

PHYSICS NOTES FOR 1ST YEAR (FOR SINDH)

CHAPTER NO 7 WORK - ENERGY

Q. Define work and its unit in S.I. System?

Ans. Work: -

Work is said to be done whenever the point of application of force is moved in the direction of force.

Or

If force is applied on a body due to which the body is displaced in the direction of force then work is said to be done.

Or

The product of component of force in the direction of displacement and displacement is called work.

If $\vec{F}$ is force applied in the direction of displacement and $\vec{d}$ is displacement then

Work = force x displacement

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

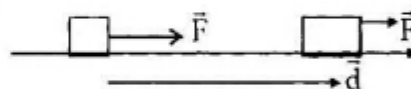
If the angle between $\vec{F}$ and $\vec{d}$ is θ then

$$W = \vec{F} \cdot \vec{d} \quad \text{but } F_x = F \cos \theta$$

therefore

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

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



Since dot product of two vectors is a scalar therefore work is a scalar quantity.

If $\theta = 0^\circ$ then

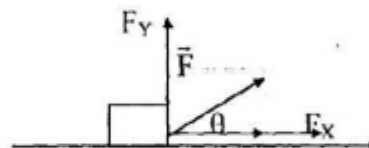
$$W = \vec{F} \cdot \vec{d} = Fd \cos 0 = Fd$$

If $\theta = 90^\circ$ then

$$W = \vec{F} \cdot \vec{d} = Fd \cos 90 = 0$$

If $\theta = 180^\circ$ then

$$W = \vec{F} \cdot \vec{d} = Fd \cos 180 = -Fd \quad \text{i.e. Work is negative.}$$



Unit: -

The unit of work in S.I. System is Joule

Definition of Joule:-

One joule is the amount of work done when a force of 1 Newton acts through a distance of 1 meter in its own direction.

In British engineering system the unit of work is foot-pound and

1 foot-pound = 1.355 Joules

In electricity unit of work is electron volt where $1\text{eV} = 1.6 \times 10^{-19}\text{J}$

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- Q.** Define gravitational field. Calculate work done against gravitational field and Prove that work done on a closed path (loop) in gravitational field is zero, and is independent of path.

Ans. Gravitational field: -

The area or region around the earth in which earth exerts force of attraction on the other body is known as gravitational field.

Gravitational force: -

The force by which earth attracts a body toward its center is called gravitational force and is equal to weight of body.

If body moves toward earth it is positive and if body moves upward it is negative.

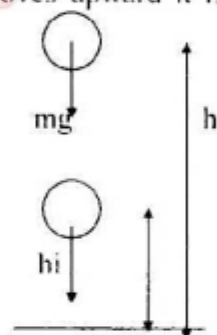
Work done in gravitational field: -

Consider a body of mass 'm' is at a height h_i is taken upward to a height h_f such that $(h_f - h_i) = h$ then the work done on it is given by

$$\begin{aligned} W &= F \cdot S = F \cdot h \\ &= F h \cos 0 \\ &= F h \cos 180^\circ \quad \text{but} \quad F = mg \\ &= -m g h \end{aligned}$$

Since the work done against the gravitational force is negative.

It also shows that work done depends on the initial and final position and is conserve as $P.E. = m g h$.



- Q.** Define Conservative field. Prove that work done in conservative field on a closed path (loop) in gravitational field is zero, and is independent of path.

Ans. Conservative Field: -

If the net work done on an object taken around a closed path is zero, then the field is called conservative field.

Prove: -

Work done on closed path (Loop): -

Consider a closed path like a triangle ABC as figure.

If the body of mass 'm' is taken from A to B and cover distance S_1 then work will

$$W_{A \rightarrow B} = \vec{F} \cdot \vec{S}_1 = F S_1 \cos \alpha$$

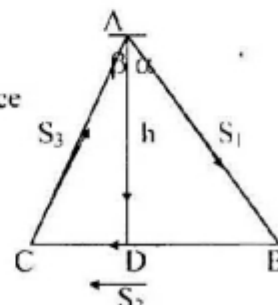
but $S_1 \cos \alpha = h$ therefore $W_{A \rightarrow B} = F h = m g h$.

If body is taken from B to C covering distance S_2

and the angle between Force and BC is 90° there fore

$$W_{B \rightarrow C} = \vec{F} \cdot \vec{S}_2 = F S_2 \cos 90^\circ = 0$$

This shows that work done against gravitational force, when body moves on horizontal path is zero. Now body is taken from C to A covering distance S_3 then



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$$W_{C \rightarrow A} = \vec{F} \cdot \vec{S}_3$$

The angle between $\vec{F}$ and $\vec{S}_3$ for this motion is $(180 - \beta)$ therefore

$$W_{C \rightarrow A} = F \cdot S_3 \cos (180 - \beta)$$

But $\cos (180 - \beta) = -\cos \beta$ therefore

$$W_{C \rightarrow A} = F \cdot (-S_3 \cos \beta) \text{ but } S_3 \cos \beta = h$$

$$= -mgh$$

Thus the total work along closed path ABCA will be

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

$$= mgh + 0 - mgh = 0$$

If path is divided in two parts A to C and C to A then

$$W_{A \rightarrow B \rightarrow C} + W_{C \rightarrow A} = 0$$

$$\text{or } W_{A \rightarrow B \rightarrow C} = -W_{C \rightarrow A}$$

These equation shows that the work done on a closed path is always be zero, however the path may be i.e. the work done on closed path is independent of path in gravitational field or gravitational field is conservative field.

Q. Define Power, average power and instantaneous power also give its units.

Ans. Power: -

The work done in unit time is called power or the rate of doing work is called power.

Average power: -

If a body works ΔW in time Δt then average power P_{av} is written as

$$P_{\text{average}} = \frac{\Delta W}{\Delta t}$$

Instantaneous Power: -

If a body works ΔW in time Δt where Δt is very small i.e. $\Delta t \rightarrow 0$ then

$$P_{\text{instantaneous}} = \lim_{\Delta t \rightarrow 0} \frac{\Delta W}{\Delta t}$$

Unit of Power: -

The unit of power in S.I. system is watt.

The unit of power in British engineering system is foot pound per second; it is a small unit therefore its unit is taken as horsepower.

$$1 \text{ horse power} = 550 \text{ ft. lb/sec.}$$

$$1 \text{ horsepower} = 746 \text{ watt.}$$

Relation between power and velocity: -

$$\text{As } P_{\text{average}} = \frac{\Delta W}{\Delta t} \quad \text{but } \Delta W = \vec{F} \cdot \vec{S}$$

$$\text{Therefore } P_{\text{average}} = \frac{\vec{F} \cdot \vec{S}}{\Delta t} \quad \text{but } V_{\text{average}} = \frac{S}{\Delta t}$$

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$$P_{\text{average}} = \dot{\mathbf{F}} \cdot \dot{\mathbf{V}}_{\text{average}}$$

i.e. Power is the dot product of force and velocity.

Work done by variable force: -

Let variable force is applied on a body then work can not find out by $\mathbf{F} \cdot \mathbf{S}$ because of changing of force.

To calculate work in this case divide the displacement in small interval of width ΔX such that the force in each interval is nearly same then for each piece work may be written as

$$W_1 = F_{X_1} \Delta X_1, W_2 = F_{X_2} \Delta X_2, W_3 = F_{X_3} \Delta X_3, \dots, W_n = F_{X_n} \Delta X_n,$$

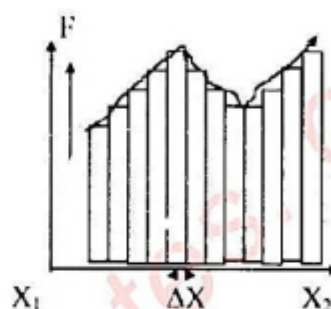
The total work done $= W_1 + W_2 + W_3 + \dots + W_n$
 or $= F_{X_1} \Delta X_1 + F_{X_2} \Delta X_2 + F_{X_3} \Delta X_3 + \dots + F_{X_n} \Delta X_n$

$$W = \sum_{i=1}^n F_{X_i} \times \Delta X_i$$

Where $F_{(X_i)}$ is the force acting for the interval of width ΔX .

In order to get better results approaching to the exact values we take integral in place of sum. i.e.

$$W = \int_{x=a}^{x=b} F(x) dx$$



Q. Define energy and drive an expression for kinetic energy of a body.

Ans. Energy: -

Energy is the capability of a body to do work.

Kinetic Energy: -

The energy possess by a body by virtue of its motion is called Kinetic energy.

Derivation of Formula: -

Consider a body of mass 'm' thrown upward with velocity 'V' and it reaches to height 'h' then its kinetic energy is consumed to do work against gravitational force i.e.

$$K.E. = \text{work} = \mathbf{F} \cdot \mathbf{d} = F d \cos \theta$$

As $\theta = 0$ because Force and displacement are in same direction.
 and $F = mg$ therefore

$$W = m g h \dots\dots\dots(1)$$

Let the initial velocity of body = $V_i = V$

the final velocity of body = $V_f = 0$

The distance covered by body = $S = h$

and $a = -g$

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Then putting values in second equation of motion

$$V_f^2 - V_i^2 = 2as$$

$$0 - V^2 = 2(-g)h$$

$$V^2 = 2gh$$

$$h = \frac{V^2}{2g}$$

Putting value of 'h' in equation (1) we get

$$K.E. = mg \frac{V^2}{2g}$$

$$\text{or } K.E. = \frac{1}{2} mV^2$$

This equation gives K.E and shows that it is independent of the way by which it is derived.

Q. Define potential energy and drive formula for it.

Ans. *If a body is moved from one point to the other point against the field then work done is stored as energy in the body and known as potential energy.*

Consider a body of mass 'm' in the gravitational field. Let body is moved upward (against the gravitational field) by applying external force ($F_{ex} = mg$) then

$$W_{ex} = F_{ex} \cdot S = F_{ex} h \cos 0 \quad (S = h)$$

Since the external force and displacement are in same i.e. upward direction i.e. $\theta = 0$, $\cos \theta = 1$ therefore

$$W_{ex} = mgh$$

This work is stored in the body as gravitational potential energy. Hence

$$P.E. = mgh$$

Q. Define absolute potential and drive an expression for absolute P.E of a body at

(1) Surface of earth.

(2) Height 'h' from surface of earth.

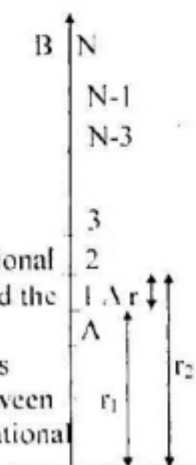
Ans. Definition: -

The work done in moving a body from a point in the field to a point outside the field is known absolute potential.

Derivation of formula: -

In the formula $P.E. = mgh$, it is supposed that the value of gravitational P.E. is constant, but if body is moved to long distance or out of field the magnitude of field is different at different points.

To calculate P.E. divide the line of motion is 'N' small pieces such that the magnitude of gravitational force is nearly constant between two points as figure. Let body is taken from point 1 to 2 then gravitational force between two points will be written as



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$$F_1 = G \frac{mM_E}{r_1^2} \quad \text{and} \quad F_2 = G \frac{mM_E}{r_2^2}$$

The average value between two points may be written as

$$F = \frac{F_1 + F_2}{2}$$

Substituting values we get

$$F = \frac{1}{2} \left[G \frac{mM_E}{r_1^2} + G \frac{mM_E}{r_2^2} \right]$$

$$F = \frac{1}{2} GmM_E \left[\frac{1}{r_1^2} + \frac{1}{r_2^2} \right] = \frac{1}{2} GmM_E \left[\frac{r_2^2 + r_1^2}{r_1^2 r_2^2} \right]$$

According to figure $r_2 = r_1 + \Delta r$ Putting this value we get

$$F = \frac{1}{2} GmM_E \left[\frac{(r_1 + \Delta r)^2 + r_1^2}{r_1^2 r_2^2} \right]$$

$$F = \frac{1}{2} GmM_E \left[\frac{r_1^2 + 2r_1\Delta r + \Delta r^2 + r_1^2}{r_1^2 r_2^2} \right]$$

$$F = \frac{1}{2} GmM_E \left[\frac{2r_1^2 + 2r_1\Delta r + \Delta r^2}{r_1^2 r_2^2} \right]$$

As Δr is small therefore its higher powers may be neglected then

$$F = \frac{1}{2} GmM_E \left[\frac{2(r_1^2 + r_1\Delta r)}{r_1^2 r_2^2} \right]$$

$$F = GmM_E \left[\frac{r_1^2 + r_1\Delta r}{r_1^2 r_2^2} \right]$$

Putting $\Delta r = r_2 - r_1$ we get

$$F = GmM_E \left[\frac{r_1^2 + r_1(r_2 - r_1)}{r_1^2 r_2^2} \right]$$

$$F = GmM_E \left[\frac{r_1^2 + r_1r_2 - r_1^2}{r_1^2 r_2^2} \right] = GmM_E \left[\frac{r_1r_2}{r_1^2 r_2^2} \right]$$

$$F = GmM_E \left[\frac{1}{r_1 r_2} \right]$$

As $W_{1-2} = F \cdot \Delta r$ Putting values we get

$$W_{1-2} = GmM_E \frac{1}{r_1 r_2} (r_2 - r_1)$$

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

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

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

Similarly

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

$$W_{3 \rightarrow 4} = GmM_E \left(\frac{1}{r_3} - \frac{1}{r_4} \right)$$

$$W_{N-2 \rightarrow N-1} = GmM_E \left(\frac{1}{r_{N-2}} - \frac{1}{r_{N-1}} \right)$$

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

To get work from 1 to N adds all above equation i.e.

$$W_{1 \rightarrow N} = W_{1 \rightarrow 2} + W_{2 \rightarrow 3} + W_{3 \rightarrow 4} + \dots + W_{N-2 \rightarrow N-1} + W_{N-1 \rightarrow N}$$

Substituting values we get

$$W_{N-1 \rightarrow N} = GmM_E \left(\frac{1}{r_1} - \frac{1}{r_2} + \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_3} - \dots + \frac{1}{r_{N-2}} - \frac{1}{r_{N-1}} + \frac{1}{r_{N-1}} - \frac{1}{r_N} \right)$$

$$W_{N-1 \rightarrow N} = GmM_E \left(\frac{1}{r_1} - \frac{1}{r_N} \right)$$

This equation gives the potential energy to move a body from one point to the other in gravitational field.

Absolute Potential energy: -

The work done in taking the body from a point in the gravitational field to out side the field is known as absolute potential energy.

For a point out side the field $r_N = \infty$ i.e. $1/r_N = 1/\infty = 0$ therefore

$$P.E._{\text{Absolute}} = -GmM_E \left[\frac{1}{r_1} - \frac{1}{\infty} \right] = -GmM_E \frac{1}{r_1}$$

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$$P.E._{Absolute} = -\frac{GmM_E}{r}$$

The work is store in the body as P.E.

The negative sign. Shows that at any point the potential energy is always be negative.

P.E. at surface of earth: -

For surface of earth $r_1 = R_E$ therefore

$$P.E._{Absolute} = -\frac{GmM_E}{R_E}$$

P.E. at height 'h' from surface of earth: -

If body is at height 'h' from surface of earth then $r = R_E + h$ therefore

$$P.E._{Absolute} = -\frac{GmM_E}{R_E + h} = -\frac{GmM_E}{R_E \left[1 + \frac{h}{R_E} \right]}$$

$$P.E._{Absolute} = -\frac{GmM_E}{R_E} \left[1 + \frac{h}{R_E} \right]^{-1}$$

$$P.E._{Absolute} = -\frac{GmM_E}{R_E} \left[1 - \frac{h}{R_E} \right]$$

Q. Drive work-energy equation for a body falling freely in air.

Ans. Work-Energy equation: -

Consider a ball of mass 'm' at height 'h' above P.E. Max earth surface. where its P. E. is m g h. If the ball is allowed to fall due to which its K.E. is increases while P.E. is decreases.

i.e. Loss of P. E. = Gain in K.E.

If the force of air friction is 'f' then the work done against friction will be (fh) therefore

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

$$m g h = \frac{1}{2}mV^2 + fh$$

$$\text{or } \frac{1}{2}mV^2 = m g h - fh$$

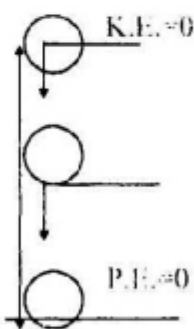
This equation is known as work energy equation.

Q. State and explain the law of conservation of energy.

Ans. Statement: -

It states that the energy can not be created nor be destroyed but total amount of it remains constant. Or

For an isolated system total amount of energy is conserve.



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Prove: -

Let a body of mass 'm' is dropped from height 'h'.
 At height 'h' its P.E. is mgh while K.E. is zero i.e.

$$\begin{aligned} \text{Total energy} &= \text{K.E.} + \text{P.E.} \\ &= 0 + mgh = mgh \quad \dots\dots\dots (1) \end{aligned}$$

If body is dropped and cover a distance 'X' then at point 'B'

$$\text{P.E.} = mg(h - X)$$

and $\text{K.E.} = \frac{1}{2}mV^2$ Where as

$$V_f^2 - V_i^2 = 2gX \quad \text{but}$$

as $V_i = 0$

$$V_f = V \quad \text{therefore}$$

$$V^2 = 2gX$$

i.e. $\frac{1}{2}m \cdot 2gX = m g X.$

$$\begin{aligned} \text{Total energy at point B} &= \text{P.E.} + \text{K.E.} \\ &= mg(h - X) + m g X \\ &= m g h \quad \dots\dots\dots (2) \end{aligned}$$

If body is dropped and comes to earth then at point 'C'

$$\text{P.E.} = 0$$

and $\text{K.E.} = \frac{1}{2}mV^2$ Where as

$$V_f^2 - V_i^2 = 2gX \quad \text{but}$$

as $V_i = 0$

$$V_f = V \quad \text{therefore}$$

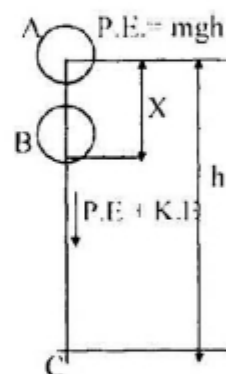
$$V^2 = 2gh$$

i.e. $\frac{1}{2}m \cdot 2gh = m g h.$

$$\begin{aligned} \text{Total energy at point C} &= \text{P.E.} + \text{K.E.} \\ &= 0 + m g h = m g h \quad \dots\dots\dots (3) \end{aligned}$$

Comparing equation (1) ,(2) and (3) we conclude that the total energy remain constant only the energy is converted from one form to other.

There fore we can say that energy may not be created nor be destroyed.



IMPORTANT FORMULA OF CHAPTER

1. $W = F \cdot d = Fd \cos \theta$

2. $P_{\text{average}} = \frac{\Delta W}{\Delta t}$

$P_{\text{average}} = \vec{F} \cdot \vec{V}_{\text{average}}$

3. $\text{K.E.} = \frac{1}{2}mV^2$

4. $\text{P.E.} = mgh$

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SCIENTIFIC REASONS

Q. Does the work done in rising a box on to a plate form depends upon how fast it is raised up? If not, why?

Ans. The work done W in rising a box of mass m on to a plate form of height ' h ' is given by $\text{Work} = mgh$
This equation shows that work is independent of velocity. Therefore, it does not depend upon how fast the box is raised up.

Q. A girl drop a cup from a certain height which break into pieces. What energy changes are involved in it?

Ans. At the height cup has certain P.E. when it drop this energy is converted into K.E. and K.E. is maximum near earth. When the cup strikes the ground this energy is converted into heat and sound energy.

Q. When an arrow is shot from its bow, it has K.E., from where it has gain K.E.?

Ans. When an arrow is shot from its bow. The string of bow is pulled backward direction along with arrow and elastic P.E. developed which when arrow is released is converted into K.E.

Q. What type of energy is stores in the spring of the watch?

Ans. When the spring of the watch is wound the work done in winding is store in the form of elastic P.E. of the spring.

Q. A bucket is taken to the bottom of a well, does the bucket possess any potential energy.

Ans. Yes, when the bucket is taken to the bottom of the well we have to do work on the bucket against the upward thrust of water. This amount of work done in taking the bucket of the bottom of the well is stored in it in the form of its P.E.

Q. A block of mass 1 kilogram is placed on a shelf located at a height of 5m from the top of a table which is 1.5m high. What is its potential energy?

Ans. The P.E. of the block with respect to the top of the table.

$$\begin{aligned}\text{P.E.} &= mgh \\ &= 1 \times 9.8 \times 5 \\ &= 49 \text{ J}\end{aligned}$$

P.E. of the block with respect to the surface of earth. Where h_2 is total height from the surface of earth.

$$\begin{aligned}\text{P.E.} &= mgh_2 \\ &= 1 \times 9.8 (5 + 1.5) \\ &= 9.8 \times 6.5 \\ \text{P.E.} &= 63.7 \text{ J}\end{aligned}$$

Q. The force between pair of protons is that of repulsion. Does the P.E. increase as the pair of protons is brought together?

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Ans. Yes, when two protons are brought together their electrostatic P.E. is increased. This increase in electrostatic P.E. appears due to the work done on the protons to bring them together against the repulsive force.

Q. A meteor when enters into Earth's atmosphere burns. What happens to its energy and momentum.

Ans. When meteorite enters into Earth's atmosphere its K.E. is converted into heat energy because of frictional force between the atmosphere and the meteorite so it burns. In this case, the momentum of the meteorite is lost with the K.E. of the meteorite.

Q. A man rowing boat upstream is at rest with respect to shore, is he doing work?

Ans. When a man rowing boat upstream is at rest with respect to shore he is doing work but work is being done on water by the man in pushing it.

Q. Due to smaller value of 'g' a man can jump higher on the surface of the moon. Can he run faster on this account explain.

Ans. Yes, due to the smaller value of 'g' the man can run faster on the surface of the moon due to its smaller weight.

Q. Find your muscle power. (If it is 100 watts it is not bad).

Ans. Let us suppose that I can do work 600 joules in three seconds, then the muscle power can be given as,

$$P = \frac{W}{t}$$
$$P = \frac{600}{3} = 200 \text{ J/Sec or 200 watt.}$$

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Chapter 7

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Work-Energy

Chapter 7

M.C.Qs.

1. The scalar product of force and displacement is called
 (a) Torque (b) Power (c) **work** (d) angular momentum
2. Work is said to be done when a force produce _____ in the body
 (a) Torque (b) acceleration (c) velocity (d) **displacement**
3. S.I. unit of work is
 (a) watt (b) N/m (c) **Joule** (d) kilometer
4. kilowatt-hour is unit of
 (a) Energy (b) **Power** (c) Time (d) Work
5. The work done by the centripetal acceleration is always
 (a) Positive (b) **Zero** (c) Negative
6. 1 horse power is equal to
 (a) 546 watt (b) **746 watt** (c) 646 watt (d) 647 watt
7. In case of negative work the angle between the force and displacement is
 (a) 0° (b) 90° (c) **180°** (d) 45°
8. Which of the following is not a unit of power
 (a) Kilowatt (b) **kilowatt-hour** (c) 1 horse power (d) ft.Lb/sec
9. If the speed of a moving body is doubled, its kinetic energy becomes
 (a) 2 times (b) 3 times (c) **4 times** (d) 1 half
10. If mass and speed both are doubled, the kinetic energy of a moving body
 (a) **Increasing 4 times** (b) Increasing 6 times
 (c) Increasing 8 times (d) Remains the same
11. The unit of work in S.I. system is
 (a) Pound (b) Dyne (c) **Joule** (d) Watt
12. The ability to do work is called
 (a) Force (b) **Energy** (c) Power (d) Momentum
13. An expression for power is
 (a) $P = \vec{F} \cdot \vec{V}$ (b) $P = \frac{F}{V}$ (c) $P = \frac{V}{F}$ (d) $P = \vec{F} \cdot \vec{V}^2$
14. Power is equal to
 (a) $\frac{\vec{F} \times \vec{d}}{t}$ (b) $\frac{\vec{F} \cdot \vec{V}}{t}$ (c) $\frac{\vec{F} \cdot \vec{d}}{t}$ (d) $\frac{\vec{F} \times \vec{V}}{t}$

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PROBLEMS

- 7.1 Calculate the work done by a force $\vec{F}$ specified by**

$$\vec{F} = 3\hat{i} + 4\hat{j} + 5\hat{k}$$

In displacing a body from position B to A along a straight path. The position vectors A & B are respectively given as

$$\vec{r}_A = 2\hat{i} + 5\hat{j} + 2\hat{k}$$

and $\vec{r}_B = 7\hat{i} + 3\hat{j} + 5\hat{k}$

Solution: -

$$\text{Displacement} = \vec{r} = \vec{r}_B - \vec{r}_A = (2\hat{i} + 5\hat{j} + 2\hat{k}) - (7\hat{i} + 3\hat{j} + 5\hat{k})$$

$$\vec{r} = 2\hat{i} + 5\hat{j} + 2\hat{k} - 7\hat{i} - 3\hat{j} - 5\hat{k} = -5\hat{i} + 2\hat{j} - 3\hat{k}$$

$$\text{Work} = \vec{F} \cdot \vec{r} = (3\hat{i} + 4\hat{j} + 5\hat{k}) \cdot (-5\hat{i} + 2\hat{j} + 3\hat{k}) = -15 + 8 + 15 = 8 \text{ J} \quad \text{Ans.}$$

- 7.2 A 2000kg car travelling at 20 m/s come to rest on a level ground in a distance of 100 m. How large is the average fractional force tending to stop it.**

Data: -

$$m = 2000 \text{ Kg}$$

$$V_i = 20 \text{ m/s}$$

$$V_f = 0$$

$$d = 100 \text{ m}$$

$$f = ?$$

Solution: -

$$\text{Work against friction} = \text{Kinetic Energy}$$

$$f \cdot d = \frac{1}{2} m V_i^2$$

$$f = \frac{\frac{1}{2} m V_i^2}{d}$$

$$f = \frac{1}{2} \times \frac{2000 \times (20)^2}{100} = 4000 \text{ N} \quad \text{Ans}$$

- 7.3 A 100-kg man in a car travelling at 20-m/s.**

(a) Find his Kinetic energy.

(b) The car strikes concrete wall and comes to rest after the front of the car collapsed 1m. The man wearing a seat belt and harness. What is the average force exerted the belt and harness during the crash?

Data: -

$$m = 100 \text{ Kg}$$

$$V_i = 20 \text{ m/s}$$

PHYSICS NOTES FOR 1ST YEAR (FOR SINDH)

Chapter 7

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Work-Energy

$$\begin{aligned} \text{K.E.} &= ? \\ V_i &= 0 \\ d &= 1\text{m} \\ F &= ? \end{aligned}$$

Solution: -

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

$$\text{K.E.} = \frac{1}{2} \times 100 \times (20)^2 = 20000 \text{ J} \quad \text{Ans.}$$

Work against friction = Kinetic Energy

$$F.d = \text{K.E.}$$

$$F = \frac{\text{K.E.}}{d} = \frac{20000}{1} = 20000 \text{ N} \quad \text{Ans.}$$

- 7.4 When an object is thrown upward, it rises to a height 'h'. How high is the object, in term of h, when it has lost one-third of its original kinetic energy?

Data: -

$$\begin{aligned} \text{Height} &= h \\ X &= ? \end{aligned}$$

$$\text{Loss of K.E.} = \frac{1}{3} (\text{original K.E.}) = \frac{1}{3} \left(\frac{1}{2} m v^2 \right)$$

Solution: -

Loss of K.E. = Gain in P.E

$$\frac{1}{3} \left(\frac{1}{2} m v^2 \right) = m g X \quad \text{but} \quad \frac{1}{2} m v^2 = m g h$$

$$X = \frac{1}{3 m g} (m g h) = \frac{1}{3} h \quad \text{Ans.}$$

- 7.5 A pump is needed to lift water through a height of 2.5m at the rate of 500 g/min. What must the minimum horsepower of the pump be?

Data: -

$$h = 2.5 \text{ m}$$

$$m = 500 \text{ g/min} = \frac{0.5}{60} = 8.33 \times 10^{-3} \text{ Kg/sec}$$

$$P = ?$$

$$t = 1 \text{ sec} \quad \text{and} \quad 1 \text{hp} = 746 \text{ watt}$$

Solution: -

$$P = \frac{\text{work}}{\text{time}} = \frac{m g h}{t} = \frac{8.33 \times 10^{-3} \times 9.8 \times 2.5}{1} = 0.2042 \text{ watt}$$

$$P = \frac{0.2042}{746} = 2.74 \times 10^{-4} \text{ hP} \quad \text{Ans.}$$

PHYSICS NOTES FOR 1ST YEAR (FOR SINDH)

- 7.6 A horse pulls a cart horizontally with a force of 40lb at an angle of 30° above the horizontal and moves along at a speed of 6.0 mil/h. (a) How much work does the horse do in 10 minutes? (b) What is the power output of the horse?

Data: -

$$F = 40\text{lb}$$

$$\theta = 30^\circ$$

$$V = 6 \text{ mile/h} = \frac{6 \times 1760 \times 3}{60 \times 60} = 8.8 \text{ ft/sec.}$$

(a) $W = ?$

$$t = 10 \text{ min} = 10 \times 60 = 600 \text{ sec.}$$

(b) $P = ?$

Solution: -

$$d = V \times t = 8.8 \times 600 = 5280 \text{ ft}$$

(a) $W = F d \cos \theta = 40 \times 5280 \cos 30^\circ = 1.8 \times 10^5 \text{ ft.lb}$ Ans.

(b) $P = \frac{W}{t} = \frac{F \cdot d \cos \theta}{t} = F \cdot \frac{d}{t} \cos \theta = FV \cos \theta$

$$P = 40 \times 8.8 \times \cos 30^\circ = 304.84 \text{ ft.lb/sec.}$$

$$P = \frac{304.84}{550} = 0.554 \text{ hp}$$
 Ans.

- 7.7 A boy of mass 'm' accelerates uniformly from rest to a speed V_f in time t_f . Show that the work done on the boy as a function of time 't' in term of V_f and t_f is

$$\frac{1}{2} m \frac{V_f^2}{t_f^2} t^2.$$

Data: -

$$\text{Initial Velocity} = V_i = 0$$

$$\text{Final Velocity} = V_f$$

$$\text{Time} = t_f$$

$$\text{Work} = ?$$

Solution: -

$$\text{Work} = F \cdot S = m \cdot a \cdot S$$

Where as $V_f = V_i + at = V_i + at_f$

$$a = \frac{V_f}{t_f}$$

and $S = v_i t + \frac{1}{2} at^2 = 0 + \frac{1}{2} \frac{V_f}{t_f} t^2 = \frac{1}{2} \frac{V_f}{t_f} t^2$

Putting values

PHYSICS NOTES FOR 1ST YEAR (FOR SINDH)

$$\text{Work} = m \cdot \frac{V_i}{t_i} \cdot \frac{1}{2} \frac{V_f}{t_f} t^2 = \frac{1}{2} m \frac{V_f^2}{t_f^2} t^2 \quad \text{Ans.}$$

- 7.8 A rocket of mass 0.200kg is launched from rest. It reaches a point P lying at a height 30.0m above the surface of the earth from starting point. In the process +425J of work is done on the rocket by burning chemical propellant. Ignoring air-resistance and the amount of mass lost due to the burning propellant, find the speed V_f of the rocket at the point P.

Data: -

$$\begin{aligned} m &= 0.200 \text{ kg} \\ V_i &= 0 \\ S &= 30 \text{ m} \\ W &= +425 \text{ J} \\ V_f &= ? \end{aligned}$$

Solution: -

$$\text{Work} = F \cdot S = m \cdot a \cdot S$$

$$425 = 0.2 \times a \times 30 = 6a$$

$$a = 70.83 \text{ m/s}^2$$

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

$$V_f = \sqrt{2aS - V_i^2} = \sqrt{2aS} = \sqrt{2 \times 70.83 \times 30} = 65.19 \text{ m/s} \quad \text{Ans.}$$

PHYSICS NOTES FOR 1ST YEAR (FOR SINDH)

EXAMPLE

Example 7.1

A neutron travels a distance 12m in a time interval of 3.6×10^{-4} s. Assuming its speed was constant; find its kinetic energy. Take 1.7×10^{-27} kg as the mass of neutron.

Data: -

$$S = 12\text{m}$$

$$T = 3.6 \times 10^{-4} \text{ s}$$

$$\text{K.E.} = ?$$

$$m = 1.7 \times 10^{-27} \text{ kg}$$

Solution: -

$$V = \frac{S}{t} = \frac{12}{3.6 \times 10^{-4}} = 3.3 \times 10^4 \text{ m/s}$$

$$\text{K.E.} = \frac{1}{2} mV^2$$

$$\text{K.E.} = \frac{1}{2} \times 1.7 \times (3.3 \times 10^4)^2 = 9.256 \times 10^{-19} \text{ J}$$

$$\text{K.E.} = \frac{9.256 \times 10^{-19}}{1.6 \times 10^{-19}} = 5.78 \text{ eV} \quad \text{Ans.}$$

Example 7.2

A person pushes a toy car, initially at rest, toward a child by exerting a constant horizontal force F of magnitude 5N through a distance of 1-m. (a) How much work is done on the car? (b) What is its final kinetic energy? (c) if the car has mass of 0.1kg. What is its final speed? (Assuming the absence of frictional forces).

Data: -

$$F = 5\text{N}$$

$$T = 1 \text{ m}$$

$$W = ?$$

$$\text{K.E.}_{\text{final}} = ?$$

$$V = ?$$

Solution: -

$$(a) \quad W = F \cdot S = 5 \times 1 = 5 \text{ J} \quad \text{Ans.}$$

$$(b) \quad \text{As initial K.E.} = 0 \text{ therefore} \\ \text{K.E.}_{\text{final}} = \text{K.E.}_{\text{initial}} + W = 0 + 5 = 5 \text{ J} \quad \text{Ans.}$$

$$(c) \quad \text{K.E.} = \frac{1}{2} mv^2$$

PHYSICS NOTES FOR 1ST YEAR (FOR SINDH)

$$V = \sqrt{\frac{2K.E.}{m}} = \sqrt{\frac{2 \times 5}{0.1}} = 10 \text{ m/s} \quad \text{Ans.}$$

Example 7.3

A 70kg man runs up a hill through a height of 3m in 2 seconds. (a) How much work does he do against gravitational force? (b) What is his average power output?

Data: -

$$\begin{aligned} m &= 70 \text{ kg} \\ h &= 3 \text{ m} \\ \Delta t &= 2 \text{ Sec.} \\ \Delta W &= ? \\ P &= ? \end{aligned}$$

Solution: -

$$(a) \quad W = mgh = 70 \times 9.8 \times 3 = 2060 \text{ J} \quad \text{Ans.}$$

$$(b) \quad P_{av} = \frac{\Delta W}{\Delta t} = \frac{2060}{2} = 1030 \text{ watt} \quad \text{Ans.}$$

Example 7.3

What is the change in gravitational potential energy when 7000N elevator moves from street level to the top of a building 300m above the street level?

Data: -

$$\begin{aligned} W &= 7000 \text{ N} \\ h &= 300 \text{ m} \\ P.E. &= ? \end{aligned}$$

Solution: -

$$\begin{aligned} P.E. &= mgh = Wh \\ &= 7000 \times 300 = 2.1 \times 10^6 \text{ J} \quad \text{Ans.} \end{aligned}$$

PHYSICS NOTES FOR 1ST YEAR (FOR SINDH)

EXAMPLES FORM LAST PAPERS

Example 1:

An object of 98N is drop from a height of 10m. If the frictional force acting upon the object is 26N, calculate the velocity of object just before hits the ground.

Data: -

$$W = 98\text{N}$$

$$m = \frac{W}{g} = \frac{98}{9.8} = 10\text{kg}$$

$$h = 10\text{ m}$$

$$f = 26\text{ N}$$

$$V = ?$$

Solution: -

$$\text{K.E.} = \text{P.E.} - \text{work against friction}$$

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

$$\frac{1}{2} \times 10v^2 = 10 \times 9.8 \times 10 - 26 \times 10$$

$$5v^2 = 980 - 260 = 720$$

$$v^2 = \frac{720}{5} = 144$$

$$v = \sqrt{144} = 12\text{ m/s} \quad \text{Ans.}$$

Example 2:

A 80kg man is travelling in a car at 30m/sec. The car strikes a building and stops, the front part have collapsed by 1meter; calculate the force exerted on the man during the crash. Also find his kinetic energy before crash.

Data: -

$$m = 80\text{ kg}$$

$$V_i = 30\text{ ms}^{-1}$$

$$d = 1\text{m}$$

(a) $\text{K.E.} = ?$

(b) $F = ?$

Solution: -

$$\text{K.E.} = \frac{1}{2}mV_i^2 = \frac{1}{2} \times 80 \times (30)^2 = 36000\text{ J} \quad \text{Ans.}$$

$$\text{Work against friction} = \text{Kinetic Energy}$$

$$F.d = \text{K.E.}$$

$$F = \frac{\text{K.E.}}{d} = \frac{36000}{1} = 36000\text{ N} \quad \text{Ans.}$$

PHYSICS NOTES FOR 1ST YEAR (FOR SINDH)

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Example 3

A ball of mass 100gm is thrown up in air vertically and reaches a height of 9.8m; calculate the velocity with which it is thrown and its kinetic energy. (Neglect air friction and take $g = 10\text{m/s}^2$)

Data: -

$$m = 100\text{gm} = 0.1\text{kg}$$

$$h = 9.8\text{m}$$

$$V_i = ?$$

$$\text{K.E.} = ?$$

$$g = 10\text{m/s}^2$$

Solution: -

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

$$V = \sqrt{2gh} = \sqrt{2 \times 10 \times 9.8} = \sqrt{196} = 14\text{m} \quad \text{Ans.}$$

$$\text{K.E.} = \frac{1}{2}mv^2 = \frac{1}{2} \times 0.1 \times (14)^2 = 9.8\text{J} \quad \text{Ans.}$$

