OBRAHM PRAKASH DAV SCHOOL

CLASS IX

WORK POWER ENERGY

RUNNING NOTES

WORK

In physics, work is said to be done when a force acts on an object and the object shows displacement.

Examples: i) A crane tow a broken car and takes it to a workshop.

Ii) a batman hitting a ball during a cricket match

iii) a person pushing a block from point A to point B

note: when force or displacement is zero the work done is zero. for example, if a person tries to push a heavy rock by applying maximum force but if the rock does not displace from its position the work done is zero.

Two conditions need to be satisfied for work to be done

i) A force should act on an object

ii) The object must be displaced.

Therefore **W = F S**

TYPES OF WORK

i) POSITIVE WORK

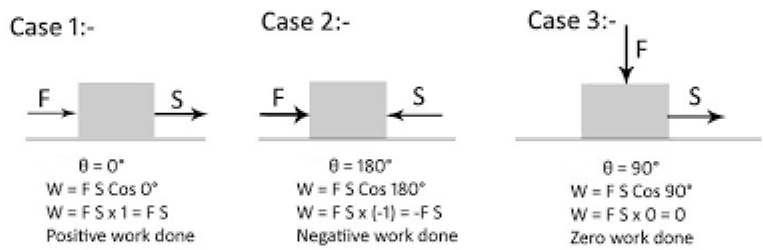
When the direction of force and displacement are the same, the work done is positive

ii) NEGATIVE WORK

When the direction of force and displacement are same, the work done is positive.

iii) ZERO WORK

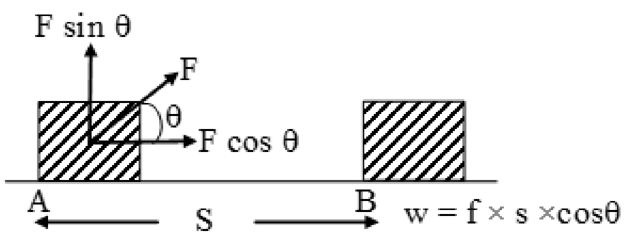
When the direction of force is perpendicular to the direction of displacement, work done is zero



EXAMPLE: i) when a person carrying a weight on his head and walks, the force is applied perpendicular to the direction of displacement

ii)a body moving in a circular path does no work because the force always acts at right angle to the direction of displacement. For this reason, satellites going around do no work.

<u>EXPRESSION FOR WORKDONE WHEN FORCE ACTS WITH SOME DIRECTION:</u>



When force is acting with making some angle to the direction of displacement then the force is is resolved into two components

- F cosθ in the direction of displacement and
- F sinθ perpendicular to the direction of displacement

The force component f cos θ in the direction of displacement. Hence

Work = Force X displacement X cosθ

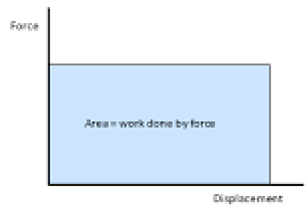
or **W = FSCosθ** where θ is the angle between the direction of force and direction of displacement

- Work is scalar quantity
- The SI unit of work is Joule (J) or Newton meter (N m).
- I Joule = 1 N.m = 1 kg m^2 / s^2
- 1 joule of work is done when a force of 1N acts on a body such that the body gets displaced by 1m
- The CGS unit of work is dyne cm (or) erg.

CALCULATION OF WORK FROM FOECE-DISPLACEMENT GRAPH:

We know that work is a product of Force and displacement. If a graph is plotted between the force acting on a body and the displacement of the body, then the area under the graph gives the magnitude of work done.

I)



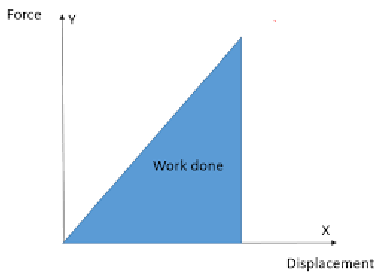
Work done = area under the graph

W = l x b

= OC x BC or

= OA x AB

II)



Work done = area under ΔAOB

= ½ x b x h = ½ x OB x AB

ENERGY

Let us consider some examples to understand the term ENERGY in terms of physics

i) When a raised hammer hits the nail placed on a piece of wood, the nail penetrates into the wood.

ii) When the striker hits the stationery carrom coins, the coin gets displaced

iii) When wind the spring of a toy car and place it on the floor the car gets displaced

In the above examples the objects acquire the capabilities to do work by different means such as, height, change in position and motion.

DEFINITION OF ENERGY

The ability of a body to do work is known as Energy. The body acquires energy because of its height, motion, change in shape.

- SI unit of energy is joule (J)

KINETIC ENERGY

The energy possessed by a body due to its motion is known as kinetic energy.

Examples : i) flowing water

ii)flying aero plane

iii)moving bus

MATHEMTICAL EXPRESSION FOR KINETIC ENERGY

Consider a body of mass ‘m’ kg is moving with velocity ‘v’ m/s then the work done to stop the body equls to the kinetic energy of the body

$$W = F \times s$$

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

$$W = \frac{1}{2} m (v^2 - u^2)$$

If u = 0, (object starts at rest)

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

Work done = Change in kinetic energy

$$\therefore \quad E_k = \frac{1}{2} mv^2.$$

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POTENTIAL ENERGY

The energy possessed by a body due to its position (height) or change in its shape is known as potential energy.

- If the energy possessed by the body is due to its height, it is known as gravitational potential energy.
- If the energy possessed by the body is due to its shape, it is known as elastic potential energy.

Example: i) Consider a brick lying at the ground level of a building, in this situation brick has no energy. If we carry the brick to the top of the building, we do some work against the gravity. The amount of work done in carrying it will be stored in it, in the form of gravitational potential energy

ii) Consider a bow and arrow. Place the arrow on the string of a bow but don't pull it. In this situation the system of bow and arrow has no energy. Now pull the string along with arrow in backward direction by applying some force. In doing so, you change the shape of bow. The energy spent by you in changing the shape of the bow will be stored inn the bow as static potential energy.

- Potential energy is always dormant (latent)

MATHEMATICAL EXPRESSION FOR POTENTIAL ENERGY

Consider an Object of mass m that is kept on ground. Let the object be raised vertically upwards to a height h against the force of gravity. in order to lift the store we need to apply force equal to the way of the stone

The object is lifted to a height = h

Let:
Force applied on the object = F
The mass of the object = m
The acceleration due to gravity = g

$$PE = W$$
$$W = F \times s$$
Here, $s = h$
$$\Rightarrow \quad PE = F \times h \qquad \dots (1)$$

$$F = m \times g$$
Substituting $F = mg$ in (1):
$$PE = m \times g \times h$$

$$\boxed{PE = mgh}$$

LAW OF CONSERVATION OF ENERGY

The energy in a system is created nor destroyed it may be transformed from one form to another. but the total energy of the system remains constant.

consider a body of mass M at height h held by a person

- Case 1

body is at height H from the ground level but not really, as a body is stationary at a particular height its velocity = 0

KE = ½ mv2

Here v = 0

Therefor KE = 0

PE = mgh

Total energy = PE + KE = 0 + mgh = mgh -----------(i)

- Case 2

when the body just reaches ground, let us calculate the final velocity of freely falling body on the ground level

V2 - u2 = 2gs here u = 0, as the body is dropped

V2 = 2gh ---------(ii)

The kinetic energy I was just by the body

KE = 1/2mv2

KE = 1 /2 * m* 2gh = mgh ---------(iii)

The potential energy possessed by the body at ground level

PE= mgh here h=0

PE = 0 --------- (iv)

From equation (iii) and (iv)

Total energy = PE + KE = 0 + mgh = mgh -------(v)

Total energy on reaching the ground is equals to the the total energy possessed by the body on height h.

hence energy is conserved .

POWER

Rate of doing work or the rate of transfer if energy is known as Power.

If an object does a work W in time t , then

Power = work / time

P = W / t

- SI unit of power is Watt
- 1W = 1J/s = 1N - m / s = 1kg m^2 / s^3
- The energy used in one hour at the rate of 1kw is called 1kWh
- 1kWh = 3.6 * 10^6 J
- 1000 watt = 1 kW (Kilo Watt)
- 1KWH = 1 unit,

  which is an International Trade unit whereon we pay Electric Charges to the Electricity Supply Utility . 1 KWH is an unit of Energy not Power.

Work and Energy

Q1. Look at the activities listed below. Reason out whether or not work is done in the light of your understanding of the term 'work'.
(a) Suma is swimming in a pond.
(b) A donkey is carrying a load on its back.
(c) A wind mill is lifting water from a well.
(d) A green plant is carrying out photosynthesis.
(e) An engine is pulling a train.
(f) Food grains are getting dried in the sun.
(g) A sailboat is moving due to wind energy.
(a) While swimming, Suma applies a force to push the water backwards. Therefore, Suma swims in the forward direction caused by the forward reaction of water. Here, the force causes a displacement. Hence, work is done by Suma while swimming.
(b) While carrying a load, the donkey has to apply a force in the upward direction. But, displacement of the load is in the forward direction. Since, displacement is perpendicular to force, the work done is zero.
(c) A wind mill works against the gravitational force to lift water. Hence, work is done by the wind mill in lifting water from the well.
(d) In this case, there is no displacement of the leaves of the plant. Therefore, the work done is zero.
(e) An engine applies force to pull the train. This allows the train to move in the direction of force. Therefore, there is a displacement in the train in the same direction. Hence, work is done by the engine on the train.
(f) Food grains do not move in the presence of solar energy. Hence, the work done is zero during the process of food grains getting dried in the Sun.
(g) Wind energy applies a force on the sailboat to push it in the forward direction. Therefore, there is a displacement in the boat in the direction of force. Hence, work is done by wind on the boat.

Q2. An object thrown at a certain angle to the ground moves in a curved path and falls back to the ground. The initial and the final points of the path of the object lie on the same horizontal line. What is the work done by the force of gravity on the object?
Since the body returns to a point which is on the same horizontal line through the point of projection, no displacement has taken place against the force of gravity, therefore, no work is done by the force due to gravity.

Q3. A battery lights a bulb. Describe the energy changes involved in the process.
Within the battery the chemical energy changes into electrical energy. The electric

energy on flowing through the filament of the bulb, first changes into heat energy and then into the light energy.

Q4. Certain force acting on a 20 kg mass changes its velocity from 5 m s^{-1} to 2 m s^{-1}. Calculate the work done by the

Kinetic energy is given by the expression,

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

Where,

K. E = Kinetic energy of the object

v = velocity of the object

- Kinetic energy when the object was moving with a velocity of 5 m/s

$(K. E)_5 = 1/2 \times 20 \times (5)^2$

$(K. E)_5 = 250$ J

- Kinetic energy when the object was moving with a velocity 2 m/s

$(K. E)_2 = 1/2 \times 20 \times (2)^2$

$(K. E)_2 = 40$ J

Work done = Change in kinetic energy

= 40 J – 250 J

= – 210 J

Therefore, work done = -210 J

Q5. A mass of 10 kg is at a point A on a table. It is moved to a point B. If the line joining A and B is horizontal, what is the work done on the object by the gravitational force? Explain your answer.

The work done is zero. This is because the gravitational force and displacement are perpendicular to each other.

Q6. The potential energy of a freely falling object decreases progressively. Does this violate the law of conservation of energy? Why?

It does not violate the law Of conservation of energy. Whatever, is the decrease in PE due to loss of height, same is the increase in the KE due to increase in velocity of the body.

Q7. What are the various energy transformations that occur when you are riding a bicycle?
The chemical energy of the food changes into heat and then to muscular energy. On paddling, the muscular energy changes into mechanical energy

Q8. Does the transfer of energy take place when you push a huge rock with all your might and fail to move it? Where is the energy you spend going?
Energy transfer does not take place as no displacement takes place in the direction of applied force. The energy spent is used to overcome inertia of rest of the rock.

Q9. A certain household has consumed 250 units of energy during a month. How much energy is this in joules?

Energy consumed in a month = 250 units

$= 250 \text{ kW h}$

$= 250 \text{ kW} \times 1 \text{ h}$

$= 250 \times 1000 \text{ W} \times 3600 \text{ s}$

$= 900{,}000{,}000 \text{ J} = 9.0 \times 10^8 \text{ J}$

Q10. An object of mass 40 kg is raised to a height of 5 m above the ground. What is its potential energy?If the object is allowed to fall, find its kinetic energy when it is half-way down.

Potential energy (K.E) is given by the expression,

K.E = m × g × h

Where,

- m = Mass of the object
- h = Vertical displacement
- g = Acceleration due to gravity (9.8 ms^{-2})

P.E = 40 × 9.8 × 5

P.E = 1960 J

At half-way down, the Kinetic energy of the item:

At this time, the item has an equal quantity of potential and K.E.

This can be due to law of conservation of energy. Hence, half-way down, the K.E. of the object can be calculated as

1960 J/ 2

⇒ 980 J

half way down = 980 J

Q11. What is the work done by the force of gravity on a satellite moving round the earth? Justify your answer.
When a satellite moves round the Earth, then at each point of its path, the direction of force of gravity on the satellite (along the radius) is perpendicular to the direction of its displacement (along the tangent). Hence, the work done on the satellite by the force of gravity is zero.

Q12. Can there be displacement of an object in the absence of any force acting on it? Think. Discuss this question with your friends and teacher.
The answer is both Yes and No. Yes because when an object moves in deep space from one point to another point in a straight line, the displacement takes place, without the application of force. No, because force cannot be zero for displacement on the surface of earth. Some force is essential.

Q13. A person holds a bundle of hay over his head for 30 minutes and gets tired. Has he done some work or not? Justify your answer.
The person does not do work because no displacement takes place in the direction of applied force as the force acts in the vertically upward direction.

Q14. An electric heater is rated 1500 W. How much energy does it use in 10 hours?
Energy consumed by an electric heater can be obtained with the help of the expression,
$P=W/t$
where,
Power rating of the heater, $P = 1500\text{ W} = 1.5\text{ kW}$
Time for which the heater has operated, $t = 10\text{ h}$
Work done = Energy consumed by the heater
Therefore, energy consumed = Power × Time
$= 1.5 \times 10 = 15\text{ kWh}$
Hence, the energy consumed by the heater in 10 h is 15 kWh or 15 units.

Q15. Illustrate the law of conservation of energy by discussing the energy changes which occur when we draw a pendulum bob to one side and allow it to oscillate. Why does the bob eventually come to rest? What happens to its energy eventually? Is it a violation of the law of conservation of energy?
When the pendulum bob is pulled (say towards left), the energy supplied is stored in the form of PE on account of its higher position. When the pendulum is released so that it starts moving towards right, then its PE changes into KE such that in mean position, it has maximum KE, and Zero PE. As the pendulum moves towards extreme right, its KE changes into PE such that at the extreme position, it has maximum PE and zero KE. When it moves from this extreme position to mean position, its PE again changes to KE. This illustrates the law Of conservation of energy. Eventually, the bob comes to rest, because during each oscillation a part of the energy possessed by it transferred to air and in overcoming friction at the point of suspension. Thus,

the energy of the pendulum is dissipated in air.
The law of conservation of energy is not violated because the energy merely changes its form and is not destroyed.

Q16. An object of mass, m is moving with a constant velocity, v. How much work should be done on the object in order to bring the object to rest?
Kinetic energy of an object of mass m moving with a velocity v is given by the expression $1/2mv^2$. To bring the object to rest, an equal amount of work i.e. $1/2mv^2$ is required to be done on the object.

Q17. Calculate the work required to be done to stop a car of 1500 kg moving at a velocity of 60 km/h.

Mass of car, $m = 1500$ kg

Velocity of car, $v = 60$ km/h $= 60 \text{x} \frac{5}{18} \text{m/s}$

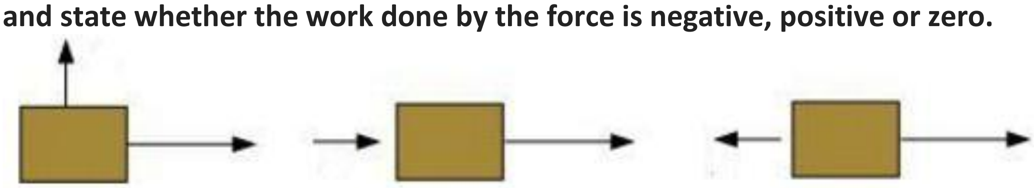
Kinetic energy, $E_k = \frac{1}{2} mv^2$

$$E_k = \frac{1}{2} \text{x} 1500 \text{x} \left(60 \text{x} \frac{5}{18}\right)^2 = 20.8 \text{x} 10^4 \text{J}$$

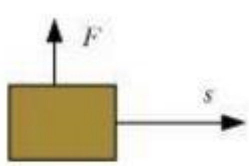
To stop the car, an amount of work equal to E_k is required to be done.

Hence, 20.8×10^4 J of work is required to stop the car.

Q18. In each of the following a force, *F* is acting on an object of mass, *m* . The direction of displacement is from west to east shown by the longer arrow. Observe the diagrams carefully and state whether the work done by the force is negative, positive or zero.

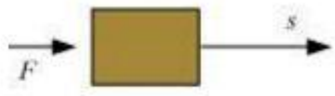


Case I



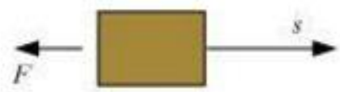
In this case, the direction of force acting on the block is perpendicular to the direction of displacement. Therefore, work done by force on the block will be zero.

Case II



In this case, the direction of force acting on the block and the direction of displacement is same. Therefore, work done by force on the block will be positive.

Case III



In this case, the direction of force acting on the block is opposite to the direction of displacement. Therefore, work done by force on the block will be negative.

Q19. Soni says that the acceleration in an object could be zero even when several forces are acting on it. Do you agree with her? Why?

Yes, acceleration in an object could be zero even when several forces are acting on it. This happens when all the forces cancel out each other i.e., the net force acting on the object is zero.

Q20. Find the energy in kWh consumed in 10 hours by four devices of power 500 W each.

Power rating of each device, P = 500 W = 0.50 kW
Time for which each device runs, t = 10 h
Work done = Energy consumed by each device (E)
We know, power = Energy consumed / Time
Energy consumed by each device= Power × Time
E = P x t
= 0.50×10 = 5 kWh
Hence, the energy consumed by four devices of power 500 W each in 10 h will be
4 × 5 kWh = 20 kWh = 20 units

Q21. A freely falling object eventually stops on reaching the ground. What happens to its kinetic energy?

As the object hits the hard ground, its kinetic energy gets converted into
(i) heat energy (the object and the ground become slightly warm)
(ii) sound energy (sound is heard when the object hits the ground)
(iii) potential energy of configuration of the body and the ground (the object and the ground get deformed a little bit at the point of collision).