *gravitational potential energy* and *electric potential energy*.

The energy an object possesses by virtue of its position in a gravitational field is G.P.E whereas in an electric field is E.P.E. [2]

(b) A body of mass *m* moves vertically through a distance *h* near the Earth's surface. Use the defining equation for work done to derive an expression for the gravitational potential energy change of the body.

$W = F \times s \Rightarrow W \times h \Rightarrow mgh = G.P.E$



[2]

(c) Water flows down a stream from a reservoir and then causes a water wheel to rotate, as shown in Fig. 4.1.

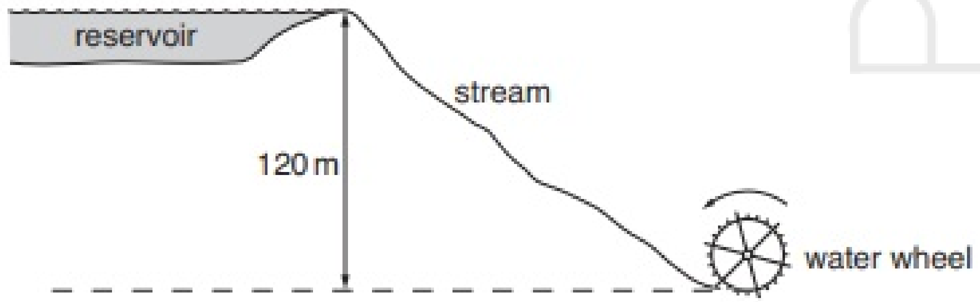


Fig. 4.1

As the water falls through a vertical height of 120 m, gravitational potential energy is converted to different forms of energy, including kinetic energy of the water. At the water wheel, the kinetic energy of the water is only 10% of its gravitational potential energy at the reservoir.

(i) Show that the speed of the water as it reaches the wheel is $15\,m\,s^{-1}$.

$K.E = \frac{10}{100} \times G.P.E$

$\frac{1}{2} m v^2 = \frac{1}{10} \times m \times 9.81 \times 120$

$v^2 = \frac{2}{10} \times 9.81 \times 120 = \sqrt{235.44} = 15.3 \simeq 15$

(ii) The rotating water wheel is used to produce 110 kW of electrical power. Calculate the mass of water flowing per second through the wheel, assuming that the production of electric energy from the kinetic energy of the water is 25% efficient.

$\eta = \frac{\text{useful power output}}{\text{total power input}} \times 100 \Rightarrow 25 = \frac{110 \times 10^3}{\frac{1}{2} m v^2 / t} \times 100$

$\frac{m}{t} = \frac{110 \times 10^3}{\frac{1}{2} \times 235.44 \times 25} \times 100 = 3737$

mass of water per second = 3700 $kg\,s^{-1}$ [3]

2 **(a)** Explain what is meant by

(i) *work done,*

Product of the force into the distance moved in the line of action of the force ....[1]

(ii) *kinetic energy.*

energy an object possesses by virtue of its motion. ....[1]

(b) A leisure-park ride consists of a carriage that moves along a railed track. Part of the track lies in a vertical plane and follows an arc XY of a circle of radius 13 m, as shown in Fig. 2.1.

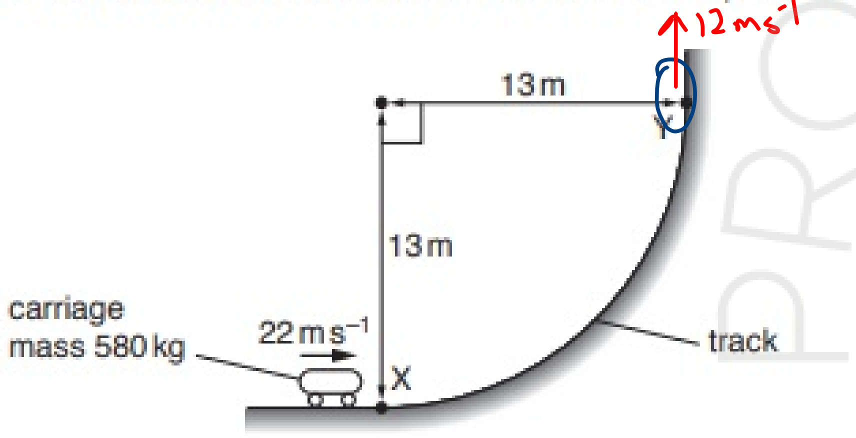


Fig. 2.1

The mass of the carriage is 580 kg. At point X, the carriage has velocity 22 m s^{-1} in a horizontal direction. The velocity of the carriage then decreases to 12 m s^{-1} in a vertical direction at point Y.

(i) For the carriage moving from X to Y

1. show that the decrease in kinetic energy is 9.9 × 10^4 J,

$\Delta K.E = \frac{1}{2}m(v^2 - u^2) = \frac{1}{2} \times 580 \times (12^2 - 22^2)$

$= -98600$

$= 9.9 \times 10^4$ J [2]

2. calculate the gain in gravitational potential energy.

$\Delta G.P.E = mg\Delta h = 580 \times 9.81 \times 13$

$= 74000 \,/\, 7.4 \times 10^4$

(ii) Show that the length of the track from X to Y is 20 m.

$\frac{1}{4} \times 2\pi r = \frac{1}{4} \times 2 \times \pi \times 13 = 20$m

or $s = r\theta \Rightarrow (13)\left(\frac{\pi}{2}\right)$ [1]

(iii) Use your answers in **(b)(i)** and **(b)(ii)** to calculate the average resistive force acting on the carriage as it moves from X to Y.

Einput = Eoutput

$K.E = G.P.E + W_{F_r}$

$9.9 \times 10^4 - W_{F_r} = 7.4 \times 10^4$

$W_{F_r} = 2.5 \times 10^4$

$W_{F_r \times s} = F_r \times s$

$2.5 \times 10^4 = F_r \times 20$

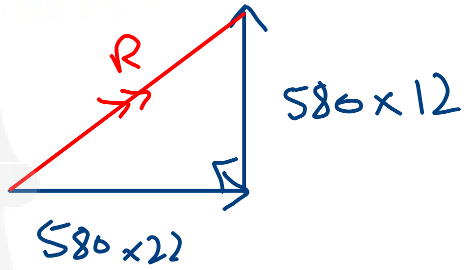
$1250 = F_r$

resistive force = ...1250........ N [2]

(iv) Describe the change in the direction of the linear momentum of the carriage as it moves from X to Y.

The linear momentum changed from a horizontally right to a vertically up direction. ....[1]

(v) Determine the magnitude of the change in linear momentum when the carriage moves from X to Y.



$R = \sqrt{(580 \times 22)^2 + (580 \times 12)^2}$

$= 1.5 \times 10^4$

change in momentum = ...1.5×10^4........ Ns [3]

[Total: 13]

3 (a) Explain what is meant by *work done*.

Product of the force into the distance moved in the line of action of the force .... [1]

(b) A ball of mass 0.42 kg is dropped from the top of a building. The ball falls from rest through a vertical distance of 78 m to the ground. Air resistance is significant so that the ball reaches constant (terminal) velocity before hitting the ground. The ball hits the ground with a speed of 23 m s^{-1}.

no constant a

(i) Calculate, for the ball falling from the top of the building to the ground:

1. the decrease in gravitational potential energy

$\Delta G.P.E = mg\Delta h$

$= 0.42 \times 9.81 \times 78$

$= 321\ J$

decrease in gravitational potential energy = ...320........ J [2]

2. the increase in kinetic energy.

$\Delta K.E = \frac{1}{2}mv^2$

$= \frac{1}{2} \times 0.42 \times 23^2$

$= 110$

increase in kinetic energy = ...110........ J [2]

(ii) Use your answers in **(b)(i)** to determine the average resistive force acting on the ball as it falls from the top of the building to the ground.

Einput = Eoutput

$\Delta G.P.E - W_{Fr} = \Delta K.E$

$320 - W_{Fr} = 110$

$W_{Fr} = 210$

$W_{Fr} = F_r \times s$

$210 = F_r \times 78$

$F_r = 2.7$

average resistive force = ...2.7........ N [2]

(c) The ball in **(b)** is dropped at time $t = 0$ and hits the ground at time $t = T$. The acceleration of free fall is g.

On Fig. 3.1, sketch a line to show the variation of the acceleration a of the ball with time t from time $t = 0$ to $t = T$.

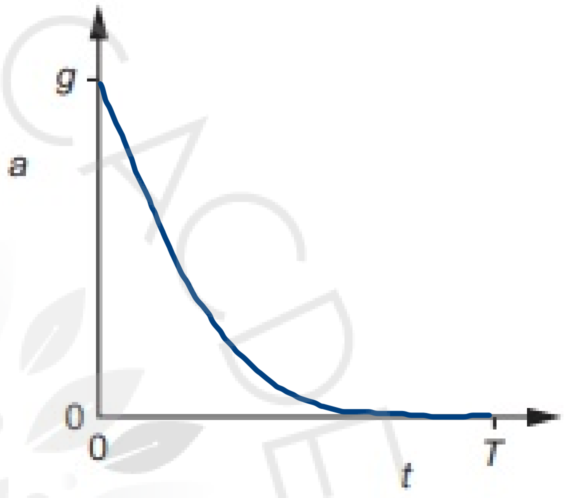


Fig. 3.1

[2]

[Total: 9]

Q. Explain the energy conversions for the ball falling through the air.

Before terminal velocity:-

↓G.P.E ⟶ K.E↑ + W_{Fr} (heat)

The gravitational potential energy converts to the increase in kinetic energy and heat

After terminal velocity (const velocity):- $\Delta K.E = 0$

↓G.P.E ⟶ W_{Fr} (heat)

As v is const, $\Delta K.E = 0$, so gravitational potential energy changes into heat only.