1st Year Physics

Chapter # 04

Work and Energy

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Ch #04

Work And Energy

Work: In physics, work is said to be done if a force is applied on a body and it covers some displacement.

Work Done By A Constant Force:

Defination: Thus, the work done on a body by a constant force is defined as the product of the magnitudes of the displacement and the component of the force in the direction of the displacement.

OR

The dot product of force $\vec{F}$ and displacement $\vec{d}$ is called work done.

$$W = \vec{F} \cdot \vec{d}$$

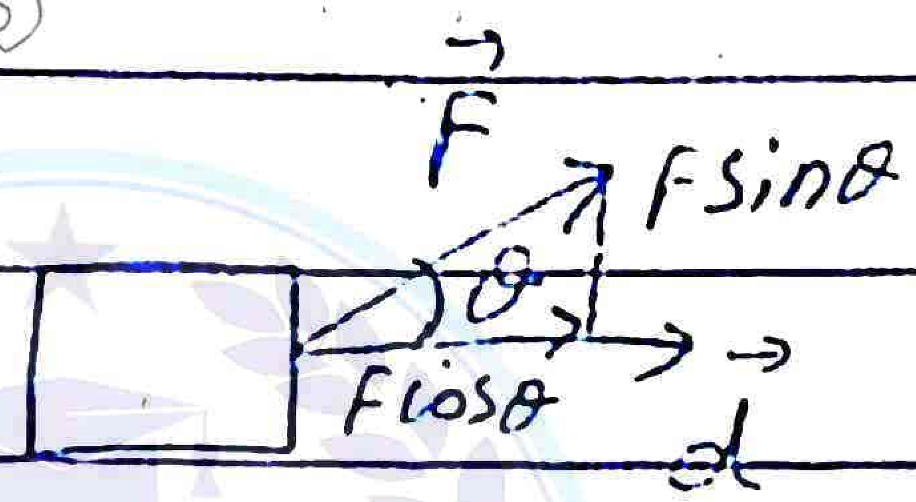
Work is a scalar quantity and its SI unit is Nm called joule (J)

Joule: The work done will be 1 joule if a force of 1 newton acts on a body and body covers a displacement of 1m.

$$1J = 1N \times 1m$$

Explanation:

Consider a body of mass "m" on which a constant force $\vec{F}$ is applied and it covers a displacement $\vec{d}$ while θ is the angle between force and displacement.



Now we resolve force F into its rectangular components F sinθ and F cosθ. Here F cosθ is acting along the displacement of body. So, it is effective component.

$$W = \begin{pmatrix}\text{effective component} \\ \text{of force}\end{pmatrix}(\text{displacem}$$

$$W = (F\cos\theta)(d)$$

$$W = Fd\cos\theta$$

Maximum work done:

Work done will be maximum when force and displacement are parallel.

$$W = Fd\cos\theta$$

here $\theta = 0^\circ$

$$W = Fd\cos 0^\circ$$

$$= Fd(1)$$

$$W = Fd$$

Minimum work done:

Work done will be minimum when force and displacement are perpendicular.

$$W = Fd\cos\theta$$

here $\theta = 90^\circ$

$$W = Fd \cos 90^\circ$$
$$= Fd(0)$$
$$W = 0$$

Positive work done:

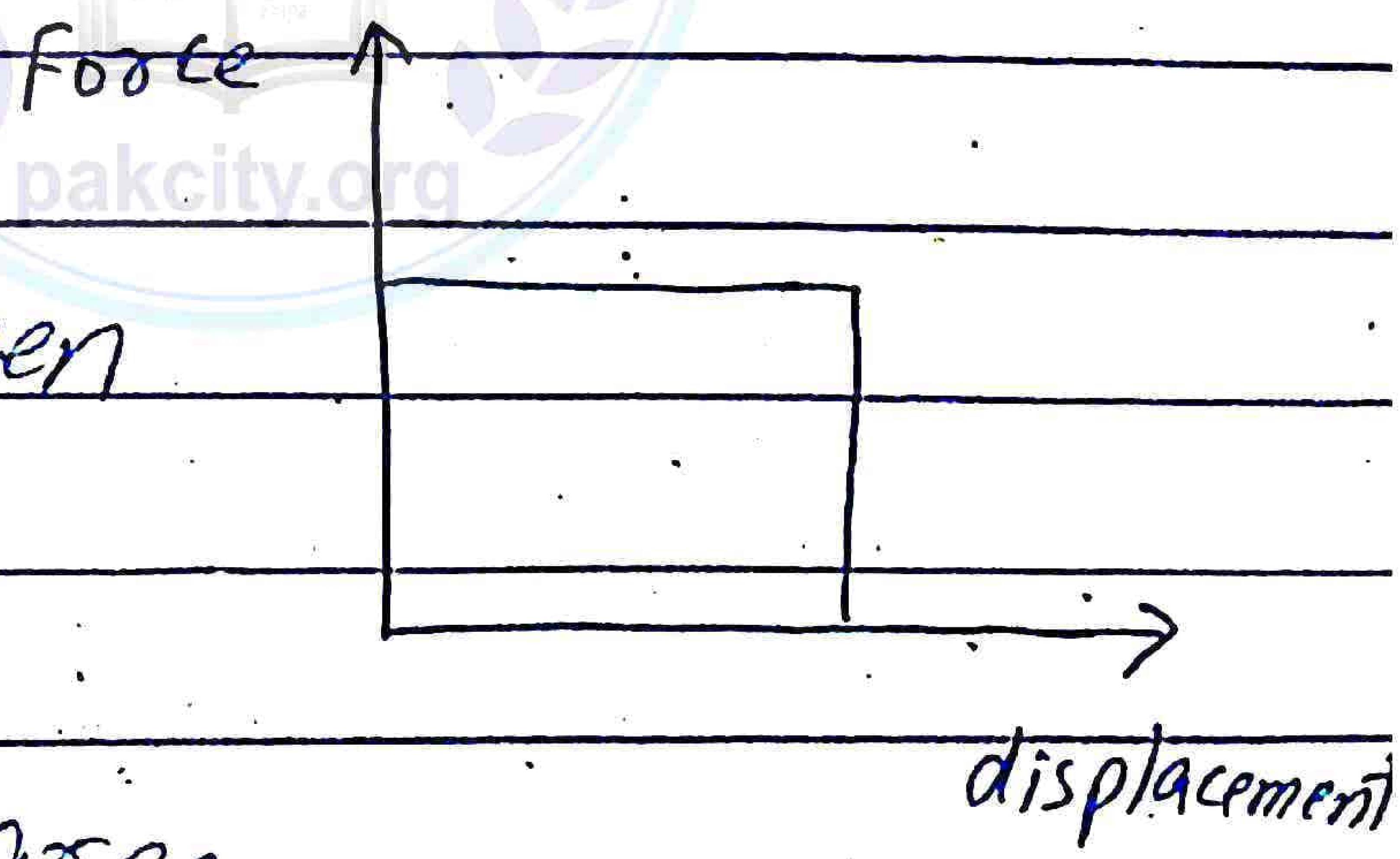
Work done will be positive when $\theta < 90^\circ$

Negative work done:

Work done will be negative when $\theta > 90^\circ$.

Graphical representation:

If we draw the graph between force and displacement.



Then the area of graph will show the work done by the constant force

Work Done By Variable Force:

Variable force:

The force whose magnitude or direction changes with some conditions is called variable force.

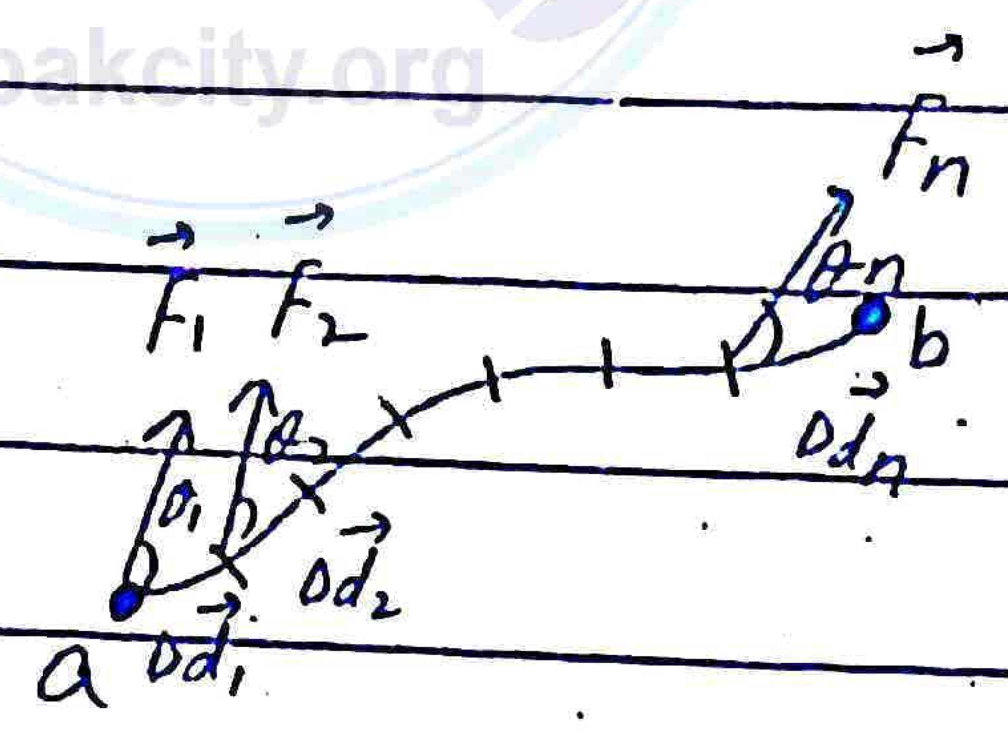
Examples:

i- The gravitational force decreases when we move to height.

ii- The force required to compress the spring increases while compressing.

Explanation:

Consider a body of mass "m" moved from point a to point b. As the gravitational force is variable. So, we divide the path into n



number of small pieces such that each piece has constant force. The forces for each segments are $\vec{F}_1, \vec{F}_2, \ldots \vec{F}_n$ having displacements $\Delta\vec{d}_1, \Delta\vec{d}_2 \ldots \Delta\vec{d}_n$ making angle $\theta_1, \theta_2, \ldots \theta_n$ with each other. Now the work done for first segment will be:

$$\Delta W_1 = \vec{F}_1 \cdot \Delta\vec{d}_1$$

$$\Delta W_1 = F_1 \Delta d_1 \cos\theta_1$$

similarly, for second segment

$$\Delta W_2 = F_2 \Delta d_2 \cos\theta_2$$

$$\vdots \qquad \vdots \qquad \vdots$$

$$\Delta W_n = F_n \Delta d_n \cos\theta_n$$

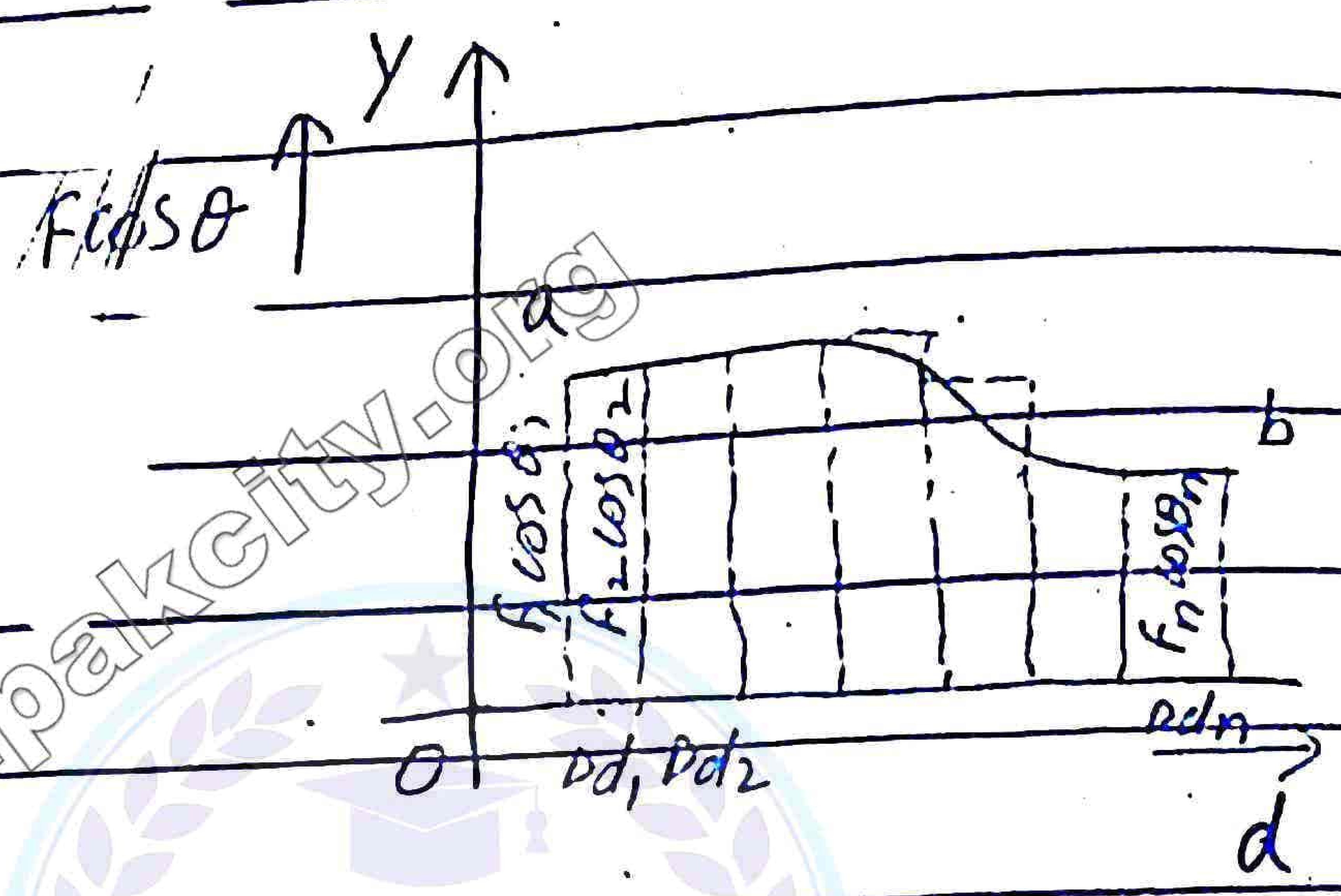
The total work done for path ab will be equal to sum of all work done.

$$W_{total} = \Delta W_1 + \Delta W_2 + \cdots + \Delta W_n$$

$$W_{total} = F_1 \Delta d_1 \cos\theta_1 + F_2 \Delta d_2 \cos\theta_2 + \cdots + F_n \Delta d_n \cos\theta_n$$

$$W_{total} = \sum_{i=1}^{n} F_i \Delta d_i \cos\theta_i$$

Graphical representation:



To represent work done by variable force, we draw a graph between $F\cos\theta$ and d. We divide the area under curve into n number of small rectangles. Now the area under the curve will show the work done.

Area under curve = sum of areas of rectangles

$$\text{Area} = (F_1 \cos\theta_1)(\Delta d_1) + (F_2 \cos\theta_2)(\Delta d_2) + \cdots + (F_n \cos\theta_n)(\Delta d_n)$$

$$\text{Area} = F_1 \cos\theta_1 \Delta d_1 + F_2 \cos\theta_2 \Delta d_2 + \cdots + F_n \cos\theta_n \Delta d_n$$

$$\text{Area} = \sum_{i=1}^{n} F_i \cos\theta_i \Delta d_i$$

This area shows the total work done.

$$W_{total} = \sum_{i=1}^{n} F_i \cos\theta_i \Delta d_i$$

For more accurate work done the rectangles should be small.

$$W_{total} = \lim_{\Delta d \to 0} \sum_{i=1}^{n} F_i \cos\theta_i \Delta d_i$$

Work Done By Gravitational Field:

Gravitational field:

The area or region around the earth in which it can exert its gravitational force of attraction is called gravitational field. If displacement is in the direction of gravitational field then work done will be positive. while if displacement ~~is~~ against the gravitational field then work done will be negative.

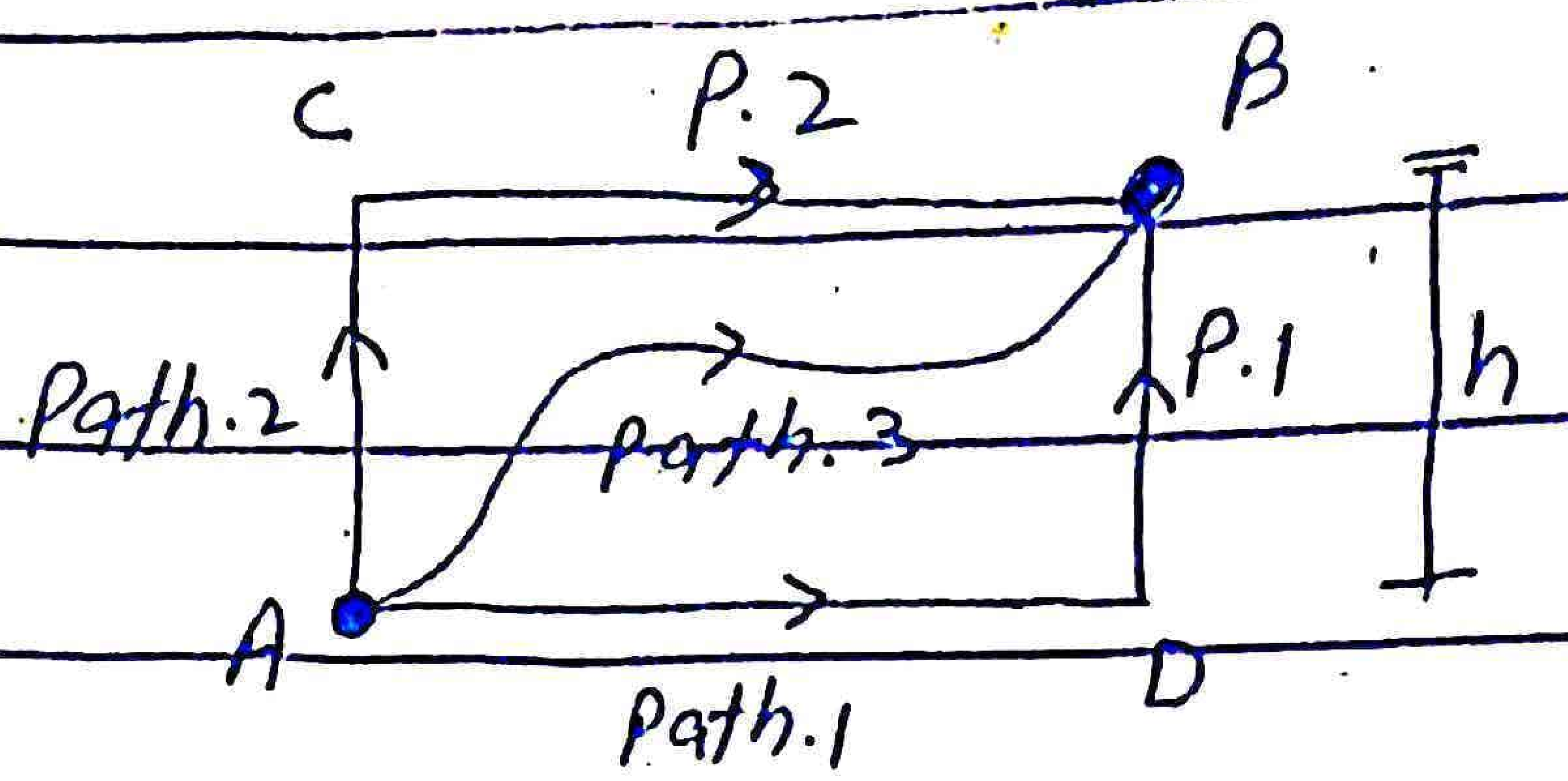
Statement:

work done in the Earth's gravitational field is independent of the path followed.

Explanation:

consider a body of

mass "m" moved from point A to point B. There may be three



different paths 1, 2 and 3. The height is "h". We have to prove that the work done for these paths will be same.

For Path.1: This path has two parts. So, work done for this path will be:

$$W_{ADB} = W_{A\to D} + W_{D\to B}$$

$$= F(AD)\cos\theta + F(DB)\cos\theta$$

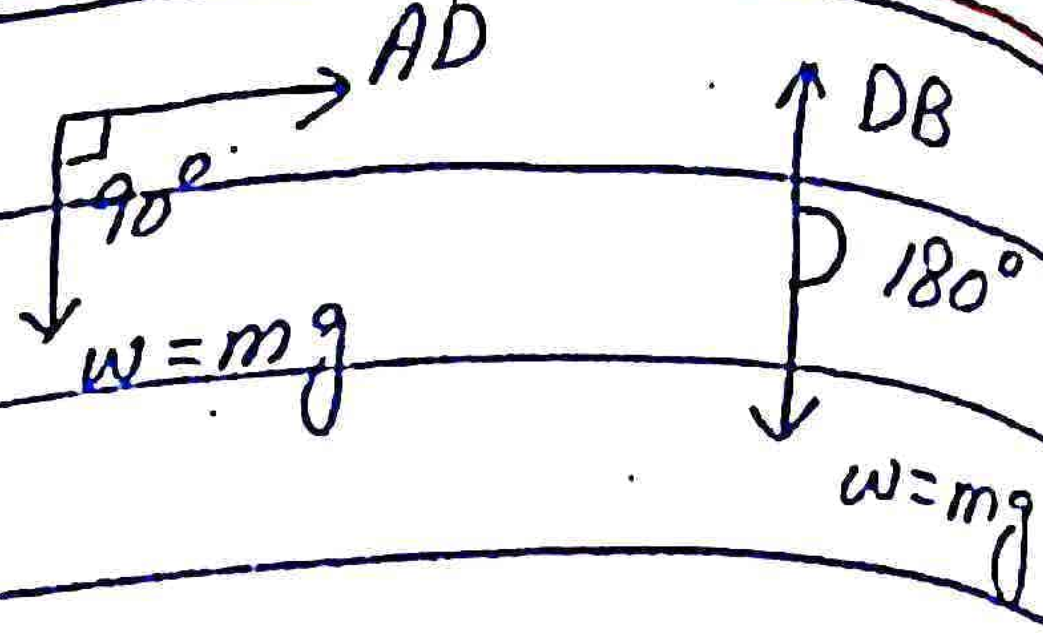
Here the weight of the body will act as force.

$$F = W = mg$$

So,

$$W_{ADB} = mg(AD)\cos\theta + mg(DB)\cos\theta$$

$$W_{ADB} = mg(AD)\cos 90^\circ + mg(DB)\cos 180^\circ$$



$$W_{ADB} = mg(AD)(0) + mg(DB)(-1)$$
$$= 0 + mg(DB)(-1)$$

Here $DB = h$

$$W_{ADB} = -mgh \longrightarrow (1$$

For Path 2: This path has two parts. So, total work done will be:

$$W_{ACB} = W_{A\rightarrow C} + W_{C\rightarrow B}$$

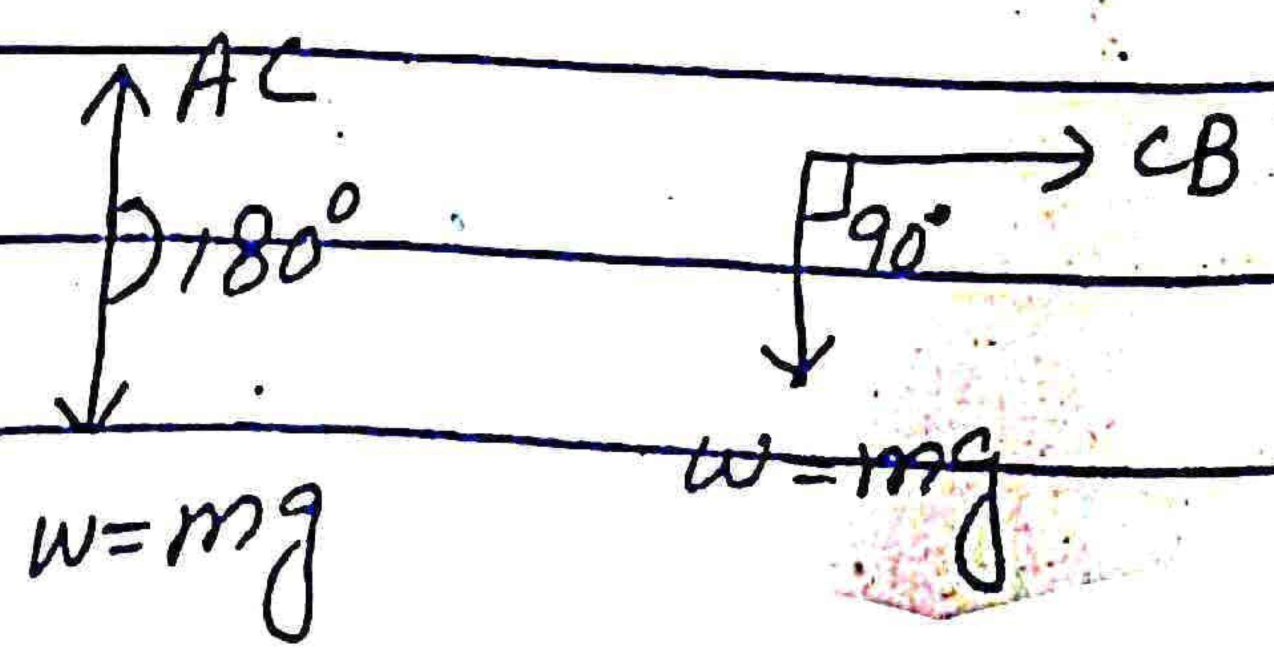
$$= F(AC)\cos\theta + F(CB)\cos\theta$$

Here the weight of body will act as force.

$$F = w = mg$$

So,

$$W_{ACB} = mg(AC)\cos\theta + mg(CB)\cos\theta$$



$$W_{ACB} = mg(AC)\cos 180^\circ + mg(CB)\cos 90^\circ$$
$$= mg(AC)(-1) + mg(CB)(0)$$

$$W_{ACB} = -mg(AC) + 0$$

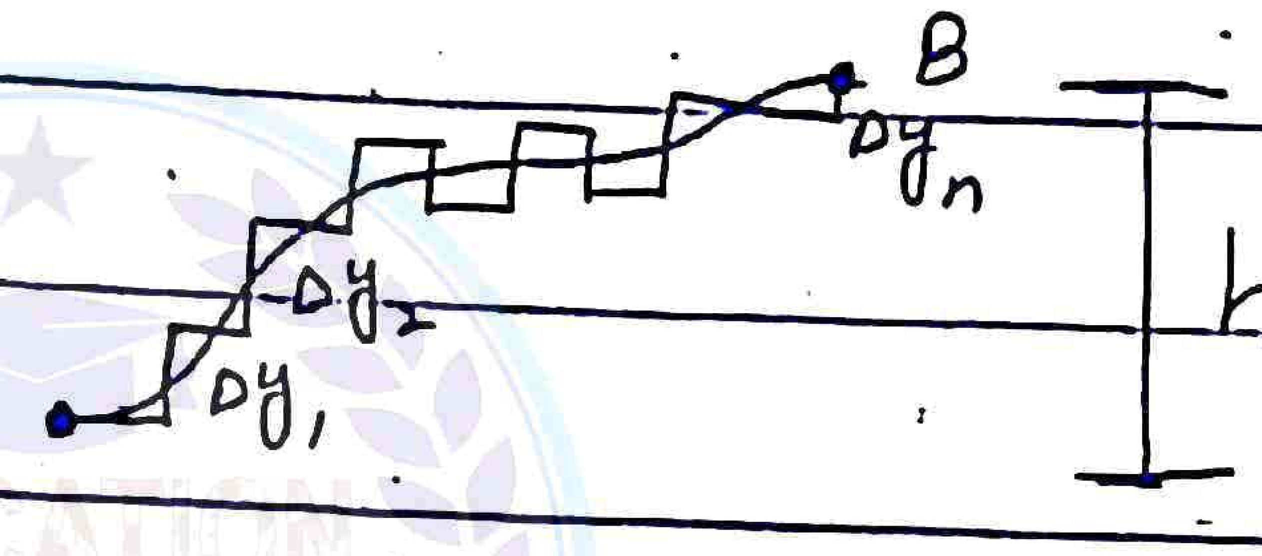
Here $AC = h$

So,

$$W_{ACB} = -mgh \longrightarrow (2$$

For Path. 3:

We divide the path. 3 into n number of horizontal and vertical pieces.



The work done for all the horizontal pieces will be zero. Because the weight will become perpendicular to pieces that makes work done zero. So, the total work done will only be due to vertical steps.

$$W_{AB} = \Delta W_1 + \Delta W_2 + \Delta W_3 + \cdots + \Delta W_n$$

$$= F\Delta y_1 \cos\theta + F\Delta y_2 \cos\theta + F\Delta y_3 \cos\theta + \cdots + F\Delta y_n \cos\theta$$

Here weight of the body acts as force.

$$F = w = mg$$

so.

$$W_{AB} = mg\Delta y_1 \cos\theta + mg\Delta y_2 \cos\theta + mg\Delta y_3 \cos\theta + \cdots + mg\Delta y_n \cos\theta$$

$$W_{AB} = mg\cos\theta\,(\Delta y_1 + \Delta y_2 + \Delta y_3 + \cdots + \Delta y_n)$$

Here $\theta = 180°$

$$W_{AB} = mg\cos 180°(\Delta y_1 + \Delta y_2 + \Delta y_3 + \cdots + \Delta y_n)$$

$$= -mg(\Delta y_1 + \Delta y_2 + \Delta y_3 + \cdots + \Delta y_n)$$

$$W_{AB} = -mgh \rightarrow (3$$

From eq. (1, (2 and (3, we conclude that work done in the Earth's gravitational field is independent of path followed.

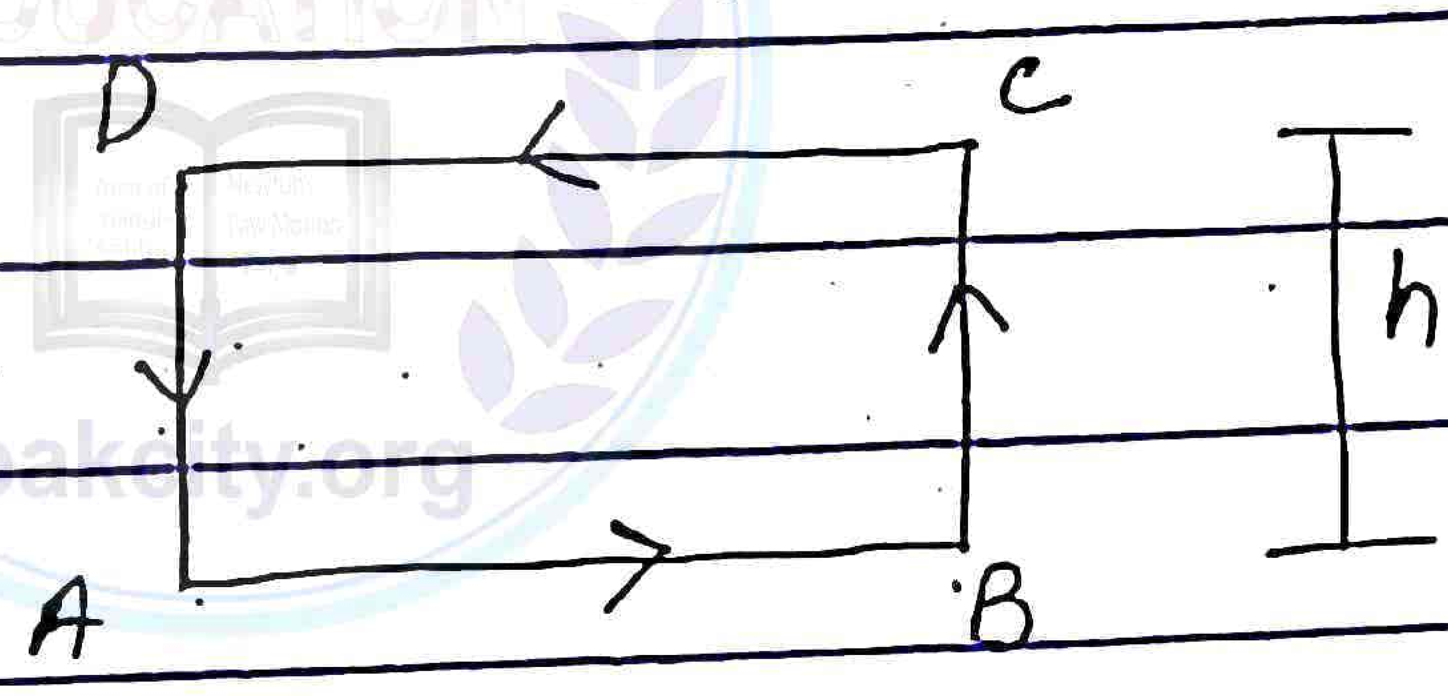
Conservative Field

Defination:

The field in which the work done is independent of the path followed or work done in a closed path be zero, is called a conservative field.

Explanation:

Consider a body of mass "m" moved in a closed path ABCDA of height "h". The total work done will be equal to the sum of the work done for all steps.



$$W_{total} = W_{A\to B} + W_{B\to C} + W_{C\to D} + W_{D\to A}$$

$$W_{total} = F(AB)\cos\theta + F(BC)\cos\theta + F(CD)\cos\theta + F(DA)\cos\theta$$

Here the weight of the body act as force directed downward.

$$F = W = mg$$

$$W_{total} = mg(AB)\cos 90^\circ + mg(BC)\cos 180^\circ + mg(CD)\cos 90^\circ + mg(DA)\cos 0^\circ$$

$$= 0 + mg(BC)(-1) + 0 + mg(DA)(1)$$

here $BC = DA = h$

so;

$$W_{total} = -mgh + mgh$$

$$W_{total} = 0$$

Power: The rate of doing work for a body is called power. It is represented by P.

$$P = \frac{W}{t}$$

Power is a scalar quantity. Its unit is Js^{-1} called watt.

Watt: The power will be 1 ~~power~~ watt if 1 joule of work is done in 1 second.

$$1\,W = \frac{1\,J}{1\,s}$$

Average power: If the total amount of work done is ΔW in total time Δt, then the power will called average power.

$$P_{av.} = \frac{\Delta W}{\Delta t}$$

Instantaneous power: The power of any body at any instant of time is called instantaneous power.

$$P_{ins} = \lim_{\Delta t \to 0} \frac{\Delta W}{\Delta t}$$

Prove that $P = \vec{F}.\vec{V}$

We know that instantaneous power is:

$$P = \lim_{\Delta t \to 0} \frac{\Delta W}{\Delta t}$$

$$= \lim_{\Delta t \to 0} \frac{\vec{F}.\Delta \vec{d}}{\Delta t}$$

$$= \lim_{\Delta t \to 0} \vec{F}. \frac{\Delta \vec{d}}{\Delta t}$$

$$= \vec{F}. \lim_{\Delta t \to 0} \frac{\Delta \vec{d}}{\Delta t}$$

$$P = \vec{F}.\vec{V}$$

Kilowatt-hour: A commercial unit of electrical energy is kilowatt-hour. It is the work done in one hour by an agency whose power is one kilowatt.

$$1\ KWh = (1000\ W)(3600\ S)$$

$$= 3600000\ WS$$

$$1\ KWh = 3.6 \times 10^{6}\ J$$

$$1\ KWh = 3.6\ MJ$$

MCQ. KWh is the greater unit for energy as compared to joule.

Energy: The ability of a body to do work is called energy.

Types: There are different forms of energy such as mechanical energy, heat energy, sound energy, light energy, electrical energy, nuclear energy etc.

Mechanical energy: The

energy possessed by a body due to its motion or position is called mechanical energy.

There are two types of mechanical energy:

i- Kinetic energy

ii- Potential energy.

Kinetic energy: The energy possessed by a body due to its motion is called kinetic energy.

Examples:

i- A moving car has K.E

ii- Moving air has K.E

iii- Flowing water has K.E

Formula: If a body of mass "m" is moving with velocity 'v'. Then

$$K.E = \frac{1}{2} m v^2$$

Potential energy: The energy possessed by a body due to its position is called potential energy.

Examples:

i- A raised hammer has P.E

ii- Water in a dam has P.E

iii- Compressed spring has P.E

iv- Stretched bow has P.E.

Types: There are two types of potential energy.

i- Gravitational potential energy

ii- Elastic potential energy

Gravitational potential energy

The energy possessed by a body due to its height is called gravitational potential energy.

Examples:

i- Raised hammer has gravitational P.E

ii- Water in a dam has gravitational P.E

Formula: If a body of mass "m" is raised to height "h", then

$$P.E = mgh$$

Elastic potential energy:

The energy possessed by a body due to its stretched or compressed position is called elastic potential energy.

Examples:

i- A compressed spring has elastic P.E

ii- A stretched bow has elastic P.E.

Work-energy principle:

Statement:

Work done on the body equals to change in its kinetic energy or potential energy.

Explanation:

Consider a body of mass "m" moving with initial velocity "V_i", a force "F" is applied on it and its velocity changes to "V_f" with acceleration "a"

According to third equation of motion

$$2ad = V_f^2 - V_i^2$$

$$d = \frac{1}{2a}(V_f^2 - V_i^2)$$

According to Newton's second law:

$$F = ma$$

Multiplying the above eq.s

$$Fd = ma\left(\frac{1}{2a}\right)(V_f^2 - V_i^2)$$

$$= \frac{1}{2}m(V_f^2 - V_i^2)$$

$$= \frac{1}{2}mV_f^2 - \frac{1}{2}mV_i^2$$

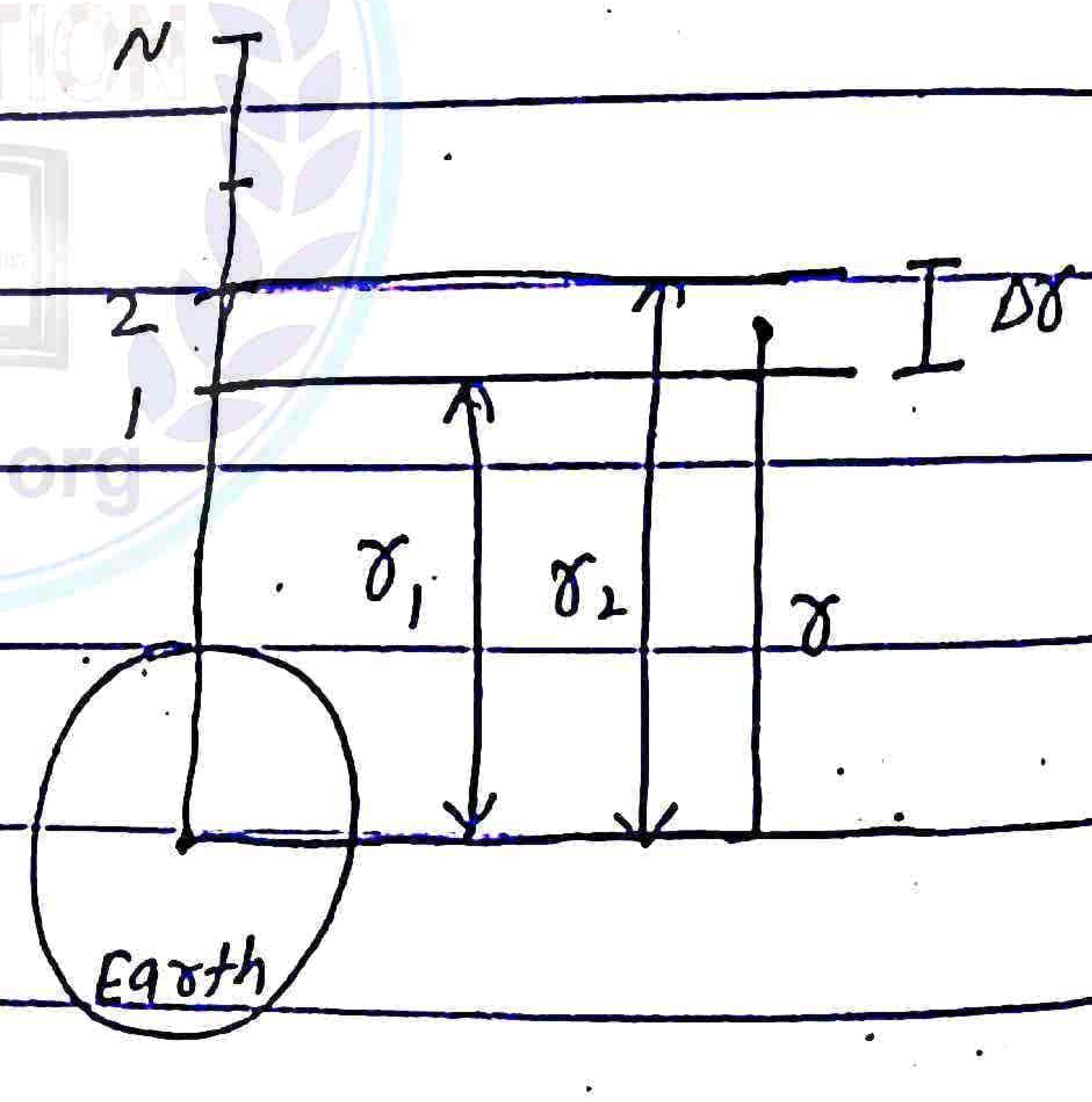
$$\text{Work done} = (K.E)_f - (K.E)_i$$

$$\text{Work done} = \text{change in } K.E$$

Absolute Potential Energy

Defination: The absolute gravitational potential energy of an object at a certain position is the work done by the gravitational force in displacing the object from that position to infinity where the force of gravity becomes zero.

Explanation:



Consider a body of mass 'm' moved upward from the surface of earth. The gravitational force decreases as we move upward. We divide the path into

N number of small steps so that the force remains constant in each step. The distance between point 1 and centre of earth is r_1 while r_2 is the distance from centre of earth to point 2 and Δr is the distance between point 1 and point 2 mathematically,

$$\Delta r = r_2 - r_1$$

$$\Delta r + r_1 = r_2$$

We take a mid point between points 1 and 2 having distance r from the centre of earth.

$$r = \frac{r_1 + r_2}{2}$$

so,

$$r = \frac{r_1 + \Delta r + r_1}{2}$$

$$= \frac{2r_1 + \Delta r}{2}$$

$$r = \frac{2r_1}{2} + \frac{\Delta r}{2}$$

$$r = r_1 + \frac{\Delta r}{2}$$

Taking square on both sides:

$$(r)^2 = \left(r_1 + \frac{\Delta r}{2}\right)^2$$

$$r^2 = (r_1)^2 + \left(\frac{\Delta r}{2}\right)^2 + \cancel{2}(r_1)\left(\frac{\Delta r}{\cancel{2}}\right)$$

$$= r_1^2 + \left(\frac{\Delta r}{2}\right)^2 + r_1 \Delta r$$

Here $\left(\frac{\Delta r}{2}\right)^2$ is a very small quantity and we neglect it.

$$r^2 = r_1^2 + r_1 \Delta r$$

But $\Delta r = r_2 - r_1$

so,

$$r^2 = r_1^2 + r_1(r_2 - r_1)$$

$$r^2 = \cancel{r_1^2} + r_1 r_2 - \cancel{r_1^2}$$

$$r^2 = r_1 r_2$$

According to law of gravitation

$$F = G\frac{m_1 m_2}{r^2}$$

so,

$$F = G\frac{mM}{r^2}$$

Here m is mass of object, M is mass of earth and r is the distance between them.

Put $r^2 = r_1 r_2$

so,

$$F = G\frac{mM}{r_1 r_2}$$

The work done in displacing the object from point 1 to point 2 is:

$$W_{1\to 2} = \vec{F} \cdot \Delta\vec{r}$$

$$W_{1\to 2} = F \Delta r \cos\theta$$

As displacement is against the force of gravitation

$\theta = 180^\circ$

$$W_{1\to 2} = G\frac{mM}{r_1 r_2}(r_2 - r_1)\cos 180^\circ$$

$$W_{1\to 2} = -GmM\left(\frac{r_2 - r_1}{r_1 r_2}\right)$$

$$= -GmM\left(\frac{r_2}{r_1 r_2} - \frac{r_1}{r_1 r_2}\right)$$

$$W_{1\to 2} = -GmM\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

Similarly,

$$W_{2\to 3} = -GmM\left(\frac{1}{r_2} - \frac{1}{r_3}\right)$$

$$\vdots \qquad \qquad \vdots$$

$$W_{N-1\to N} = -GmM\left(\frac{1}{r_{N-1}} - \frac{1}{r_N}\right)$$

The total work done in displacing the object from point.1 to Point.N can be calculated by adding work done for all steps:

$$W_{total} = W_{1\to 2} + W_{2\to 3} + \cdots + W_{N-1\to N}$$

$$W_{total} = -GmM\left(\frac{1}{r_1} - \frac{1}{r_2} + \frac{1}{r_2} - \frac{1}{r_3} + \cdots + \frac{1}{r_{N-1}} - \frac{1}{r_N}\right)$$

$$W_{total} = -GmM\left(\frac{1}{r_1} - \frac{1}{r_N}\right)$$

For absolute potential energy, point N is situated at infinity.

$$N \to \infty \quad , \quad \frac{1}{r_N} = \frac{1}{\infty} = 0$$

So,

$$W_{total} = -GmM\left(\frac{1}{r_1} - 0\right)$$

$$W_{total} = -\frac{GmM}{r_1}$$

In general form

$$W_{total} = -\frac{GmM}{r}$$

This amount of work done appears as the absolute potential energy of the object.

$$U = -\frac{GmM}{r}$$

Result: when the distance of object from centre of earth (r) increases, the absolute potential energy will become less in negative. That shows increase in absolute potential energy.

If the object is moved from the surface of earth, then the distance will be equal to the radius of earth. So, absolute potential energy becomes

$$U_g = -\frac{GmM}{R}$$

Escape velocity

Defination:

The initial velocity given to a body with which it goes out from the gravitational field of earth is called escape velocity. mathematically,

$$V_{esc} = \sqrt{2gR}$$

Explanation:

Consider a body of mass "m" thrown upward with initial velocity V_{esc} and as it moves upward it gets potential energy. The initial K.E given to the body is:

$$\text{initial } K.E = \frac{1}{2} m V_{esc}^2$$

The increase in potential energy as the body moves upward is given by:

$$\text{increase in } P.E = 0 - \left(-\frac{GmM}{R}\right)$$

$$= \frac{GmM}{R}$$

According to law of

conservation of energy, the initial K.E given to the body will be equal to increase in P.E. So,

initial K.E = increase in P.E

$$\frac{1}{2}\cancel{m}v_{esc}^2 = \frac{G\cancel{m}M}{R}$$

$$v_{esc}^2 = \frac{2GM}{R}$$

$$\boxed{v_{esc} = \sqrt{\frac{2GM}{R}}} \rightarrow (1$$

By putting the values of G, M and R, we can get the value of escape velocity

Gravitational constant = $G = 6.673 \times 10^{-11}\ Nm^2 kg^{-2}$

Mass of earth = $M = 6 \times 10^{24}\ kg$

Radius of earth = $R = 6.4 \times 10^6\ m$

The gravitational force acting between the object and earth will be equal to the weight of the object

weight = Gravitational force

$$\cancel{m}g = G\frac{\cancel{m}M}{R^2}$$

$$g = \frac{GM}{R^2}$$

$$gR = \frac{GM}{R}$$

Put this value in eq. (i

$$\boxed{V_{esc} = \sqrt{2gR}}$$

The value of escape velocity comes out $11\ kms^{-1}$

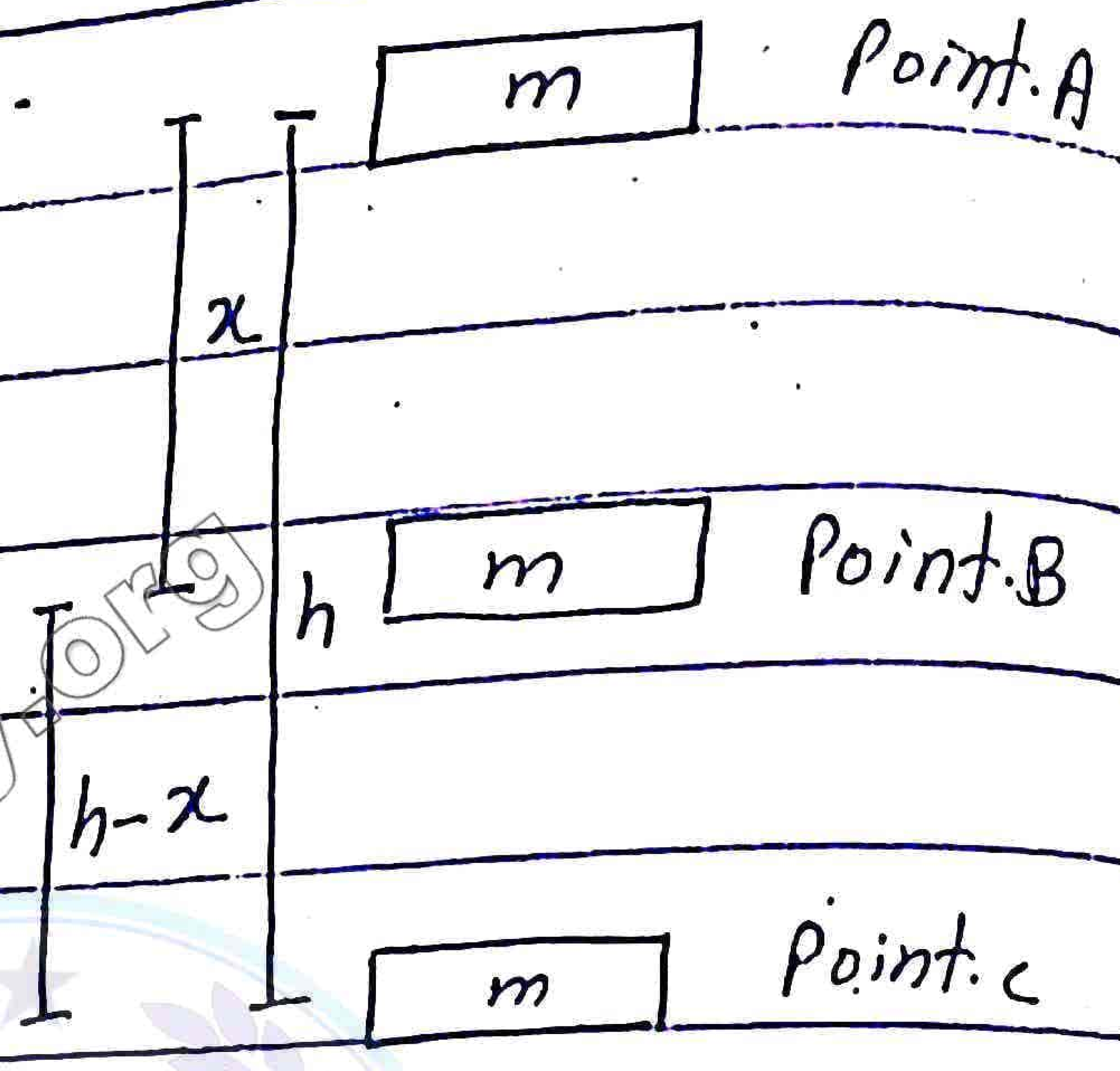
Interconversion Of Potential Energy And Kinetic Energy:

Statement:

Energy can neither be created nor be destroyed. it can be transformed from one kind into another, but the total amount of energy remains constant.

Explanation:

consider a body of mass "m" droped from point.A. It has gravitational P.E due to its height.



When it falls down, this P.E changes into K.E. But total amount of energy remains constant. We take three points A, B and C. The height of point.A is h, height of point.B is h-x while point.c has negligible height. Now we will calculate total amount of energy for these points.

For Point A:

At this point, the object has P.E due to height "h"

$$P.E = mgh$$

and

$$K.E = \frac{1}{2} m v_A^2$$

but $v_A = 0$

so, $K.E = 0$

Total energy $= P.E + K.E$

$$= mgh + 0$$

$$T.E = mgh$$

For Point B:

At this point, the object has P.E due to height $(h-x)$

$$P.E = mg(h-x)$$

and

$$K.E = \frac{1}{2} m V_B^2$$

According to third equation of motion:

$$2aS = V_f^2 - V_i^2$$

Here $a = g$, $S = x$, $V_f = V_B$

$$V_i = V_A = 0$$

$$2gx = V_B^2 - 0$$

$$V_B^2 = 2gx$$

Put in expression of K.E

$$K.E = \frac{1}{\cancel{2}} m(\cancel{2}gx)$$

$$K.E = mgx$$

Now

$$\text{Total energy} = P.E + K.E$$

$$T.E = mg(h-x) + mgx$$

$$= mgh - \cancel{mgx} + \cancel{mgx}$$

$$T.E = mgh$$

For Point C:

At this point, the P.E will be zero due to negligible height.

$$P.E = mg(0)$$

$$P.E = 0$$

and

$$K.E = \frac{1}{2} m V_c^2$$

According to third equation

of motion:

$$2aS = V_f^2 - V_i^2$$

here $a = g$, $S = h$, $V_f = V_c$

$V_i = V_A = 0$

so, $2gh = V_c^2 - 0$

$$V_c^2 = 2gh$$

Put in expression of K.E

$$K.E = \frac{1}{\cancel{2}} m (\cancel{2} g h)$$

$$K.E = mgh$$

Now

$$\text{Total energy} = P.E + K.E$$

$$T.E = 0 + mgh$$

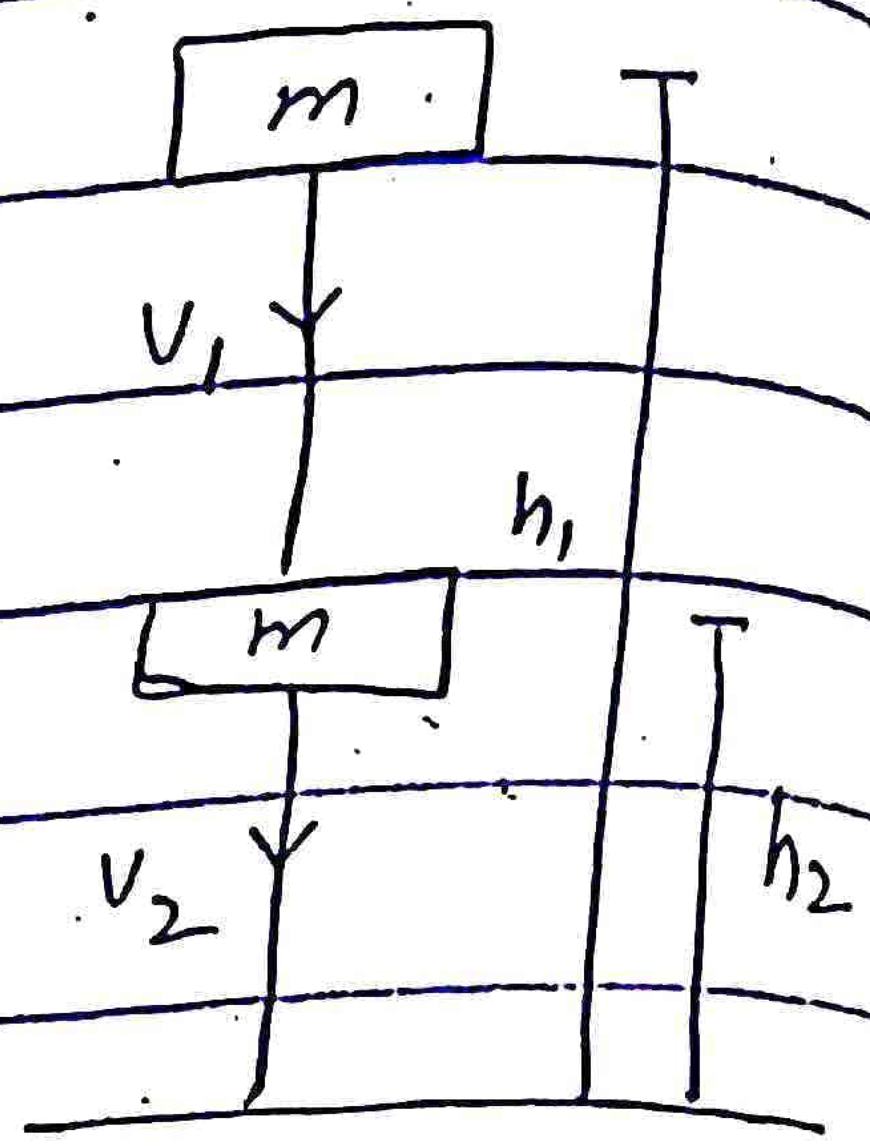
$$T.E = mgh$$

Result: The object has P.E due to its height. When it falls down, this P.E changes into K.E. At the point just before striking the ground all the P.E is converted into K.E.

Loss in P.E = Gain in K.E

$mg(h_1 - h_2)$

$= \frac{1}{2}m(v_2^2 - v_1^2)$



Effect of air friction:

If we take into consideration the air present in the path of body. Then some part of P.E will be used against the air friction.

Loss in P.E = Gain in K.E + Work done against friction

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

Here f is the force of friction.

Conservation of Energy:

Energy can neither be created nor be destroyed, it can be transformed from one kind into another but the total amount of energy remains constant.

For example: P.E of the falling object changes to k.E, but on striking the ground, the k.E changes into heat and sound.

Energy from tides:

Gravitational force of the moon gives rise to tides in the sea. The tides raise the water in the sea roughly twice a day. If the water at the high tide is trapped in a basin by constructing a dam, then it is possible to use this as a source of energy. The tides in rushing water also drives, turbines and generate electricity.

Salter's duck:

The tidal movement and the winds blowing across the surface of the ocean produce strong water waves. A device invented by professor Salter is known Salter's duck. It consists of two parts:

1. Duck float
2. Balance float.

The wave energy makes duck float move relative to balance float. The relative motion of the duck float is then used to run electricity generators.

Why is Solar ~~Constant~~ energy reduced in earth's atmosphere:

While passing through the atmosphere, the total energy is reduced due to reflection, scattering and absorption by dust particles, water vapours and other gases. On a clear day at noon, the intensity of the solar energy reaching the earth's surface is about $1kWm^{-2}$.

Solar constant:

The earth receives huge amount of energy directly from the sun each day. Solar energy at normal incidence outside the earth's atmosphere is about $1.4kWm^{-2}$ which is referred as solar constant.

Solar cells:

The devices that perform the direct conversion of sunlight into electricity through the use of semi-conductor devices called solar cells also known as photo voltaic cells. Solar cells are thin wafers made from silicon. Electrons in the silicon gain energy from sunlight to create a voltage.

Solar panel: The voltage produced by a single voltaic cell is very low. In order to get sufficient high voltage for practical uses, a large number of such cells are connected in series forming a solar cell panel.

How can we get energy from solar cell at night?

For cloudy days or nights, electric energy can be stored during the sunlight in Nickel/cadmium batteries by connecting them to solar panels. These batteries can then provide power to electrical appliances at night or on cloudy days.

Uses of solar cells:

1, Solar cells are used to power satellites having large solar pannels which are kept facing the sun.

2- The use of solar panels are remote ground based weather stations and rain forest communication systems.

3- Solar calculators are also in use nowadays.

Biomass:

Biomass is the potential source of renewable energy. This includes all organic materials such as crop residue, natural vegetation, trees, animal drug and sewage.

How can we get energy from biomas? Write methods?

There are many methods used for the conversion of biomass into fuels.

But the most common are:
1. Direct combustion
2. Fermentation.

Biofuel:

Biofuel such as ethanol (alcohol) is the replacement of gasoline. It is obtained by fermentation of biomass using enzymes and by decomposition through bacterial action in the absence of air (oxygen).

Digester:

The rotting of biomass in a closed tank called a digester produces biogas which can be piped out to use for cooking and heating.

How can we get electricity by solid waste?

Waste products like wood waste, crop residue, and particularly municipal solid waste can be used to get energy by direct conversion. It is probably the most commonly used conversion process in which waste material in burnt in a confined container. Heat produced in this way is directly utilized in the boiler to produce steam that can run turbine generator.

Geothermal energy:

The heat energy extracted from inside the Earth in the form of hot water or steam is called geothermal energy.

How is heat generated with in the earth?

1- Radioactive decay:

The energy, heating the rocks, is constantly being released by the decay of radioactive elements.

2- Residual Heat of The earth:

At some places hot igneous rocks, usually within 10km of the Earth's surface, are in a molten and partly molten state. They conduct heat energy from the Earth's interior which is still very hot. The temperature of these rocks is about 200°C or more.

3- Compression of Material:

The compression of material deep inside the Earth also causes generation of heat energy.

How can we get electricity by geothermal energy?

At places water is not present and hot rocks are not very deep, the water is pumped down through them to get steam. The steam then can be used to drive turbines or for direct heating.

Geyser: An interesting phenomenon of geothermal energy is a geyser. It is a hot spring that discharges steam and hot water, intermittently releasing an explosive column into the air. Most gyser erupt at irregular intervals. They usually occur in volcanic regions.

Aquifer: Aquifer is a layer of rock holding water that allows water to percolate through it with pressure.

Short Questions

4.1: In both the situations work done is zero because of zero displacement.

$$W = Fd\cos\theta$$

here $d = 0$

So, $W = F(0)\cos\theta$

$$W = 0$$

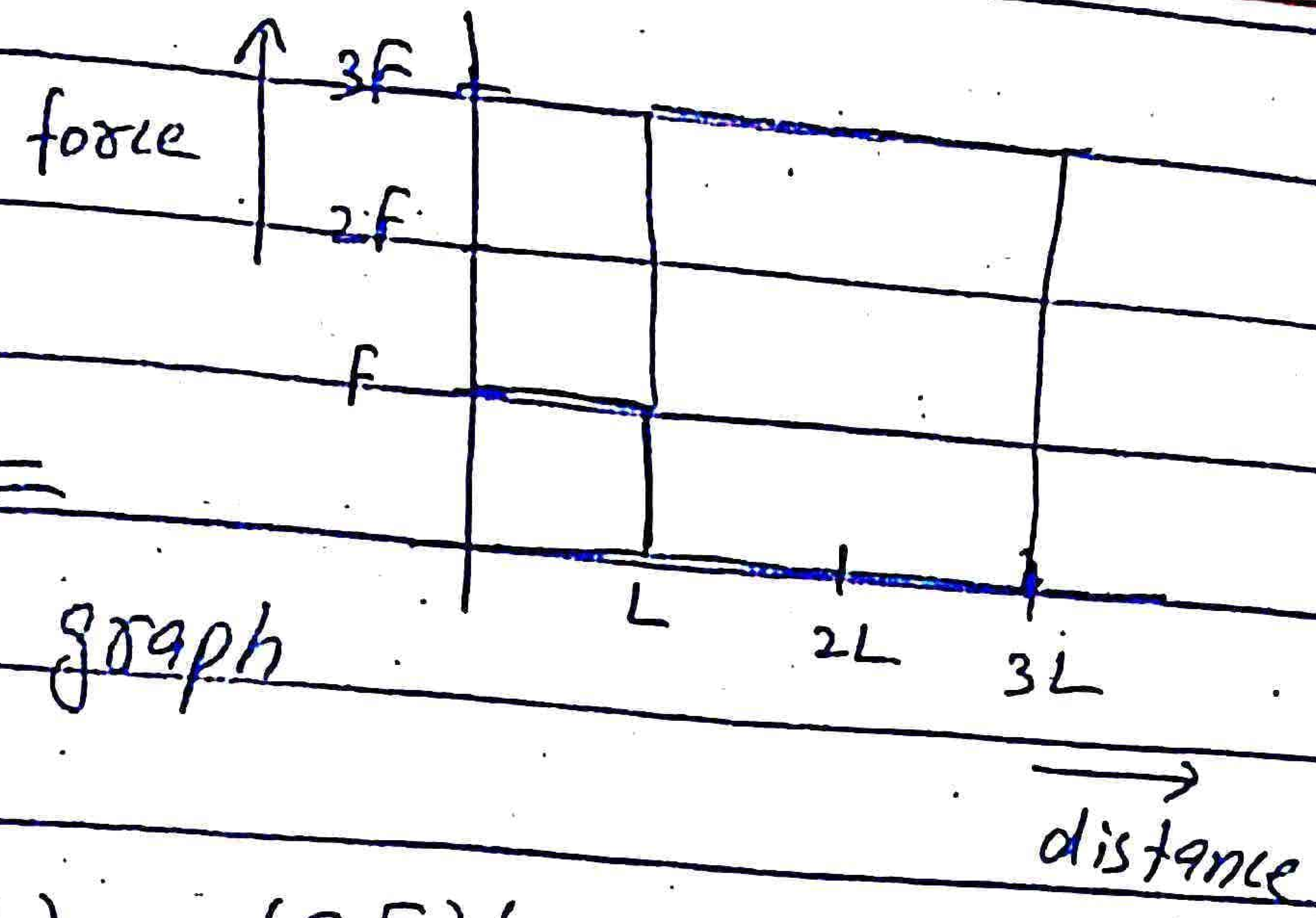
4.2: $W = ?\ (KJ)$, $m = 10\ kg$

$h = 10\ m$; $g = 9.8\ ms^{-2}$

For height

$$W = P.E$$
$$= mgh$$
$$= (10)(9.8)(10)$$
$$W = 980\ J$$
$$= 0.980 \times 10^{3}\ J$$
$$W = 0.98\ KJ$$

4.3:



work done = area of graph

$W = (F)(L) + (3F)(2L)$

$= FL + 6FL$

$W = 7FL$

4.4:

case.1

$m = 50\,kg$,

$h = 50\,cm = \frac{50}{100}\,m$

$h = 0.5\,m$, $g = 9.8\,ms^{-2}$

For height

$W = P.E$

$= mgh$

$= (50)(9.8)(0.5)$

$W = 245\,J$

case.2

$m = 50\,kg$, $d = 2\,m$

$F = 50\,N$

$W = Fd$

$= (50)(2)$

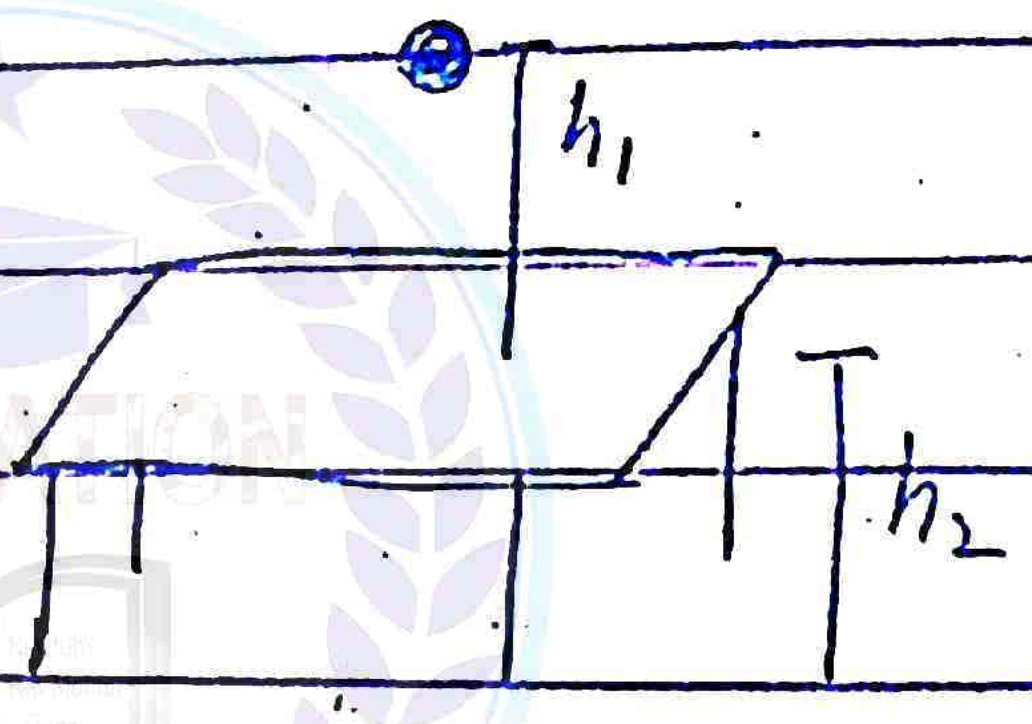
$W = 100\,J$

so, for case.1, work done is greater.

4.5: when an object has 1 J of potential energy, it means that 1 J of work has done on it. Moreover, the object can now exert a force of 1 N through a distance of 1 m.

$$1\,J = 1\,N \times 1\,m$$

4.6: Both the students are correct the difference is only due to reference point. If we take table as reference point, then P.E is mgh_1. If we take floor as reference point then P.E is $mg(h_1 + h_2)$



4.7: When a rocket re-enters the atmosphere, its nose cone becomes very hot due to its friction with dust particles and water vapours present in the atmosphere.

4.8:

a) compressed spring has elastic potential energy

b) water in a high dam has gravitational potential energy.

c) A moving car has kinetic energy.

4.9: The cup has gravitational potential energy due to its height. When it falls down this P.E changes into kinetic energy. Just before striking the ground, all P.E is converted into K.E. When the cup strikes the ground, K.E is converted into sound energy, heat energy and used to break the cup into pieces.

4.10: Firstly, the stone has elastic potential energy due to stretched position of catapult when the stone is thrown, this P.E changes into kinetic energy when stone hits the greenhouse window then K.E is converted into sound energy, heat energy and used to smash the window.

Numericals

4.1 Data

force = $F = 40\,N$, angle $= \theta = 20^\circ$

Work done $= W = ?$

displacement $= d = 20\,m$

Solution:

$$W = F \cdot d \cos\theta$$

$$= (40)(20)\cos 20^\circ$$

$W = 751\ J$

$= 7.51 \times 10^{2}\ J$

$$\boxed{W = 7.5 \times 10^{2}\ J}$$

4.2 Data

mass $= m = 3.35 \times 10^{-5}\ kg$

height $= h = 100\ m$

work done by gravity = ?

work done by friction = ?

$g = 9.8\ ms^{-2}$

Solution: For height

$P.E = W = mgh$

$W = (3.35 \times 10^{-5})(9.8)(100)$

$W = 0.0328\ J$

work done by gravity $= 0.0328 J$

The work done due to air friction will be equal but opposite to it. so,

work done by friction $= -0.0328 J$

4.3 Data

thickness of brick $= h = 6\,cm$

$$h = \frac{6}{100}\,m = 0.06\,m$$

mass $= m = 1.5\,kg$, $g = 9.8\,ms^{-2}$

work done $= W = ?$

Solution:

To stack the ten bricks one on the top of another, there will be no work done for first brick. So,

$$W = 0 + mgh + 2mgh + 3mgh + 4mgh + 5mgh + 6mgh + 7mgh + 8mgh + 9mgh$$

$$W = 45mgh$$

$$= 45(1.5)(9.8)(0.06)$$

$$W = 39.69\,J$$

$$\boxed{W = 40\,J}$$

4.4 Data

mass of car $= m = 800\,kg$

initial velocity $= v_i = 54\,kmh^{-1}$

$$v_i = \frac{54\,km}{h} = \frac{54000\,m}{3600\,s}$$

$v_i = 15\,ms^{-1}$, distance $= d = 60m$

final velocity $= v_f = 0$

retarding force $= F = ?$

Solution: According to work-energy principle:

$$Fd = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$$

$$F(60) = 0 - \frac{1}{2}(800)(15)^2$$

$$F(60) = -90000$$

$$F = -\frac{90000}{60}$$

$$F = -1500\,N$$

$-ve$ sign shows that force is retarding.

$$\boxed{F = 1500\,N}$$

The original K.E is used to overcome the friction.

4.5 Data

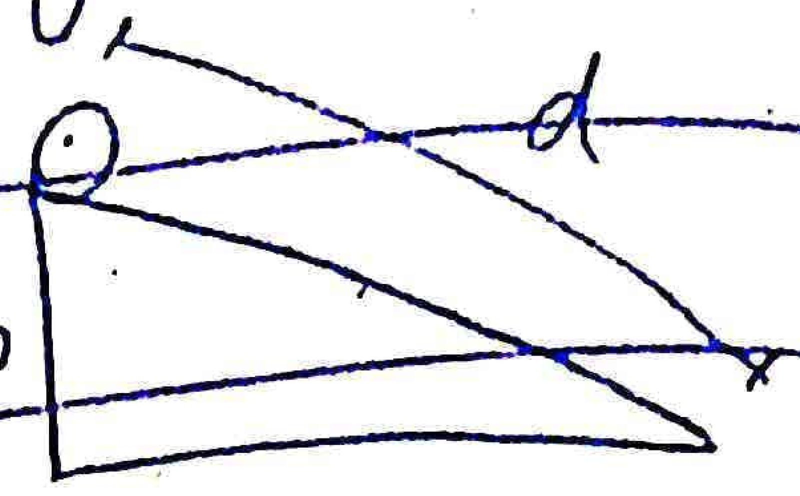
mass = m = 1000 Kg, height = h = 10m

distance = d = 100m

speed = v = ?

retarding force

= F = 480 N, g = 9.8 ms^{-2}



Solution: According to work-energy principle:

loss in P.E = gain in K.E + work done against friction

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

$$(1000)(9.8)(10) = \frac{1}{2}(1000)v^2 + (480)(100)$$

$$98000 = 500v^2 + 48000$$

$$98000 - 48000 = 500v^2$$

$$50000 = 500v^2$$

$$\frac{50000}{500} = v^2$$

$$\sqrt{v^2} = \sqrt{100}$$

$$\boxed{v = 10\ ms^{-1}}$$

4.6 **Data**

Volume $= V = 100\ m^3$, height $= h = 10 m$

time $= t = 20$ min. $= (20)(60)$ s

$t = 1200$ s ; density $= \rho = 1000\ kgm^{-3}$

increase in P.E $= ?$

Power $= P = ?$, $g = 9.8\ ms^{-2}$

Solution:

$$P.E = mgh$$

As

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

$$\rho = \frac{m}{V}$$

$$\rho V = m$$

So,

$$P.E = \rho V g h$$

$$= (1000)(100)(9.8)(10)$$

$$\boxed{P.E = 9.8 \times 10^6\ J}$$

$$P = \frac{W}{t}$$

For height

$$P = \frac{P.E}{t} = \frac{9.8 \times 10^6}{1200}$$

$P = 8166 \ W$

$P = 8.166 \times 10^3 \ W$

$\boxed{P = 8.2 \ KW}$

4.7 Data

force $= F = 400 \ N$,

velocity $= v = 80 \ km \ h^{-1} = \frac{80 \ km}{h}$

$v = \frac{80000 \ m}{3600 \ s} = 22.2 \ ms^{-1}$

Power $= P = ? \ (KW)$

Solution:

$P = FV$

$= (400)(22.2)$

$P = 8880 \ W$

$= 8.880 \times 10^3 \ W$

$\boxed{P = 8.9 \ KW}$

4.8 Data

force = F = ? , initial speed = $v_i = 0$

mass of electron = $m = 9.1 \times 10^{-31}$ kg

final speed = $v_f = 2 \times 10^{7}\ ms^{-1}$

distance = $d = 5cm = \frac{5}{100}m = 0.05m$

Solution: According to work-energy principle:

$$Fd = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$$

$$F(0.05) = \frac{1}{2}(9.1 \times 10^{-31})(2 \times 10^{7})^2 - 0$$

$$F(0.05) = 1.82 \times 10^{-16}$$

$$F = \frac{1.82 \times 10^{-16}}{0.05}$$

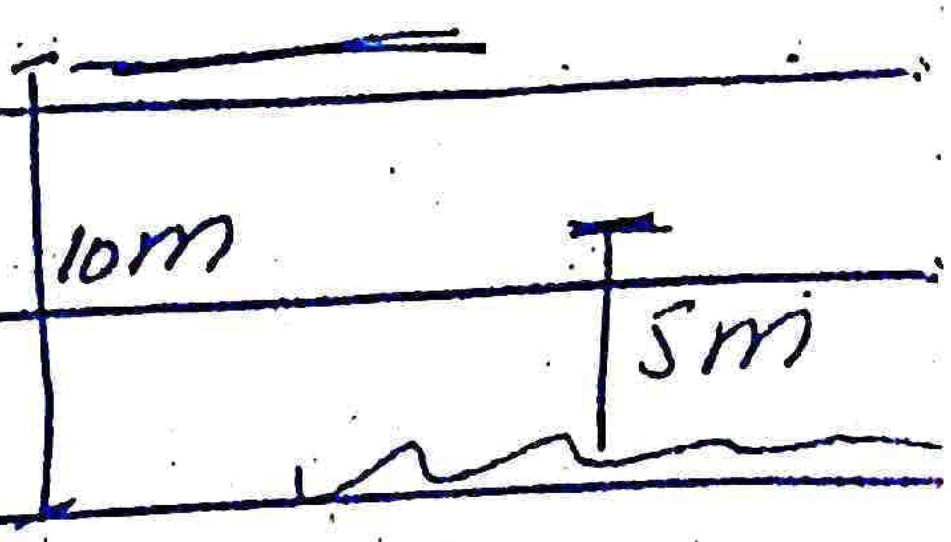
$$\boxed{F = 3.6 \times 10^{-15}\ N}$$

4.9 Data

weight = $W = 750$ N

total height = 10m

speed = V = ?



height $= h = 5m$, $g = 9.8\ ms^{-2}$

Solution:

loss in P.E = gain in K.E

$$\cancel{m}gh = \frac{1}{2}\cancel{m}v^2$$

$$2gh = v^2$$

$$\sqrt{v^2} = \sqrt{2gh}$$

$$v = \sqrt{2(9.8)(5)}$$

$$\boxed{v = 9.9\ ms^{-1}}$$