Chapter = 07

Work, Power and Energy

THEORY NOTES

WORK

PHYSICAL DEFINITION:

"Work is said to be done if a force causes a displacement in a body in the direction of force".

OR

" The work done by a constant force is defined as the product of the component of the force and the displacement in the direction of displacement".

MATHEMATICAL DEFINITION:

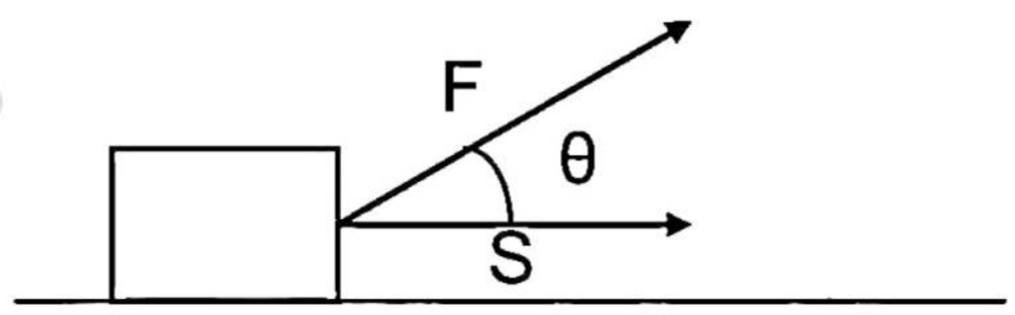
" Work is the scalar product or dot product of the force and displacement".

$$W = \vec{F}.\vec{S} = FScos\,\theta = (Fcos\theta)S \text{-------(i)}$$

Where, F= Magnitide of Force

S= Magnitude of Displacement

θ= Angle between $\vec{F}$ and $\vec{S}$



or eq(i) can also be written as,

$$W = F(Scos\theta)$$

Where $Scos\theta$ is the component of Displacement in the direction of Force.

DIMENSION AND NATURE:

Work is a scalar quantity and it's dimension is ML^2T^{-2}

UNITS OF WORK:

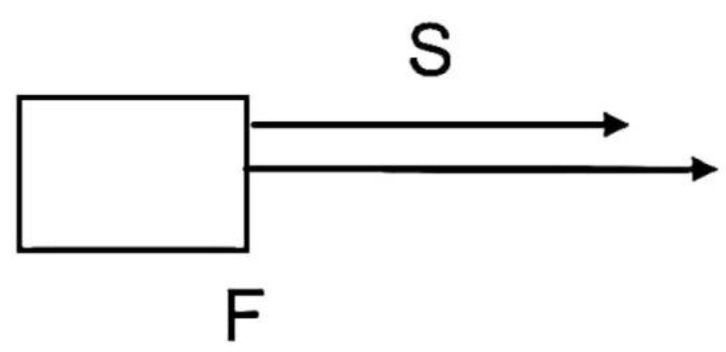
- In S.I system: Joule (j)
- In C.G.S. system: Erg
- In F.P.S system: ft X lb

SPECIAL CASES OF WORK :

(i) **POSITIVE WORK:** if force and displacement are in the same direction , work will be positive or if

$\theta > 0$ or $\theta < 90°$

Let $\theta = 0°$



As

Work = FS Cos θ

Work = FS Cos 0°

Work = (F) (S) (1)

Work = FS

(ii) ZERO WORK: if force and displacement are perpendicular to each other, work will be zero. I.e

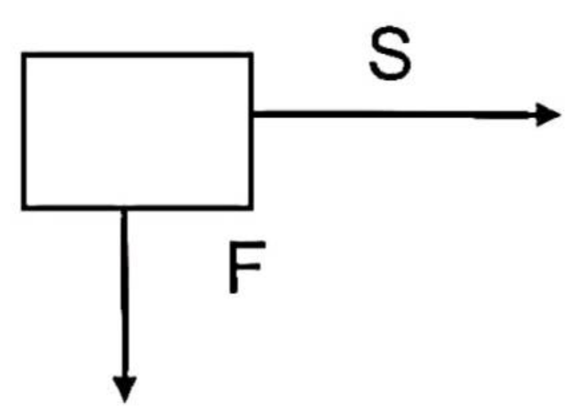
Since $\theta = 90°$

As

Work = FS Cos θ

Work = FS Cos 90°

Work = (F) (S) (0)



Work = 0

iii) NEGATIVE WORK: If force and displacement are in the opposite direction, work will be negative.

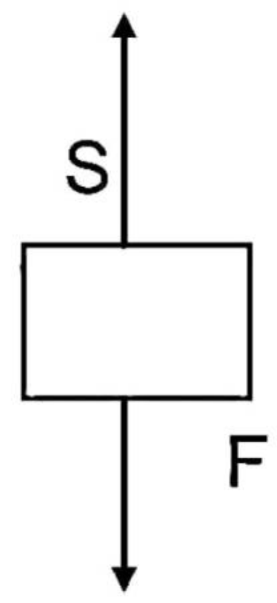
Since $\theta = 180°$

As

Work = FS Cos θ

Work = FS Cos 180°

Work = (F) (S) (-1)



Work = -FS

POWER

DEFINITION: " The rate of work done of a body is called power"

AVERAGE POWER:

Average power of a body doing work is numerically equal to the total work done divided by the time taken to perform the work.

MATHEMATICALLY:

Power = Work done / time

Power = W / Δt

As we know that

$W = \vec{F}.\vec{S}$

Therefore,

$P = \vec{F}.\vec{S} / \Delta t$ -----------(i)

According to the definition of Velocity,

$$v = \vec{S}/\Delta t$$

Therefore,Eq(i)=>

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

or

$$P = \vec{F}.\vec{v} = Fv\cos\theta$$

DIMENSION AND NATURE:

Power is a scalar quantity and its dimension is ML^2T^{-3}

UNITS OF POWER:

1. Watt [1 watt = 1joule / sec]
2. Kilo watt [1 Kw = 1000 watt]
3. Mega watt (Mw) [1Mw = 10^6 watt]
4. Horse Power [1 Hp = 746]

CONSERVATIVE FIELD

DEFINITION:

A force is said to be conservative if the work done by moving a body along a closed path equals to zero.

FOR EXAMPLE:

1. Gravitational Field 2. Electrostatic Field 3.Magnetic Field

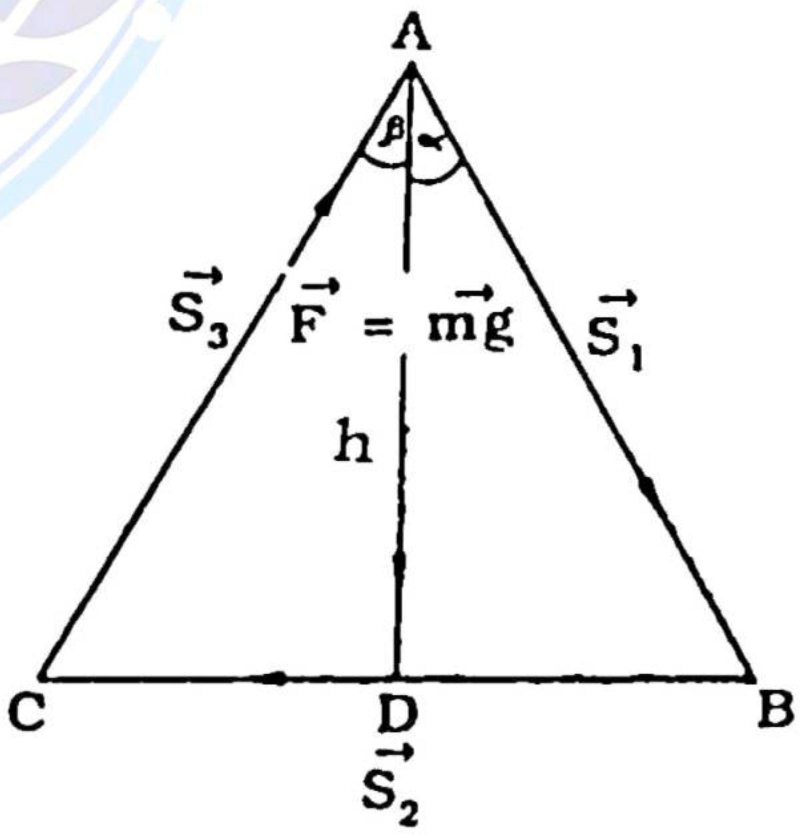
GRAVITATIONAL FIELD IS A CONSERVATIVE FIELD

PROOF:

Suppose a closed path is triangular pat is ABCA in gravitational field as shown in figure

Now we calculate the work in moving a body from A to B,B to C and C to A.

1. WORKDONE FROM A TO B:



$W_{A\rightarrow B}$ =F . S_1 =F S_1 Cosα------(i)

In Δ BAD,

Cosα=h/ S_1

or S_1 Cosα=h

Then $W_{A\rightarrow B}$ = Fh

Or

$$\boxed{W_{A\to B} = mgh}$$ ----------(ii)

2. WORKDONE FROM B TO C:

$$W_{B\to C} = F.S_2 = FS_2 \cos 90^o$$

$$W_{B\to C} = S_2\,(0)$$

Or $$\boxed{W_{B\to C} = 0}$$ ------------(ii)

3. WORKDONE FROM C TO A:

$$W_{C\to A} = F.S_3 = F\,S_3 \cos(180\text{-}\beta)$$

$$W_{C\to A} = F.S_3 = F\,S_3 \cos(-\beta)$$

$$W_{C\to A} = F.S_3 = -F\,S_3 \cos(\beta)$$

In Δ CAD,

$\cos\beta = h / S_3$

or $S_3 \cos\beta = h$

Then $W_{C\to A} = -Fh$

Or

$$\boxed{W_{C\to A} = -mgh}$$

4. TOTAL WORKDONE:

Now the total work done along the path ABCA is

Work = $W_{A\to B} + W_{B\to C} + W_{C\to A}$

W = mgh + 0+ (-mgh)

$$\boxed{W = 0}$$

Hence it is proved that the gravitational field is conservative field.

ENERGY

DEFINITION:

" The ability of a body to perform work is called Energy". A body cannot perform work if it does not possess energy. A body cannot perform work more than the amount of energy.

DIMENSION AND NATURE:

Energy is a scalar quantity and it's dimension is ML^2T^{-2}

UNITS OF ENERGY:

(i) Joule

(ii) Calorie [1 Calorie =4.2 joule]
(iii) Kilo Watt Hour [1Kwh=3.6 x 10^6 J]

POTENTIAL ENERGY

DEFINITION:

Energy stored by a body due to its position in gravitational field is known as 'Gravitational potential energy'".

FORMULA:

Potential Energy=P.E = mgh

DERIVATION:

Consider a body of mass "m" placed at a height of "h" from the surface earth.

Force = Weight = W

But displacement (S) = h

According o the definition of Work Done

Work done = Fs

Or Work done = Wh [but W = mg]

Work done = mgh

As we know that the energy stored in a body when work is done on it against the gravitational field is known as potential energy .Therefore,

Potential Energy=P.E = mgh

KINETIC ENERGY

DEFINITION:

" Energy posses by a body by virtue of its motion is refused to as ' Kinetic Energy' ".

FORMULA:

$K.E = 1 / 2\ mv^2$

Where m is the mass of body and v is the speed of body.

DERIVATION:

Consider a body of mass "m" starts moving from rest. After a time interval ''t" its speed becomes v. If initial velocity of the body is $V_i = 0$, final velocity $V_f = V$ and the displacement of body is ''S''. Then

First of all we will find the acceleration of body.

Using 3rd equation of motion

$2aS = Vf^2 - Vi^2$

Putting the above mentioned Values

$2aS = v^2 - 0$

or $a = v^2 / 2S$

Now force is given by

$F = ma$

Putting the value of acceleration

$F = m(v^2 /2S)$

As we know that

Work done = FS

Putting the value of "F"

Work done $= \left(\frac{mv^2}{2S}\right)(S)$

Work done $= mv^2/ 2$

OR

Work done $=1/2\ mv^2$

Since the ability of doing work by a moving body is called "Kinetic Energy". Therefore,

K.E = Work done

OR **K.E. = 1 / 2 mv²**

LAW OF CONSERVATION OF ENERGY

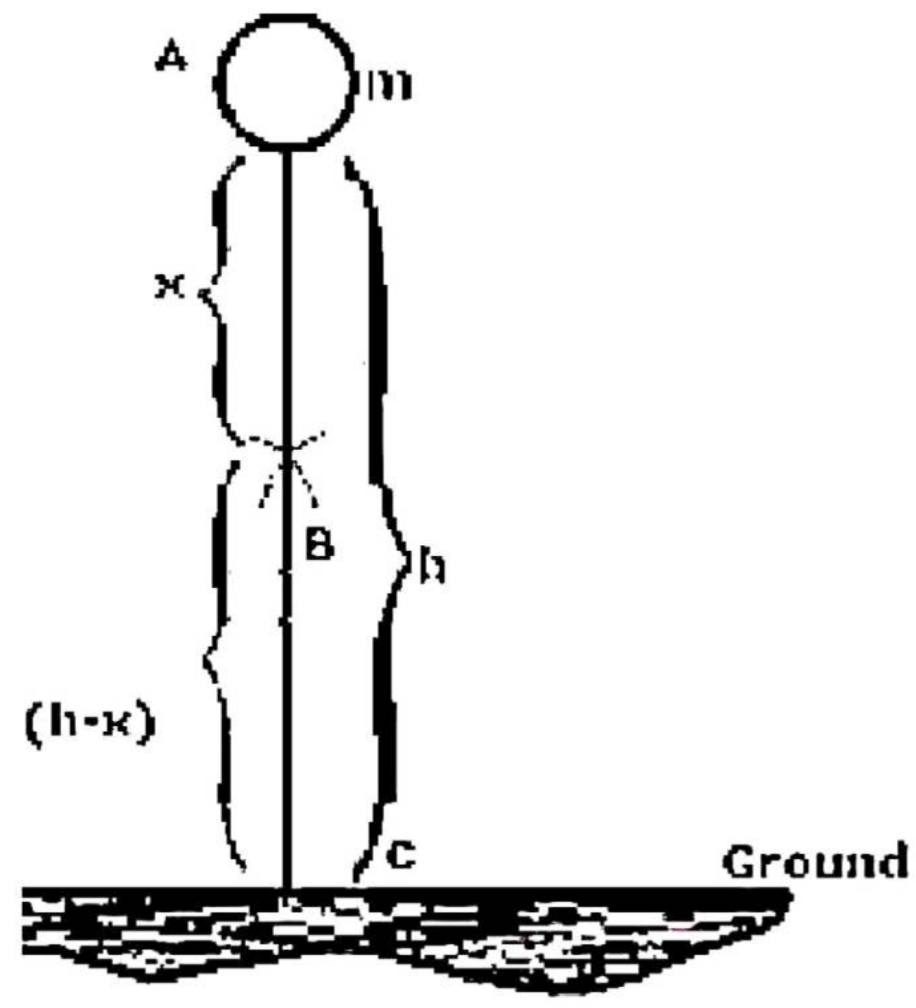
STATEMENT:

According to the law of conservation of energy

" Energy can neither be created nor it is destroyed, however energy can be converted from one from energy to any other form of energy".

Explanation:

Consider a body of mass "m" at height h above the ground. Its kinetic energy at that point A is:



1. At Point A:

A/c to the definition of Kinetic Energy

$K.E = 1/2(mv^2)$

$K.E = 1/2\ m * (0)$ (At point A body is at rest)

K.E = 0 .... (i)

The potential Energy at point A is :

$$P.E = mgh \text{ ....(ii)}$$

So the total energy at point A will be :

$$T.E = K.E + P.E$$

$$E(A) = 0 + mgh$$

$$\boxed{E(A) = mgh} \text{ ----------(A)}$$

2. At Point B:

Suppose the body is released from this height and falls through a distance x. Its new height will be (h-x). The velocity with which it reaches point B is calculated by using the third equation of motion:

$$2gs = V_f^2 - Vi^2$$

As we know:

* $Vi = 0$
* $S = x$

Therefore,

$$2gx = V_f^2 - 0$$

$$2gx = v^2$$

The kinetic energy at point B is:

$$K.E. = 1/2\ mv^2$$

Substituting the value of v^2:

$$K.E. = 1/2 \times m \times 2gx$$

$$K.E = mgx$$

The Potential Energy at point B is:

$$P.E = mgh$$

The height of the body is (h-x):

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

The total energy at point B is :

$$E(B) = P.E + K.E.$$

$$E(B) = mgx + mg(h-x)$$

$$E(B) = mgx + mgh - mgx$$

$$\boxed{E(B) = mgh} \text{ --------(B)}$$

3. At Point C:

Now the body reaches at point "C" which is just before striking the ground.

The Potential Energy at point C is:

$$P.E = 0 \qquad (h=0)$$

The velocity with which it reaches point C is calculated by using the third equation of motion:

$$2gs = V_f^2 - Vi^2$$

As we know:

* $Vi = 0$
* $S = h$

Therefore,

$$2gh = V_f^2 - 0$$

$$2gh = v^2$$

The kinetic energy at point B is:

$$K.E. = 1/2\ mv^2$$

Substituting the value of v^2:

$$K.E. = 1/2 \times m \times 2gh$$

$$K.E = mgh$$

The total energy at point B is :

$$E(C) = P.E + K.E.$$

$$E(C) = 0 + mgh$$

$$E(C) = mgh \quad \text{----------(C)}$$

Hence, the total energy at point A ,B and C are same. It means that the total value of energy remains constant. That is, Law of conservation of energy.

INTERCONVERSION OF P.E AND K.E
(WORK ENERGY EQUATION)

DERIVATION:

Let us consider a body of mass "m" is placed at point A at a height h from the surface of earth.At this point the body possesses gravitational potential energy equal to mgh w.r.t point C lying on the ground.

Now consider a point B at a distance x below the point A during downward motion of body.At this stage the height of the body becomes (h-x).

so, potential energy at point B becomes,

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

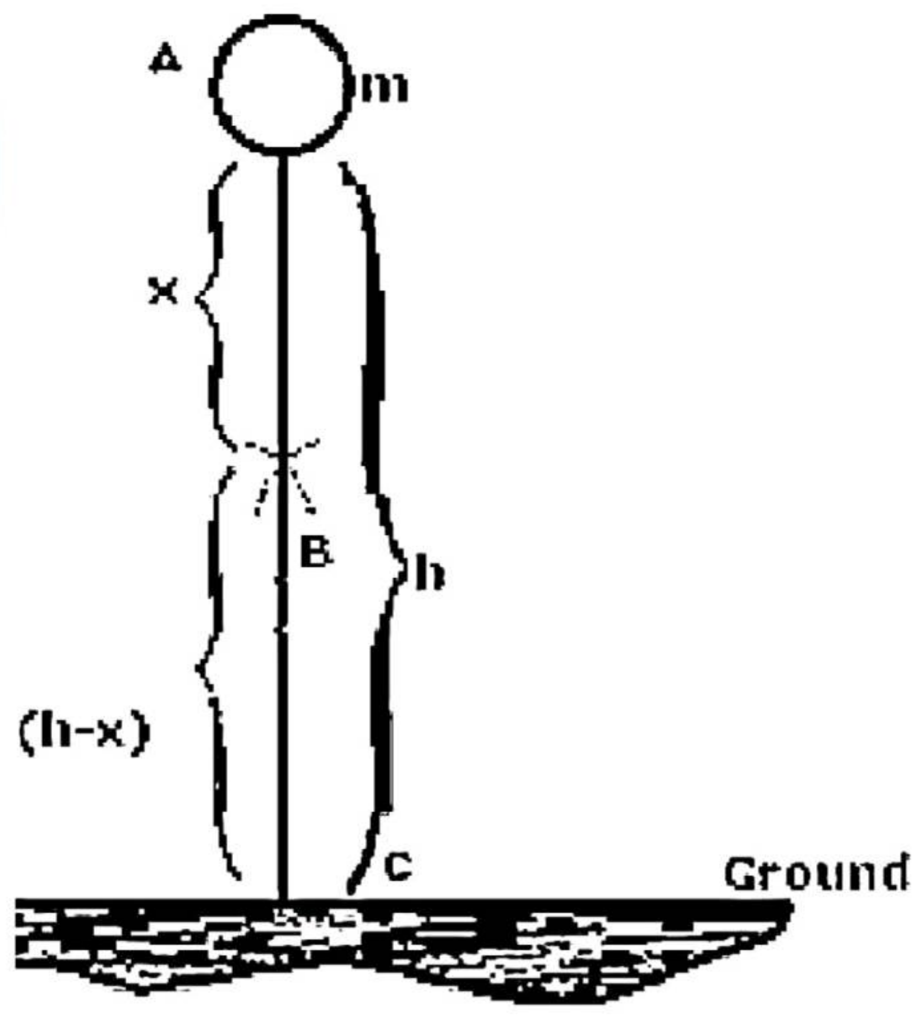
As we know that potential energy at point B is less than the potential energy at point A,i.e.

$$mg(h-x) < mgh$$

or $$mgh - mgx < mgh$$

The loss in potential energy at point B is mgx.

The Kinetic Energy at point A is equal to zero because the body is at rest.During its downward motion its velocity increases ,so its kinetic energy also increases.If there is no air friction then the loss of P.E is equal to the gain in K.E, means P.E is converted into K.E.



When the body reaches at point C its P.E becomes zero which means all of its P.E is converted into K.E,so we can write as

Loss in P.E = Gain in K.E

Practically there is always a force of friction which opposes the downward motion of the body.Let if friction f is present in this case then some amount of P.E is lost in work done against friction.Now, the modified equation can be written as,

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

$$mgx = 1/2\ mv^2 + fx$$

or $$1/2\ mv^2 = mgx - fx$$

In terms of "h"

$$1/2\ mv^2 = mgh - fh$$

The above equation is known as "Work Energy Equation".

ABSOLUTE GRAVITATIONAL POTENTIAL ENERGY (A.G.P.E.)

DEFINITION:

The potential energy of a body at height "h" from centre of earth w.r.t. a point at which the gravitational field is zero i.e. a point which has no potential is called absolute gravitational potential energy.

1. Gravitational Potential Energy(G.P.E.):

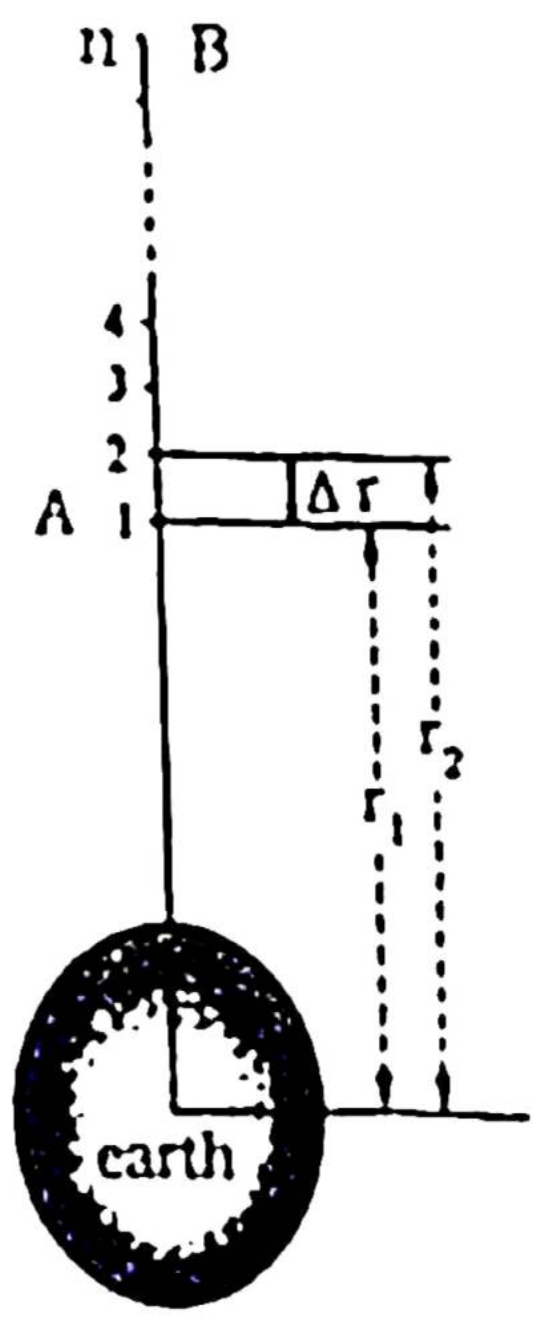
In order to derive formula for gravitational potential energy ,we have assumed that throughout the displacement of the body from the initial position to the final position force of gravity remains constant. But for large displacements (height h) as measured from the surface of the earth. e.g in spa ce flights we cannot take the gravitational force as constant. In fact. it decreases with the increase of height. Hence to calculate the work done (which is a measure of R_e) against the force of gravity the simple formula F .S cannot be applied.

To overcome this difficulty we divide the entire displacement into a large number of small displacement intervals and applying Newton's Law of Gravitation.

A point B is situated at large distance from the surface of earth. In order to find work done in bringing the mass "m" fro initial position A or 1 to final position B or n. We divide the distance between A and B into large number say, n of intervals of equal width Δreach.

Since Δr is small,the force of gravity throughout this in can be assumed to be constant. This value of constant force may taken as the average of the forces acting at the two ends of an interval. The magnitude F_1, of the force $\vec{F}_1$ acting at the point 1 (first end of the first interval) is given by

$$F_1 = \frac{GmM_e}{{r_1}^2}$$



Here M_e is the mass of earth. G is universal gravitational constant and r_1 is the distance of the point 1 from the centre of the earth.Similarly the magnitude F_2 of the force F_2 acting at point 2 is given by

$$F_2 = \frac{GmM_e}{{r_2}^2}$$

The average force acting throughout the first interval

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

where F represents the magnitude of the average force ,therefore

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

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

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

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

as Δr is very small, Δr^2 is negligibly small,

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

$$F = \frac{GmM_e}{r_1 r_2}$$

The work done in lifting the body from point 1 (position A) to point 2 by an applied force. which is equal and opposite to the average gravitational force is given by

$$W_{12} = \vec{F}.\overrightarrow{\Delta r}$$

Since the applied force F and displacement Δr are in the same direction.

$$W_{12} = F\Delta r$$

substituting for F, Δr in the above equation. we get

$$W_{12} = \frac{GmM_e}{r_1 r_2}(r_2 - r_1)$$

$$W_{12} = GmM_e\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

Similarly the work done in lifting the body from point 2 to 3, 3 to 4,...and so on

$$W_{23} = GmM_e\left(\frac{1}{r_2} - \frac{1}{r_3}\right)$$

$$W_{(n-1)n} = GmM_e\left(\frac{1}{r_{n-1}} - \frac{1}{r_n}\right)$$

Hence the total work done by the applied force in lifting the body from initial position A to final position B,we get

$$W = W_{12} + W_{23} ... + W_{(n-1)n}$$

$$W = GmM_e\left(\frac{1}{r_1} - \frac{1}{r_2}\right) + GmM_e\left(\frac{1}{r_2} - \frac{1}{r_3}\right) ... + GmM_e\left(\frac{1}{r_{n-1}} - \frac{1}{r_n}\right)$$

$$W = GmM_e\left(\frac{1}{r_1} - \frac{1}{r_2} + \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_3} - \frac{1}{r_4} ... + \frac{1}{r_{n-2}} - \frac{1}{r_{n-1}} + \frac{1}{r_{n-1}} - \frac{1}{r_n}\right)$$

$$\boxed{W = GmM_e\left(\frac{1}{r_1} - \frac{1}{r_n}\right)}$$

This is the P.E represented by U of the body at the point B with respect to the point A. Hence the potential energy of the body at the point A with respect to that at the point B is $\Delta U = -W$

$$\Delta U = -GmM_e\left(\frac{1}{r_1} - \frac{1}{r_n}\right)$$

or $$\boxed{\Delta U = GmM_e\left(\frac{1}{r_n} - \frac{1}{r_1}\right)}$$ => Gravitational Potential Energy

When the point B lies at an infinite distance i.e. r_n the P.E. at that point is zero (this point becomes reference point) then a

$$U = -\frac{Gm\,M_e}{r_1}$$

or

$$U = -\frac{Gm\,M_e}{r_1}$$

Therefore the absolute P.E of a body of mass m lying at the surface of the earth is given by

$$P.E(abs) = U = -\frac{Gm\,M_e}{R_E}$$ => Absolute Gravitational Potential Energy

Where R_E is the radius of earth.

The minus sign indicates that the potential energy is "negative" at any finite distance that is the potential energy is zero at infinity and decreases as the separation distance decreases. This is due to the fact that the gravitational force acting on the particle by earth is attractive. As the particle moves in from infinity the Work is positive which means U is negative.

VARIOUS SOURCES OF ENERGY

There are many other forms of energy except K.E and P.E ,extracted from different sources.Some of them are given below.

(i) Wind Energy (Wind Power) :

The source of this energy is the wind. This energy is used in running flour mills. In Karachi near Suhrab Goth you can see a wind mill for drawing underground water.

(ii) Hydro electricity (Water Power):

Mangla dam. Tarbela dam and other dams in our country are used to produce electrical energy. Their prime function. is to retain river water so that it can be shuttled off to a water turbine that drives an electrical generator. The principle involves a way of supplying power to a generator other than by a steam turbine.

(iii) Fossil Fuel:

Fossil fuels are remnants of plants and animals which died millions of years ago. Depending on the conditions of formation the fuel can be liquid (crude oil), gaseous (natural gas), or solid (Coal,peat,lignite). Coal is being used by man since long as a source of energy in present age the main source of energy is gasoline. Fossil fuel is used for running machines for driving engines etc.

(iv) Nuclear Energy:

The nuclear energy is produced due to the fission of a heavy nucleus. If fission reaction occurs in a controlled manner (in a reactor) the nuclear energy is used to produce electrical power. A nuclear reactor is working in Karachi to generate electrical power.The energy thus produced is more economical and non polluting. If fission reaction is uncontrolled the enormous energy produced in the form of heat causes heavy destruction. The destruction of Japan due to it is a tragic example.

(v) Geothermal Energy:

Geothermal energy is the earth's natural heat. Heat ,in fact conducted out from the interior of the surface of planet (earth) at a rate of approximately 1.5 u cal/cm^2-s and over a time interval of a year this flux to the entire surface 1020 cal. Practically, heat must be concentrated in geothermal reservoirs where it is to be exploitable. It is interesting to observe, however ,that in the upper 10 km (when the temperature exceeds 100°C) the total stored geothermal energy exceeds by order of magnitude all thermal energy available in all nuclear and fossil fuel sources.

(vi) Solar Energy:

Solar energy is by far our most available energy source. Our lives absolutely depend on it for food production and we call on it for a multitude of things ranging from sun tanning to clothes drying. Solar energy could make a major impact on our energy economy.

(1) Providing space heating,space cooling and hot water building
(2) Providing clean fuels
(3) Generating electricity by solar cells.

(vii) Tidal Energy:

The thought of harnessing the enormous energy content of both the ocean and tides have pervaded the minds of human being for centuries. The tides have their origin in the gravitational force exerted on the earth by the moon and the sun. Water-powered mills operating from tidal motion were used in New England in the 18th century. Sewage pumps functioned in Germany and London by using tidal power. These systems were (replaced by the more economical and convenient electric motors.)Although no source exists that renders less environmental damage, tidal energy is difficult to harness and marginally economical.

For Pakistan:

The fossil fuel is used as the main source of energy in Pakistan. It requires a huge amount of foreign exchange to import it. Due to its burning environmental damage is done on a very high scale. The hydro electric generation is also limited and also costly. For our present and future, needs we must provide indigenous atomic reactor to generate electrical power. Along with solar energy should be exploited to a greater extent. Solar emery is ideal source of energy to get rid of pollution. Solar energy is available in most of the parts of Pakistan throughout the year.

M.C.Qs.

1. All of them are true except:
(a) Work is defined as the product of force and displacement
(b) Joule is the unit of work
(c) Force moves in its direction or in opposite directions
(d) The resultant force on it is zero

2. Work is defined as:
(a) Scalar product of force and displacement
(b) Vector product of force and displacement
(c) Scalar product of force and velocity
(d) Vector product of force and velocity

3. Work done will be zero when force and displacement are:
(a) In the same direction
(b) In opposite direction
(c) Perpendicular to each other
(d) Not zero

4. The work done on a body undergoing a certain displacement is given by:
(a) The area under a force vs. time curve
(b) The area under a force vs. distance curve
(c) The area under a velocity vs time curve
(d) The area under an acceleration vs time curve

5. If F=3i and d=6j, the work done will be:
(a) Zero (b) 2 (c) 9 (d)18

6. Power is the dot product of:
(a) Mass & velocity (b) Force & velocity
(c) Force & Energy (d) Force & mass

7. The power required to lift a 40 kg weight, up to the height of 5 m in 10 sec will be:
(a) 80 watts (b) 200 watts
(c) 28 watts (d) 14000 watts

8. A 600 N man runs up a stair of 4m height,in 3 seconds. The power needed is:
(a) 24W (b) 350W
(c) 450W (d) 800W

9. One kilo watt hour is equal to:
(a) 3.6×10^6 J (b) 3.3×10^9 J
(c) 3.9×10^6 J (d) 3.6×10^9 J

10. This one of the following is not the unit of power:
(a) horse power (b) joule/sec
(c) kilowatt hour (d) foot-pound/sec

11. The K. E of a 1000 kg car moving at a speed of 80 km/hr will be:
(a) $2.47\text{x}10^8$ J (b) $2.47\text{x}10^5$ J
(c) $24.7\text{x}10^7$ J (d) $24.7\text{x}10^3$ J

12. The energy due the motion of a mass is known as:
(a) Potential energy (b) Motion energy
(c) Mobile energy (d) Kinetic energy

13. If the velocity of the moving particle is double the factor by, which the K. E is increased is:
(a) 4 (b) 1/2 (c) 2
(d) 6

14. The velocity of a body is doubled and mass is reduced to one fourth of its initial value, the K.E is:
(a) doubled (b) fourfold

(c) same (d) halved

15. A bucket of mass 10 kg is moved downwards in the gravitational field through a distance of 1 m. The work done in this case is equal to:

(a) 10 J (b) 98 J
(c) -98 J (d) 0.1 J

16. The work done by a conservative force along a closed path is:

a) positive (b) negative
(c) zero (d) none of these

17. When a body moves vertically upward, the work done will be:

(a) positive (b) negative
(c) zero (d) maximum

18. A body of mass 10 kg moving at a height of 2 m, with uniform speed of 2 m/s. Its total energy is

(a) 316 J (b) 216 J
(c) 116 J (d) 392 J

19. Which one has higher kinetic energy? Both light and heavy bodies have equal momentum.

(a) Heavy body (b)Light body
(c) Both (d)None of the option

20. Power is

a) Rate of doing work b) Ability to do work
c) Rate of energy creation d) Equivalent to work

21. Which of the following is true?

(a) Potential energy decreases as altitude increases
(b) Potential energy increases as altitude increases
(c) Potential energy first increases and then decreases as altitude increases
(d) Potential energy first decreases and then increases as altitude increases

22. What happens to the total energy of a moving object if all the applied forces are conserved?

(a) It increases (b) It decreases
(c) It remains constant (d) none of these

23. What happens to the kinetic energy of a moving object if the net work done is positive?

(a) The kinetic energy increases
(b) The kinetic energy decreases
(c) The kinetic energy remains the same
(d) The kinetic energy is zero

24. A spacecraft moves around Earth in a circular orbit with a constant radius. How much work is done by the gravitational force on the spacecraft during one revolution?

(a) FGd (b) - FGd
(c) mgh (d) Zero

25. When a body falls freely under gravity, then the work done by the gravity is __________

(a) Positive (b) Negative
(c) Zero d) Infinity

26. When a body slides against a rough horizontal surface, the work done by friction is __________

(a) Positive (b) Zero
(c) Negative (d) Constant

27. When a coolie walks on a horizontal platform with a load on his head, the work done by the coolie on the load is zero.

(a) Positive (b) Zero
(c) Negative (d) Constant

28. When a body slides against a rough horizontal surface, the work done by friction is __________

(a) Positive (b) Zero
(c) Negative (d) Constant

29. The tidal energy is due to:

(a) The rotation of earth about sun
(b) The rotation of earth relative moon
(c) The radioactive decay inside earth
(d) Attraction of sun and moon

30. The work done in moving a object along a vector=3i + 2j – 5k. If the applied force is F = 2i–j - k:
(a) 10j (b) 6i – 2j – 5k
(c) 0j (d) 9j

PAST PAPER M.C.Qs.

2022

2.If velocity of a body is doubled and mass is reduced to one forth, kinetic energy will be
*doubled *** unchanged** * halved * fourfold

8. One kilo watt hour is equal to:
***3.6 x 10^6 J** *3.3 x 10^9 J *3.9 x 10^6 J *3.6 x 10^9 J

10.The dot product of force and velocity is called
* work ***power** *momentum *energy

12. If F= 3i and d=6j the work done will be:
***zero** *2 *9 *18

22.A body pushes a toy car , on a horizontal floor with a force of 10 N up toa displacement of 2m then work done by gravity on the car is:
* 20J * 10J * 5J *** 0 J**

31.A force acting on a body is perpendicular to displacement , the work done is equal to:
*positive *negative ***zero** *infinite

2021

(xiv) Work energy equation is called:
* Law of conservation of mass * Law of conservation of momentum
* **Law of conservation of energy** * Law of conservation of angular momentum

(xxii) A weight lifter consumes 500 J of energy to lift a load in 2 seconds, the power consumed is:
*125 watt *500 watt ***250watt** *1000watt

(xxv) Both Kilowatt hour and electron volt are the units of:
*Power *Charge ***Energy** *Angular momentum

(xxxii) If the speed of moving body is to be halved, its kinetic energy becomes

***One fourth** *double * Half *Four times

(xxxv) If F= 3i and d 6j the work done will be:

***zero** *2 *9 *18

(xxxvii) The ocean tides are caused by:

*Earth's gravitational force only *Moon's gravitational force only
* Sun's gravitational force only ***Gravitational force of both the sun and moon**

(xli) The work done by the force of 10N applied to the direction of motion up to 20m is:

*10J ***200J** *2000J *20J

2019

1.If F=3i and d=6j, the work done will be:

*** Zero** *2 *9 *18

2018

4. A 600 N man runs up a stair of 4m height,in 3 seconds. The power needed is:

*24W *350W *450W ***800W**

15.If the velocity of a body is doubled and mass is reduced to one-fourth of its initial value ,the kinetic energy will be:

*be doubled *four fold *** remains same** * becomes zero

2017

6. The ocean tides are caused by:

*earth's gravitational force only * moon's gravitational force only
* sun's gravitational force only *** sun's and moon's gravitational force**

8. Both kilowatt hour and electron volt are the unit of :

*power ***energy** *charge *angular momentum

2016

14. One kilo watt hour is equal to:

***3.6 x 10^6 J** *3.3 x 10^9 J *3.9 x 10^6 J *3.6 x 10^9 J

2015

1. Electron volt is the unit of:

*Power *voltage ***energy** *charge

17. This one of the following is not the unit of power:

* horse power * joule/sec ***kilowatt hour** *foot-pound/sec

2014

2. Kilowatt hour is a unit of:

***Energy** * Power *Time *Force

12. If mass and speed both are doubled, the kinetic energy will be:

* double *four times *six times ***eight times**

2013

17. The weight lifter consumes 500J of energy to lift a load in 2 seconds, the power used by him is:

*125 watt ***250 watt** *500 watt *1000 watt

2012

14. The rate of doing work is zero when the angle between force and velocity is:

$*0^0$ $*\ 45^0$ $*\ 180^0$ **$*\ 90^0$**

16. The velocity of a body is doubled and mass is reduced to one fourth of its initial value, the K.E is:

*doubled * fourfold *** same** * halved

11. A bucket of mass 10 kg is moved downwards in the gravitational field through a distance of 1 m. The work done in this case is equal to:

*10 J *** 98 J** * -98 J * 0.1 J

2011

7. If the speed of moving body is halved, its kinetic energy becomes:

***one fourth** *half *three times *four times

15. The work done by a conservative force along a closed path is:

*positive * negative ***zero** *none of these

2010

2. When a body moves vertically upward, the work done will be:

*positive *** negative** * zero * maximum

TEXTBOOK NUMERICALS

Q.1: Calculate the work done by a force F specified by F = 3i + 4j + 5k in displacing a body from position B to position A along a straight path. The position vectors A & B are respectively given as r_A = 2i + 5j – 2k & r_B = 7i + 3j – 5k

Data:

Initial position = r_A = 2i + 5j -2k

Final position = r_B = 7i + 3j -5k

Force = F = 3i +4 j + 5k

Work = W =?

Solution:

According to the def. of work

$W = \vec{F}.\vec{S}$---- (i)

$\vec{S} = r_A - r_B$

$\vec{S} = 2i + 5j - 2k - (7i + 3j - 5k)$

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

$$\vec{S} = -5i + 2j + 3k$$

Putting in eq (i)

$W = \vec{F}.\vec{S}$

$W = (3i + 4j + 5k).(-5i + 2j + 3k)$

$W = -15 + 8 + 15$

$W = 8\ units$

Result: The work done is 8 units.

Q.2: A 2000 kg car traveling at 20 m/s comes to rest on a level ground in a distance of 100 m. How large is the average frictional force tending to stop it?

Data:

Mass of Car $= m = 2000\ kg$

Initial Speed of Car $= v_i = 20\ m/s$

Final Speed of Car $= v_f = 0$

Distance covered $= S = 100\ m$

Frictional Force $= F = ?$

Solution:

As we know that

$F = ma$ --- (i)

For Acceleration:

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

$2a(100) = (0)^2 - (20)^2$

$a(200) = -400$

$a = -2\ m/s^2$

Putting values in eq (i)

$F = ma$

$F = 2000 \times (-2)$

$F = -4000\ N$

Result: The average frictional force tending to stop car is 4000 N.

Q.3: A 100-kg man is in a car traveling at 20 m/s. (a) Find his kinetic energy. (b) The car strikes a concrete wall and comes to rest after the front of the car has collapsed 1 m. The man is wearing a seat bell and harness. What is the average force exerted by the belt and harness during the crash?

Data:

Mass of Man $= m = 100\ kg$

Initial Speed of Car $= v_i = 20\ m/s$

(a) Kinetic Energy of Man $= K.E = ?$

Final Speed of Car $= v_f = 0$

Distance covered $= S = 1\ m$

(b) Force exerted by the belt $= F = ?$

Solution:

(a) Kinetic Energy is given by

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

$K.E = \frac{1}{2} \times 100 \times (20)^2$

$K.E = 20000\ J$

(b) As we know that

$F = ma$ --- (i)

For Acceleration:

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

$2a(1) = (0)^2 - (20)^2$

$a(2) = -400$

$a = -200\ m/s^2$

Putting values in eq (i)

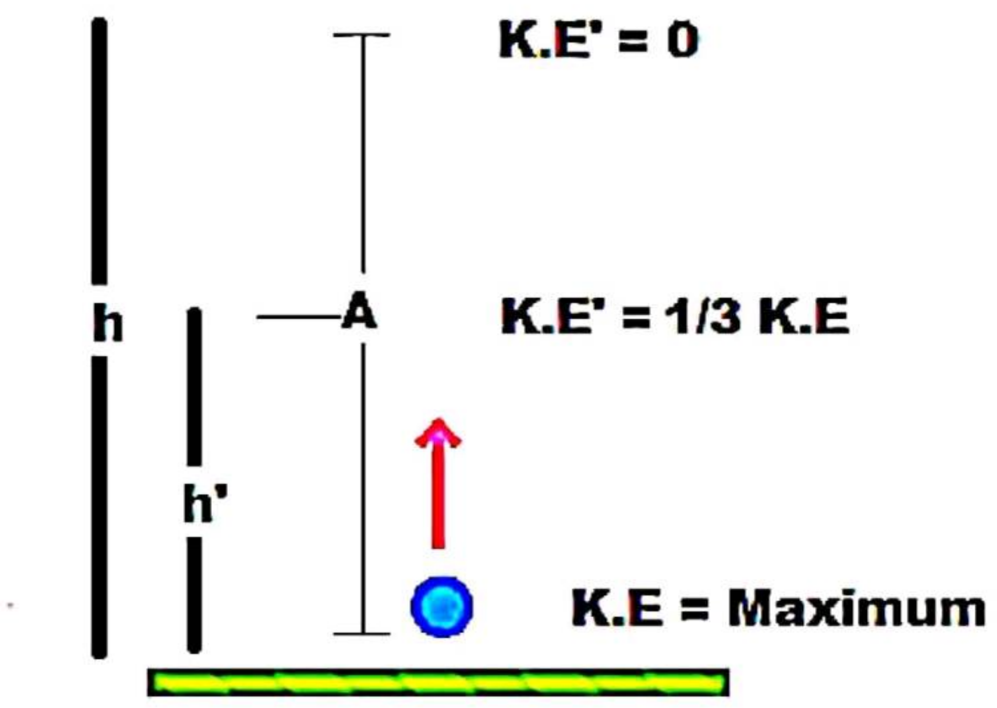
$F = ma$

$F = 100 \times (-200)$

$F = -20000\ N$

Result: The Kinetic Energy of Man is 20000 J and the force exerted by the belt is $-20000\ N$

Q.4: When an object is thrown upward, it rises to a height 'h'. How high is the object, in terms of h, when it has lost one-third of its original kinetic energy?



Data:

Final Height = h

Height where 1/3 K.E lost = h' =?

Solution:

According to the Law of conservation of Energy

$Change\ in\ K.E = Change\ in\ Potential\ Energy$

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

Similarly at point A

$$K.E' = mgh' \text{ ---(i)}$$

According to the given condition

$$K.E' = \frac{1}{3}K.E$$

so Eq (i) =>

$$\frac{1}{3}K.E = mgh'$$

Or

$$\frac{1}{3}(mgh) = mgh'$$

$$\boxed{h' = \frac{1}{3}h}$$

Result: The object will loose its One Third K.E when it has covered one-third of its height.

Q.5: A pump is needed to lift water through a height of 2.5 m at the rate of 500 g/min. What must the minimum horse power of the pump be?

Data:

$Height = h = 2.5\ m$

$Rate\ of\ flow = \frac{m}{t} = 500\frac{g}{min} = \frac{500}{(1000 \times 60)}$

$= 0.0083\ kg/sec$

$Power\ of\ pump = P = ?\ (in\ hp)$

Solution:

According to the definition of Power

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

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

$$P = \frac{m}{t} \times g \times h$$

$$P = 0.0083 \times 9.8 \times 2.5$$

$$P = 0.204\ W$$

$Since\ \ 1\ hp = 726\ watt$

$$P = \frac{0.204}{746}$$

$$\boxed{P = 2.7 \times 10^{-4} hp}$$

Result: The minimum horse power required is $2.7 \times 10^{-4} hp$.

Q.6: A horse pulls a cart horizontally with a force of 40 lb at an angle 30° above the horizontal and moves along at a speed of 6.0 miles/hr. (a) How much work does the horse do in 10 minutes? (b) What is the power out put of the horse?

Data:

Force applied by horse = F = 40 lb

Angle b/w force and displacement = $\theta = 30^0$

Speed = v = 6 mi / hr = $\frac{6 \times 5280}{3600} = 8.8\ ft/sec$

Work done by the horse = W = ?

Time = t = 10 minutes = 10 x 60 = 600 s

Power output of the horse = p = ?

Solution:

$$P = Fv\ Cos\theta$$

$$P = 40 \times 8.8 \times\ Cos30$$

$$\boxed{P = 304.8\ lb - ft\ /sec}$$

In hp:

$$1\text{ hp} = 550\ lb - ft\ /sec$$

So,

$$\boxed{P = \frac{304.8}{550} = 0.55\ hp}$$

According to the definition of Power

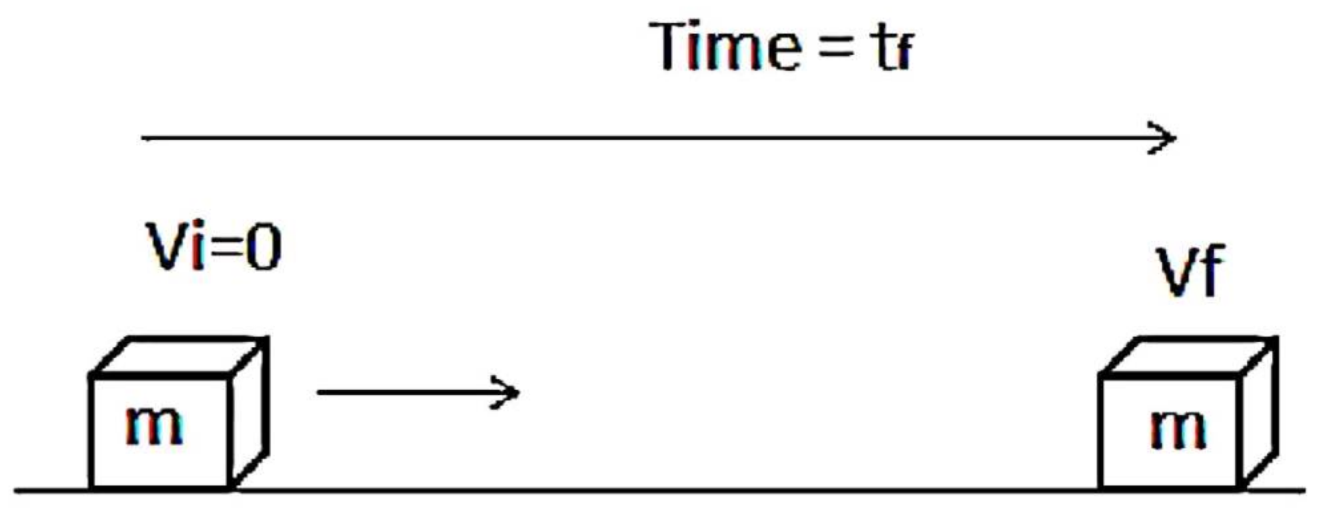
$$P = \frac{W}{t}$$

$$W = P \times t = 304.8 \times 600 = 1.82 \times 10^5 lb - ft$$

Result: The work done by the horse is $1.82 \times 10^5 lb - ft$ and power output is 0.55 hp.

Q.7: A body of mass 'm' accelerates uniformly from rest to a speed V_f in time t_f. Show that the work done on the body as a function of time 't', in terms of V_f and t_f, is $\frac{1}{2} m \frac{v_f^2}{t_f^2} t^2$.

Proof:



The work done is given by

$W = FS$ ---(i)

First we will find "F"Using newton's 2nd Law of Motion

$$F = ma$$

$$F = m\left(\frac{v_f - v_i}{t_f}\right)$$

$$F = m\left(\frac{v_f - 0}{t_f}\right)$$

$$F = \frac{m v_f}{t_f}$$

Now, we will calculate "S" using 2nd equation of Motion

$$S = v_i t + \frac{1}{2} a t^2$$

$$S = 0 \times t + \frac{1}{2}\left(\frac{v_f}{t_f}\right) t^2$$

$$S = \frac{1}{2}\left(\frac{v_f}{t_f}\right) t^2$$

Putting values of "F" and "S" in eq (i)

$$W = \frac{m v_f}{t_f} \times \frac{1}{2}\left(\frac{v_f}{t_f}\right) t^2$$

$$W = \frac{1}{2} m \frac{v_f^2}{t_f^2} \times t^2$$

Hence proved that the work done on the body as a function of time 't', in terms of V_f and t_f, is $\frac{1}{2} m \frac{v_f^2}{t_f^2} t^2$.

Q.8: A rocket of mass 0.200 kg is launched from rest. It reaches a point p lying at a height 30.0 m above the surface of the earth from the starting point. In the process + 425 J of work is done on the rocket by the 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.

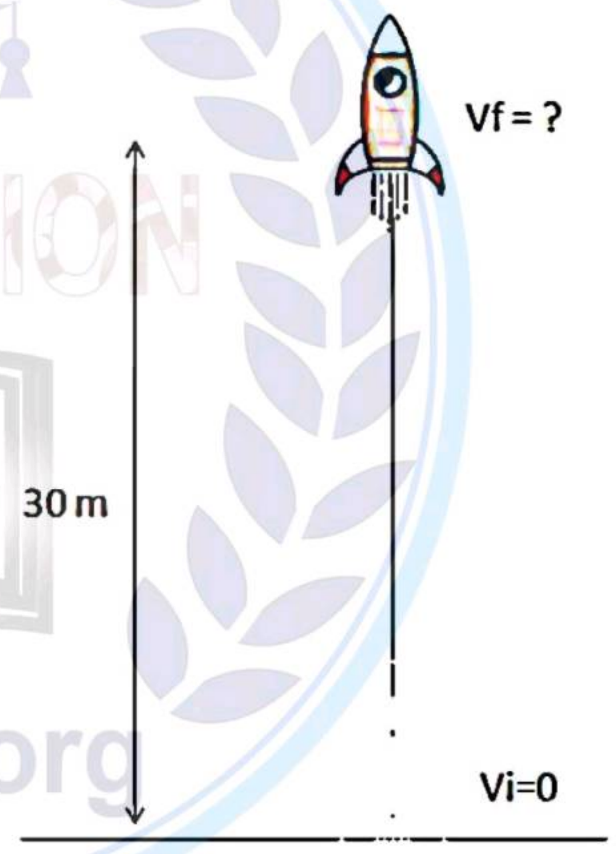
Data:

Mass of Rocket = $m = 0.200\ kg$

Height Covered by Rocket = $h = 30.0\ m$

Work done on the Rocket = $W = +425\ J$

Final Speed of Rocket = v_f =?



Solution:

In this case the total work done by the fuel will be conerted into Kinetic Energy and Potential Energy.Therefore,

$W = K.E + P.E$

$W = \frac{1}{2}mv_f^2 + mgh$

$425 = \frac{1}{2}(0.200) \times v_f^2 + 0.200 \times 9.8 \times 30$

$425 = 0.1 \times v_f^2 + 58.8$

$v_f^2 = \frac{425 - 58.8}{0.1} = 3662$

Taking Square root on both sides

$v_f = \sqrt{3662}$

$\boxed{v_f = 60.5\ m/s}$

Result: The speed V_f of the rocket will be 60.5 m/s

PAST PAPER NUMERICALS

2022

viii) Two forces $F_1 = 3i - 2j + 5k$ and $F_2 = i + 6j + 2k$ act on a body which is displaced along a vector $r = 4i - j + 3k$. Calculate the work done on the body.

Data:

$F_1 = 3i - 2j + 5k$

$F_2 = i + 6j + 2k$

$r = 4i - j + 3k$

Work done $= w = ?$

Solution:

First we have to find the net force

$F = F_1 + F_2 = 3i - 2j + 5k + i + 6j + 2k$

$\boxed{F = 4i + 4j + 7k}$

Now, according to the definition of work

$w = F.r = (4i + 4j + 7k).(4i - j + 3k)$

$w = 16 - 4 + 21$

$\boxed{w = 33\ joules}$

Result: The work done by forces is 33 J.

2019

No Numerical

2018

Q.2(ix) A crane lifts a load of 6000 N through a vertical distance of 15 m in 30 s. What is the potential energy at the highest point of this operation?

Data:

Load = W = 6000 N

Height covered = h = 15 m

Time = t = 30 s

Potential Energy = P.E = ?

Solution:

According to the definition of Potential Energy

$P.E = mgh$

$P.E = (mg)h$

$Since\ W = mg$

$\therefore P.E = Wh$

$P.E = 6000 \times 15$

$\boxed{P.E = 90000\ J}$

Result: The potential energy at the highest point is 90000 J.

2017

2(v) A horse pulls a cart horizontally with a force of 60 lb at an angle of 30 degrees above the horizontal and moves along at a speed of 8 miles per hour. How much work does the horse do in 15 minutes and what

is the power output of the horse.(1 hp=550 lb-ft / sec) and (1 mile=5280 ft).

Data:

Force applied by horse = F = 60 lb

Angle b/w force and displacement= $\theta = 30^0$

Speed = v = 6 mi / hr = $\frac{8\times 5280}{3600} = 11.73\ ft/sec$

Work done by the horse = W = ?

Time = t = 15 minutes = 15 x 60 = 900 s

Power output of the horse = p = ?

Solution:

$$P = Fv\ Cos\theta$$

$$P = 60 \times 11.73 \times\ Cos30$$

$$\boxed{P = 609.6\ lb - ft\ /sec}$$

In hp :

$$1\ \text{hp} = 550\ lb - ft\ /sec$$

So, $\boxed{P = \frac{609.6}{550} = 1.10\ hp}$

According to the definition of Power

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

$$\boxed{W = P \times t = 609.6 \times 900 = 5.48 \times 10^5 lb - ft}$$

Result: The work done by the horse is $5.48 \times 10^5 lb - ft$ and power output is $1.10\ hp$.

2016

Q.2 (vi) **Textbook Numerical 5**

2015

Q.2 iii) A 80 kg man runs up a hill through a height of 3m in 2 sec. What is his average power output?

Data:

Mass of man = m= 80 kg

Height = h = 3 m

Time = t = 2 sec

Average Power = P =?

Solution:

The Average power is given by

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

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

$$P = \frac{80\times9.8\times3}{2} = \frac{2352}{2}$$

$$\boxed{P = 1176\ W}$$

Result:

His average output power is 1176 W.

Q.2 v) An object moves along a straight line in a force field from (3, 2, -6) to (14, 13, 9) when a uniform force F=4i + j + 3k acts on it. Find the work done.

Data:

Initial position = r_1 = (3, 2,-6) = 3i + 2j -6k

Final position = r_2 = (14, 13, 9) = 14i + 13j + 9k

Force = F = 4i + j + 3k

Work = W =?

Solution:

According to the def. of work

$W = \vec{F}.\vec{S}$---- (i)

$\vec{S} = r_2 - r_1 = 14i + 13j + 9k - (3i + 2j - 6k)$

$\vec{S} = 14i + 13j + 9k - 3i - 2j + 6k$

$$\boxed{\vec{S} = 11i + 11j + 15k}$$

Putting in eq (i)

$$W = \vec{F}.\vec{S}$$

$$W = (4i + j + 3k).(11i + 11j + 15k)$$

$$W = 44 + 11 + 45$$

$$\boxed{W = 100\ units}$$

Result:

The work done is 100 units.

2014

Q.2 (xiv) **Textbook Numerical 5**

2013

Q.2 (v) A horse pulls a cart horizontally with a force of 40 N at an angle of 25 degrees above the horizontal

and moves along at a speed of 15 m/s . How much work does the horse do in 5 minutes and what is the power output of the horse. Give your answer in horse power (1 hp=746 W)

Data:

Force applied by horse = F = 40 N

Angle b/w force and displacement= $\theta = 25^0$

Speed = v = 15 m/s

Work done by the horse = W = ?

Time = t = 5 minutes = 5 x 60 = 300 s

Power output of the horse = p = ?

Solution:

$$P = Fv\, Cos\theta$$

$$P = 40 \times 15 \times \, Cos25^0$$

$$\boxed{P = 543.7\ W}$$

In hp :

$$1\text{ hp} = 746\, W$$

So, $\boxed{P = \frac{543.7}{746} = 0.72\ hp}$

According to the definition of Power

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

$$\boxed{W = P \times t = 543.7 \times 300 = 1.63 \times 10^5 J}$$

Result: The work done by the horse is $1.63 \times 10^5\ J$ and power output is $0.72\ hp$.

2012

Q.2 (iv) An object weighing 98N is dropped from a height of 10m. It is found to be moving with a velocity 12m/sec just before it hits the ground. How large was the frictional force acting upon it?

Data:

Weight of Object = W = 98 n

Height of object = h = 10 m

Initial Velocity = vi = 0

Final velocity = vf = 12 m/s

Frictional Force = f =?

Solution:

A/c Work – Energy Equation

$mgh = \frac{1}{2}mv^2 + fh$ --- (i)

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

Putting in eq (i)

$$10 \times 9.8 \times 10 = \frac{1}{2} \times 10 \times 12^2 + f \times 10$$

$$980 = 720 + f \times 10$$

$$f = \frac{980 - 720}{10}$$

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

Result: The acting frictional force is 26 N.

2011

Q.2 (xii) **Textbook Numerical 5**

2010

Q.2 (x) **Textbook Numerical 5**