WORK AND ENERGY

INTRODUCTION OF WORK

Work

The intuitive meaning of work is quite different from the scientific definition of work. In everyday activity, the term 'work' is used equally for mental work and for physical work (involving muscular force) as is clear from the following examples.

(i) You may read a book or exert yourself mentally in thinking about a simple or difficult problem.
(ii) You might be holding a weight without moving.
(iii) You may be carrying a load and moving with uniform velocity.
(iv) You may be trying hard to move a huge rock which does not move despite your best efforts, though you may get completely exhausted in the process. In all these cases, according to scientific definition, you are not doing any work.

Scientific conception of work

In physics, the term work is used in a special technical sense and has a much more precise definition which follows from the following examples.

(i) When a box is pushed on a floor by applying a force and it moves through some distance, work is said to be done. In this case, the applied force displaces the box.
(ii) When we pull a trolley by applying a force and it moves through some distance, work is again said to be done.
(iii) When we lift a box through a height, we have to apply force. In this case, the applied force does work in lifting the box. From all the examples given above, it follows that work is done if:

(a) a force is applied on the object and

(b) the object is displaced from its original position. No work is said to be done if any of the two conditions is not satisfied.

Units of work done

Work done, W = Fd

In C.G.S. system the unit of work done is dyne x cm = erg

Definition of 1 erg:

If F = 1 dyne and d = 1 cm

then, W = 1 × 1 = 1 erg.

If one dyne force is applied on a body and displacement in the body is 1 cm in the direction of force, then work done will be one erg.

S.I. unit of work done is newton × metre = joule

Definition of 1 joule:

If F = 1N and d = 1m

then, W = 1 × 1 = 1 joule (J)

If a force 1 Newton is applied on a body and displacement in the body is 1m in the direction of force then work done will be 1 joule.

Relation between joule and erg:

1 joule = 107 erg

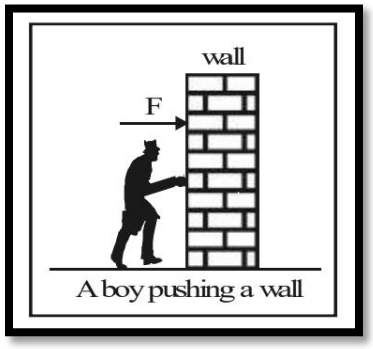
Conclusion

1. When s = 0, W = 0, i.e., work done by a force on a body is zero if the displacement of the body is zero. For example, when you push a wall with a force F, then the displacement of the wall is zero.

Therefore, the work done by force F on the wall is zero.

2. When you sit on a chair and prepare a lesson in two hours, you may feel tired. But according to physics, no work is done.

3. If you hold a briefcase for one hour and do not move the briefcase, then s = 0. Therefore, work done by you on the briefcase is zero.



Work: when constant force is acting in the direction of displacement

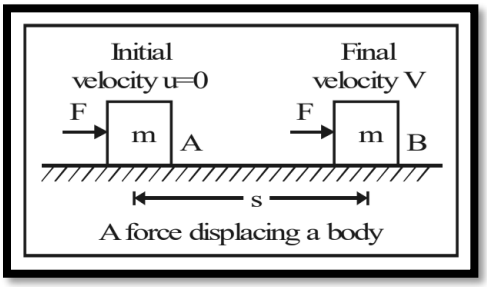
A body A is kept on a smooth horizontal surface. A force F is applied as shown. This force acts on the body for some time during which the displacement of the body is s. In such a case work is defined as follows.

Work done by a force on a body is the product of force and displacement of the body in the direction of the force.

Work = Force × Displacement

$\Rightarrow \quad W = F \times s$

Work is a scalar quantity. This means that it has no sense of direction.



Work: when a constant force is acting at an angle to the displacement

Let us consider a body A lying on a smooth horizontal surface. A constant force F acts at an angle θ to the horizontal. The body is displaced through a distance s in the horizontal direction. Here the complete force F is not responsible to displace the body. A part of the force acting in the direction of displacement is responsible for displacing the body. This horizontal part is F cos θ. Work done in this case is defined as 'work done by a constant

force acting at an angle to the displacement is the product of component of force in the direction of displacement and the displacement of the body'.

Work = component of force in the direction of displacement x displacement

$W = (F \cos \theta) \times s$

$W = F\ s \cos \theta$

Work done is maximum when force acts in the direction of displacement.

Case-1:

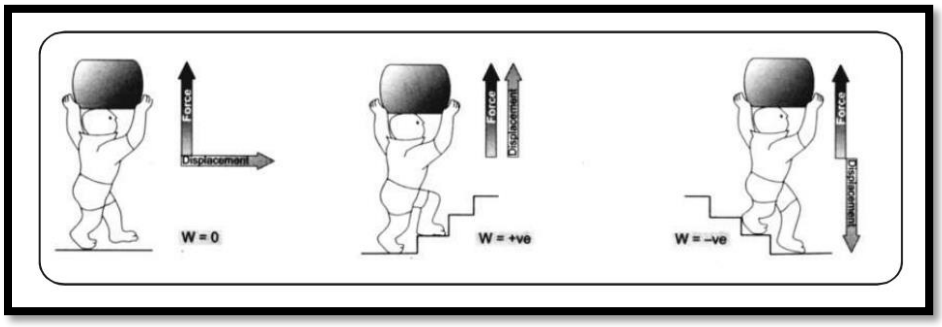
Work done is positive when θ is acute. This is because cos θ is positive, Work done is maximum when $\theta = 0°$. This is because the maximum value of cos $\theta = 1$. This happens when force acts in the direction of displacement.

Case-2:

When the angle between force and displacement is 90°, i.e., when $\theta = 90°$, then

$\cos \theta = 0$ $\cos 90° = 0$

$W = 0$



Some examples where work done is zero because $\theta = 90°$

(a) Work done by centripetal force:

When a stone is whirled in a horizontal circle, then centripetal force acts at 90° to the displacement. Therefore, work done by centripetal force is zero.

(b) Work done by coolie:

When a coolie moves on a horizontal surface, he applies a force on the load kept on his head in vertically upward direction. Therefore, $\theta = 90°$. Therefore, work done by the force applied by coolie is zero.

(c) Motion of the earth around the sun:

Work done by the centripetal force (which is the gravitational pull of sun on earth) acting on earth is zero. Because centripetal force is perpendicular to the displacement. [Remember the displacement is always tangential and centripetal force is always radically inward. The angle between radius and tangent is 90°].

Case-3:

When angle between force and displacement is 180°, i.e. when $\theta = 180°$ then $\cos 180° = -1$. In this case work done is negative.

Let us take an example where work done is negative because $\theta = 180°$

A block A is pushed by the force F and displaced through s. Work done by applied force,

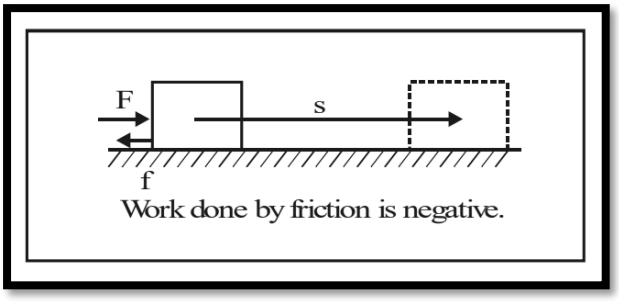
$W = F \times s \times \cos 0°$

$= Fs$

Work done by frictional force,

$W = f \times s \times \cos 180°$

$= -fs$



Note:

Work may be positive, negative or zero depending on the angle θ.

Newton's Thought

An artificial satellite is moving around the Earth in a circular path under the influence of centripetal force provided by the gravitational force between them. What is the work done by this centripetal force?

Explanation

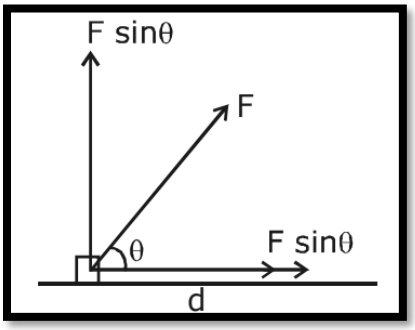
Centripetal force (F) is always perpendicular to the displacement (S) of the partial moving along a circular path. That is the angel is (θ) between them is 90°

Now work done, $FS\cos\theta\, 90^\circ = 0\left(\because\ \cos 90^\circ = 0\right)$

Thus, work done this centripetal force is zero

Positive Work done:

When the angle between force and the displacement is acute ($\theta < 90°$), then work done will be positive because one component of force (F cosθ) is in the direction of displacement so work done by this component will be positive (Fd cosθ). Work done by the vertical component (i.e F sinθ) will be zero (Θ the angle between F sinθ and displacement is 90°) so net work done will be positive



(i) In lifting weight upward by applying an upward force the work done by the applied force will be positive.

(ii) In stretching a spring, the work done by the external force will be positive.

Negative Work done:

When the angle between the force and the displacement is obtuse, ($\theta > 90°$), then work done will be negative because work done by the horizontal component of force (i.e. F cosθ) is negative (–Fd cosθ) and the work done by the vertical component (F sinθ) will be zero, so net work done will be negative.