

## 5.4.4: Work-Energy Theorem

### Kinetic Energy and Work-Energy Theorem

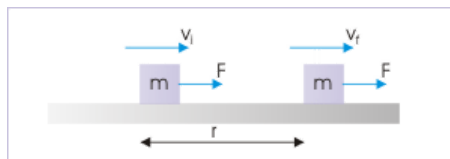
The work-energy theorem states that the work done by all forces acting on a particle equals the change in the particle's kinetic energy.

#### learning objectives

- Outline the derivation of the work-energy theorem

#### The Work-Energy Theorem

The principle of work and kinetic energy (also known as the work-energy theorem) states that the work done by the sum of all forces acting on a particle equals the change in the kinetic energy of the particle. This definition can be extended to rigid bodies by defining the work of the torque and rotational kinetic energy.



**Kinetic Energy:** A force does work on the block. The kinetic energy of the block increases as a result by the amount of work. This relationship is generalized in the work-energy theorem.

The work  $W$  done by the net force on a particle equals the change in the particle's kinetic energy  $KE$ :

$$W = \Delta KE = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 \quad (5.4.4.1)$$

where  $v_i$  and  $v_f$  are the speeds of the particle before and after the application of force, and  $m$  is the particle's mass.

#### Derivation

For the sake of simplicity, we will consider the case in which the resultant force  $F$  is constant in both magnitude and direction and is parallel to the velocity of the particle. The particle is moving with constant acceleration  $a$  along a straight line. The relationship between the net force and the acceleration is given by the equation  $F = ma$  (Newton's second law), and the particle's displacement  $d$ , can be determined from the equation:

$$v_f^2 = v_i^2 + 2ad \quad (5.4.4.2)$$

obtaining,

$$d = \frac{v_f^2 - v_i^2}{2a} \quad (5.4.4.3)$$

The work of the net force is calculated as the product of its magnitude ( $F=ma$ ) and the particle's displacement. Substituting the above equations yields:

$$W = Fd = ma \frac{v_f^2 - v_i^2}{2a} = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2 = KE_f - KE_i = \Delta KE \quad (5.4.4.4)$$

#### Key Points

- The work  $W$  done by the net force on a particle equals the change in the particle's kinetic energy  $KE$ :  
 $W = \Delta KE = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$ .
- The work-energy theorem can be derived from Newton's second law.
- Work transfers energy from one place to another or one form to another. In more general systems than the particle system mentioned here, work can change the potential energy of a mechanical device, the heat energy in a thermal system, or the electrical energy in an electrical device.

## Key Terms

- **torque:** A rotational or twisting effect of a force; (SI unit newton-meter or Nm; imperial unit foot-pound or ft-lb)

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