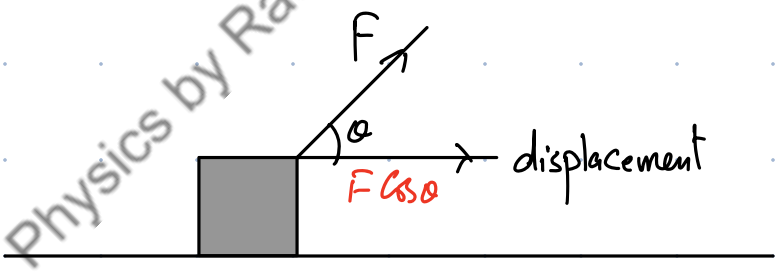
Work, Energy, Power

Work

The product of Force and Displacement in the direction of Force

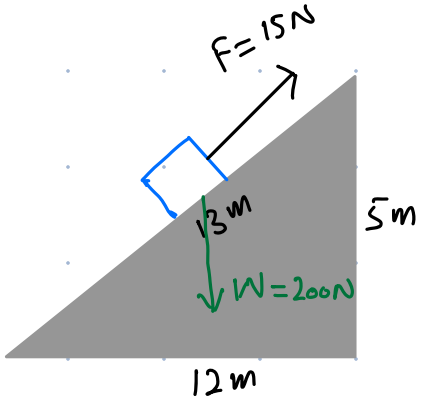
$$W = F \times S$$

- SI unit : Joule ; SI Base unit: $Nm = kgm^2s^{-2}$
- Work is Scalar Quantity.
- Work done can be negative if Net Force is Resistive force



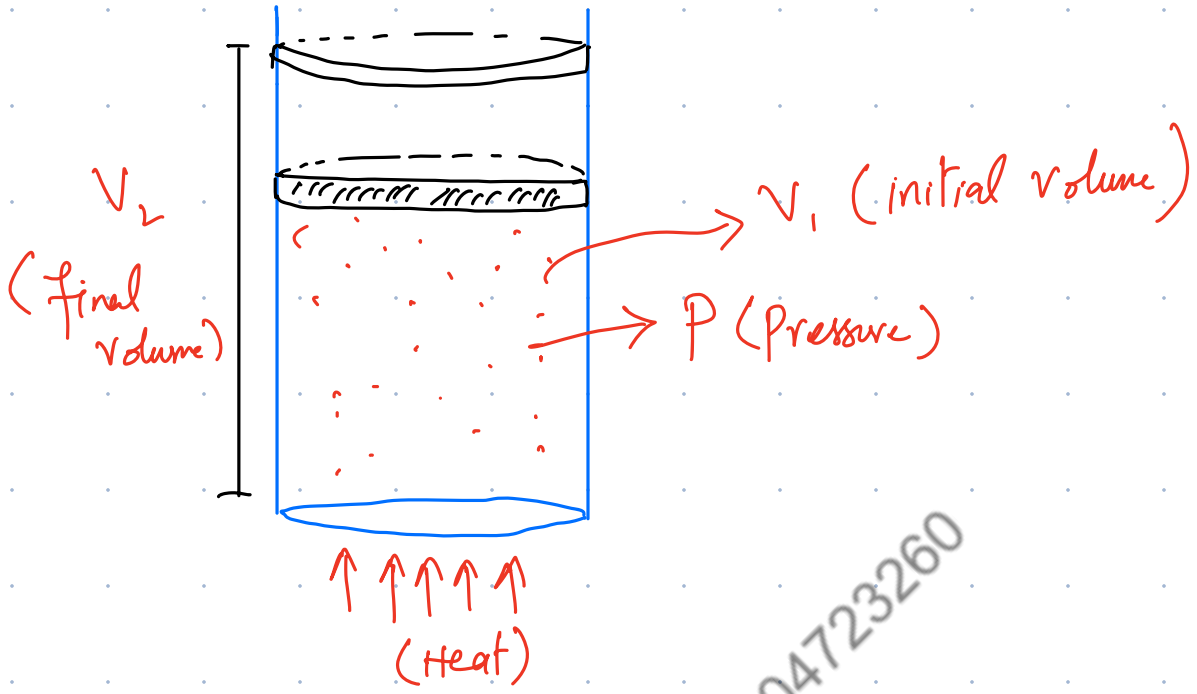
$$W = (F\cos\alpha) \times d$$

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- Work done against gravity: 200×5
  $= 1000\,J$
- Work done against friction:
  $15 \times 13 = 195\,J$

Work done by Gas : If a gas is heated, it expands

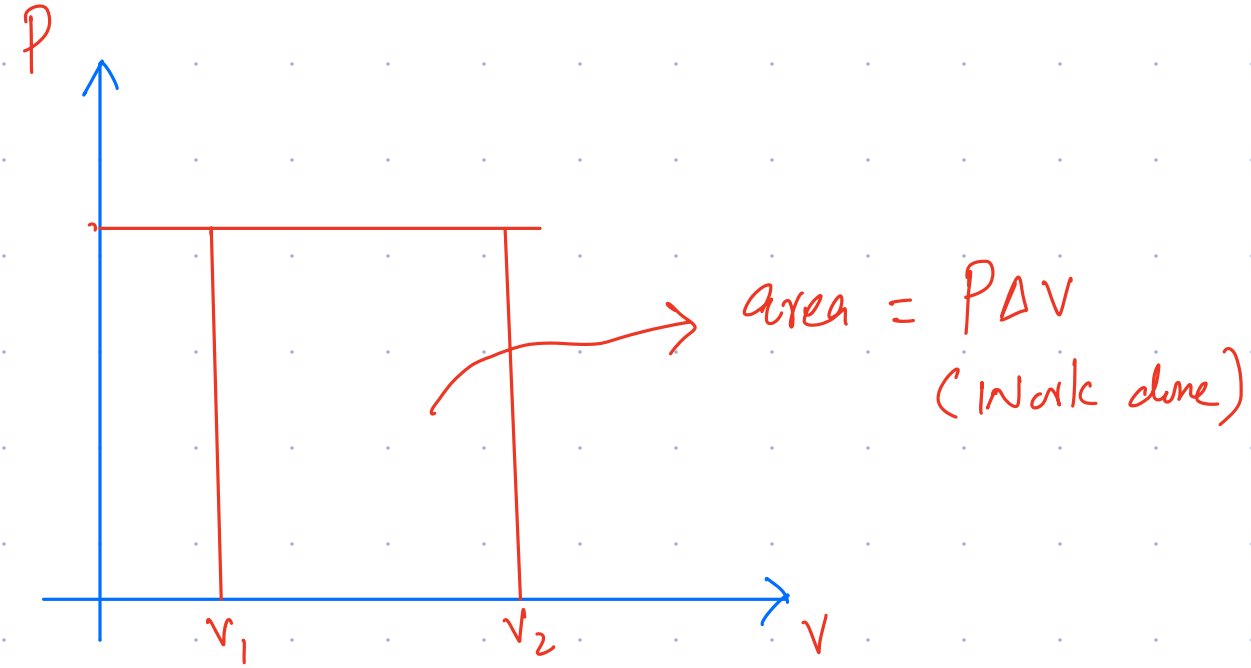


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Work done = Pressure × change in volume

$= P(V_2 - V_1)$

$$W = P\Delta V$$



Energy: Ability to do work is known as Energy

Forms of Energy:

Kinetic Energy
- translational (movement in straight line)
- rotational (energy due to spin)
- vibrational (K.E due to vibration of particles)

Potential Energy
- gravitational P.E (energy due to vertical height)
- elastic P.E (energy stored in a stretched spring)
- chemical P.E (energy obtained from fuels, food etc)

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Kinetic Energy Formula

$\therefore \quad 2as = v^2 - u^2$

Since $F = ma$

or $a = \frac{F}{m}$

$\therefore \quad 2\left(\frac{F}{m}\right)s = v^2 - u^2$

$Fs = \frac{m(v^2 - u^2)}{2}$

$\therefore \quad \boxed{K.E = \frac{1}{2}mv^2}$

Potential Energy Formula

Work done against gravity is known as potential energy

$$P.E = FS$$

$$= mgS$$

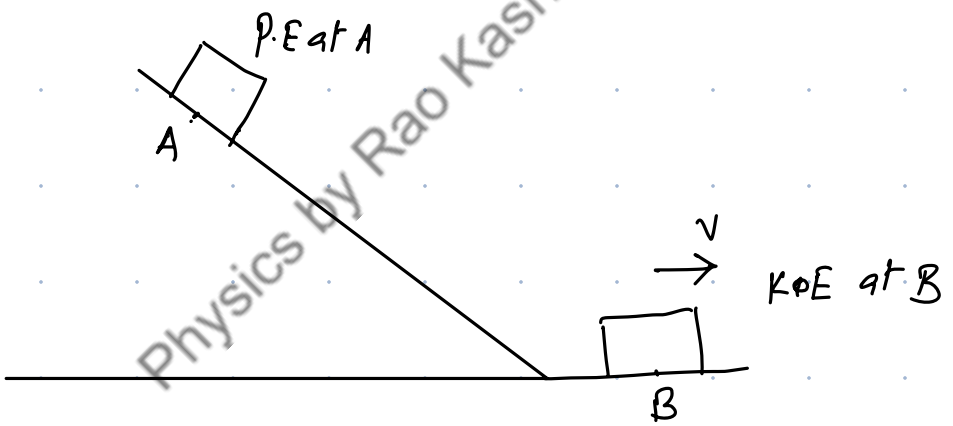
$F = W = mg$

$S = h$

$$\boxed{P.E = mgh}$$

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Work Energy Principles



Case - I

If resistance (friction) is negligible,

$$P.E \text{ at } A = K.E \text{ at } B$$

Case - II

If resistance (friction) is present,

$$P.E \text{ at } A = K.E \text{ at } B + W.D. \text{ against resistance}$$

Power It is the rate at which the work is done

OR Rate at which energy is converted.

Example: If a water pump can fill a tank is less time, it is more powerful

$$\text{Power} = \frac{\text{Work done}}{\text{time}} \quad \text{or} \quad \frac{\text{Energy}}{\text{time}}$$

- Power is Scalar Quantity
- SI unit of Power is Watt (W)

$$\boxed{\text{Power} = \text{Force} \times \text{Speed}} \Rightarrow \frac{F \times v}{\frac{F \times d}{t}} = \frac{W}{t} = \text{Power}$$

However,

$1\,kW = 10^3\,W$, $1\,MW = 10^6\,W$

$1\,mW = 10^{-3}\,W$, $1\,\mu W = 10^{-6}\,W$

Efficiency

$$\frac{\text{Useful output energy/Power}}{\text{total input energy/Power}} \times 100 \quad (\%\text{age efficiency})$$

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Past Paper Questions

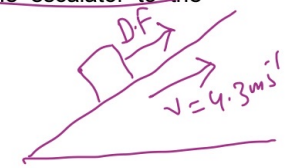
use Power = FV

17 An escalator in an underground station has 25 people standing on it and is moving with a speed 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°.

What is the minimum power required to lift these people?

A 5.4 kW **B** 6.4 kW **C** 53 kW **D** 63 kW

D.F = 78 × 25 × Sin40 × 9.81
Power = D.F × 4.3



14 During an interval of time, fuel supplies energy X to a car.

Some of this energy is converted into kinetic energy as the car accelerates.

The rest of the energy Y is lost as thermal energy.

What is the efficiency of the car?

A $\frac{X}{X-Y}$ **B** $\frac{Y}{X-Y}$ **C** $\frac{X-Y}{X}$ **D** $\frac{X-Y}{Y}$

useful output: X → Y

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1 **(a)** **(i)** Define *power*.

Work done per unit time (or) rate of energy transfer [1]

(ii) In the following list, tick the **two** boxes next to the two quantities needed to calculate the work done on an object.

- ☐ mass of the object
- ☑ force acting on the object
- ☐ speed of the object
- ☐ acceleration of the object
- ☑ distance moved by the object [1]

(b) A lift (elevator) in a high building transports 12 passengers, each of mass 65 kg, through a vertical height of 150 m in a time of 64 s.

(i) Calculate the power needed to transport the passengers through this height.

$$\text{Power} = \frac{\text{energy}}{\text{time}} = \frac{mgh}{t}$$

$$= \frac{12 \times 65 \times 9.81 \times 150}{64}$$

power = 18 kW [4]

(ii) The lift (elevator) is driven by an electric motor.

State a reason, other than friction, why the power supplied by the motor is greater than the power needed to transport the passengers.

More power is needed to provide lift force to the load of passengers [1]

[Total: 7]

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2 A soft rubber ball of mass 0.15 kg is dropped, in a vacuum, from a height of 2.0 m on to a hard surface. The ball then bounces.

(a) State the main energy changes taking place when

(i) the ball is falling,

gravitational Potential Energy to Kinetic Energy

(ii) the ball hits the surface and is changing shape,

Kinetic Energy to Elastic Potential Energy

(iii) the ball is regaining its shape and is rising from the surface.

elastic potential energy to Kinetic Energy

[3]

(b) Calculate the speed with which the ball hits the surface.

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

$\Rightarrow 2gh = v^2$

$v = \sqrt{2 \times 9.81 \times 2}$

$\approx 6.3\ ms^{-1}$

speed = $6.3\ ms^{-1}$ [4]

(c) After rebounding from the surface, the ball rises to a height of 1.9 m.

Suggest why the height to which the ball rises is less than the height from which the ball falls.

Some energy is lost due to thermal energy

[1]

[Total: 8]

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3 A scientist finds that the temperature of the water at the bottom of waterfalls is greater than the temperature of the water at the tops of those waterfalls.

(a) **(i)** State the type of energy that falling water has because of its motion.

Kinetic Energy

..... [1]

(ii) In one waterfall, the water falls 300 m.

Calculate the decrease in the gravitational potential energy (g.p.e.) of 1.0 kg of water as it falls through this distance.

$mgh = 1 \times 9.81 \times 300 \approx 3000\,J$

decrease in g.p.e. = 3000 J [2]

(iii) Assume that the increase in internal energy of the 1.0 kg of water is equal to its decrease in g.p.e.

Calculate the rise in temperature of the water. The specific heat capacity of water is 4200 J/(kg °C).

Not in Syllabus of AS

rise in temperature = ... [2]

(iv) Suggest a reason why the actual increase in temperature of the water is less than the value calculated in **(a)(iii)**.

.....

..... [1]

(b) State why the thermometer used to measure the temperature of the water in the scientist's experiment required a high sensitivity.

.....

..... [1]

[Total: 7]

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4 **(a)** On a day with no wind, a fountain in Switzerland propels 30 000 kg of water per minute to a height of 140 m.

Calculate the power used in raising the water.

$\text{Power} = \frac{mgh}{t} = \frac{30,000 \times 9.81 \times 140}{60}$ (1 min = 60 sec)

$= 700\,\text{kW} = 0.7 \times 10^6\,\text{W}$

power = 0.7 MW [4]

(b) The efficiency of the pump which operates the fountain is 70%.

Calculate the power supplied to the pump.

$70 = \frac{0.7 \times 10^6}{x} \times 100$ | $x = \frac{0.7 \times 10^6 \times 100}{70}$

power = 1.0×10^6 W or 1 MW [3]

(c) On another day, a horizontal wind is blowing. The water does not rise vertically.

Explain why the water still rises to a height of 140 m.

The horizontal component (wind) has no effect on vertical motion [1]

[Total: 8]

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5 When a salmon swims up a river to breed, it often has to jump up waterfalls. Fig. 3.1 shows a salmon jumping above the surface of the water. On this occasion the salmon falls back down into the river.

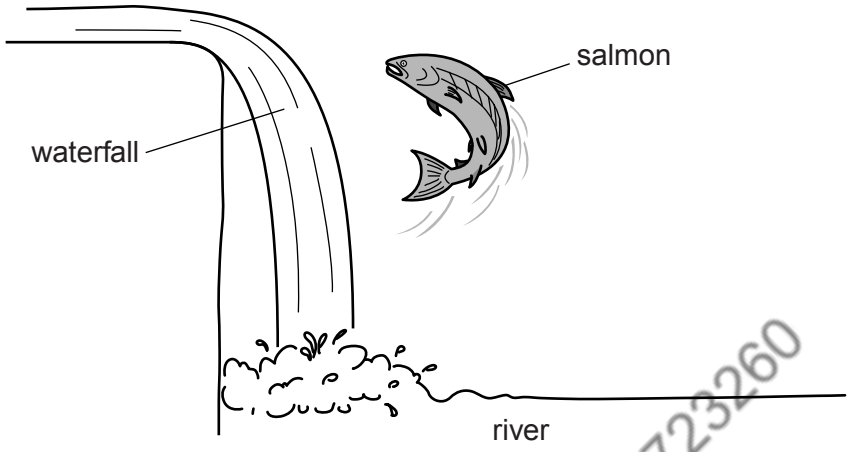


Fig. 3.1

The salmon has a mass of 2.0 kg.

(a) The salmon leaves the water vertically with a kinetic energy of 16.2 J.

(i) Calculate the speed of the salmon as it leaves the water.

$\frac{1}{2}mv^2 = 16.2$ | $v = \sqrt{\frac{2 \times 16.2}{2}}$

speed = $4.0\ ms^{-1}$ ..... [2]

(ii) Calculate the maximum height gained by the salmon. Ignore air resistance.

$mgh = \frac{1}{2}mv^2$ | $h = \frac{16.2}{2 \times 9.81}$

$= 16.2$

gain in height = 0.81 m ..... [3]

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(iii) After the salmon has re-entered the river, it has lost nearly all its original kinetic energy.

State what has happened to the lost energy.

.....

.....

.....

..... [2]

(b) Another salmon, of much greater mass, leaves the water vertically with the same speed.

State and explain how the height of this salmon's jump compares to the height reached by the first salmon.

Some part converted to heat/Internal energy of Salmon's body. Some converted to sound of water (splash) and Potential Energy [2]

[Total: 9]

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6 A diver climbs some steps on to a fixed platform above the surface of the water in a swimming-pool. He dives into the pool. Fig. 2.1 shows the diver about to enter the water.

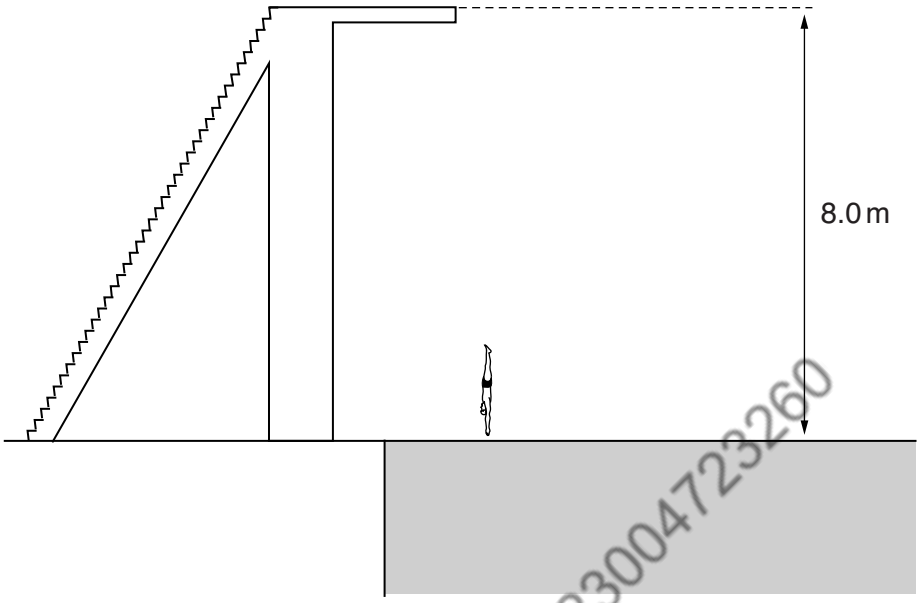


Fig. 2.1

The mass of the diver is 65 kg. The platform is 8.0 m above the surface of the water.

(a) Calculate

(i) the increase in the gravitational potential energy of the diver when he climbs up to the platform.

$mgh = 65 \times 9.81 \times 8$

increase in gravitational potential energy = 5200 J .....[1]

(ii) the speed with which the diver hits the surface of the water. Ignore any effects of air resistance.

$5200 = \frac{1}{2} m v^2$

speed = ...[4]

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(b) In another dive from the same platform, the diver performs a somersault during the descent. He straightens, and again enters the water as shown in Fig. 2.1.

Discuss whether the speed of entry into the water is greater than, less than or equal to the speed calculated in **(a)(ii)**. Ignore any effects of air resistance.

Speed will remain same. Since g.p.e is same and K.E will also be same (height is same)

.....[3]

[Total: 8]

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