**Work and Kinetic Energy**

**Work** (definition):Work is the product of the force on an object and the distance through which an object is moved; measured in Joules (J)

* The work done by a force is **POSITIVE** if the force points in the direction of motion
* The work done by a force is **NEGATIVE** if the force points in the opposite direction of motion
* The work done by a force is **ZERO** if the force points perpendicular to the direction of motion

**W = FD**

1 Joule of work is required to move an object weighing 1N through a distance of 1m;1J = 1N·m

**Example 1** Find the work done by the force of gravity if a 10 kg object moves (a) 1m downward, (b) 2m upward, (c) 10m right

1. Force of gravity (downward) and direction of motion (downward) are in the SAME direction, so the work done by the force of gravity is POSITIVE.

Start with the equation: W = FD

Use subscripts to identify which force you are plugging: Wg = FgD

Plug in your numbers: Wg = (10kg × 9.8m/s2)(1m)

The work done by the force of gravity is 98 Joules: Wg = 98J

1. Force of gravity (downward) and direction of motion (upward) are in OPPOSITE directions, so the work done by the force of gravity is NEGATIVE.

W = FD

Wg = -FgD

Wg = -(10kg × 9.8m/s2)(2m)

Wg = -196J

1. Force of gravity (downward) and direction of motion (right) are PERPENDICULAR. Therefore Wg = 0J.

**Example 2** A sky diver of mass 70kg falls a distance of 50m. During this time, he feels a downward force of gravity and an upward force of air resistance. The force of air resistance is 30N. What is the total work done by both forces as he falls?

Wg = FgD Wair = -FairD

Wg = (70kg × 9.8m/s2)(50m) Wair = -(30N)(50m)

Wg = 34,300J Wair = -1,500J

Total Work: W = W­g + Wair­­ = 34,300J – 1,500J = 32,800J

**Kinetic Energy** (definition):The energy\* of a moving object; measured in Joules (J)

\*Energy, in general, is defined as the capacity to do work.

**K = (1/2)mv2**

**Example** What is the kinetic energy of an object of mass 30kg when it is moving at a speed of (a) 20m/s, (b) 100m/s, (c) 0m/s.

1. K = (1/2)mv2 (b) K = (1/2)mv2

K = (1/2)(30kg)(20m/s)2  K = (1/2)(30kg)(100m/s)2

K = 6000J K = 150,000J

1. K = (1/2)mv2

K = (1/2)(30kg)(0m/s)2

K = 0J

**Work - Kinetic Energy Theorem** (definition):The work done on an object is equal to the kinetic energy gained by the object.

**W = Kf – Ki**

**Example 1** You pull a 150kg sled across a frictionless surface. Over a distance of 20m, you speed up the sled from 2m/s to 4m/s. (a) How much work was done on the sled? (b) How much force did you apply to the sled? (c) Now assume that friction is present, and the ground exerts a frictional force of 10N on the sled as you are dragging it. How much force would you have to apply to the sled to achieve the same change in velocity (from 2m/s to 4 m/s)?

Since you know the mass, m, and the initial and final velocities, you can find the initial and final kinetic energies. These energies are valid for all parts of the problem.

Ki = (1/2)m(vi)2 = (1/2)(150kg)(2m/s)2 = 300J

Kf = (1/2)m(vf)2 = (1/2)(150kg)(4m/s)2 = 1200J

The kinetic energy increased by 900J

(a) W = Kf – Ki

WA = 1200J – 300J

WA = 900J

The force you applied to the sled did 900J of work.

1. WA = 900J

FAD= 900J

FA(20m) = 900J

FA = 45N

You applied 45N of force to the sled.

1. W = Kf – Ki (work is done by your applied force *and* the kinetic frictional force)

WA + WK = 1200J – 300J

FAD - FKD = 900J (the kinetic frictional force does negative work)

FA(20m) – (10N)(20m) = 900J

FA(20m) = 1100J

FA = 55N

You must apply 55N of force to overcome the force of friction and achieve the same increase in kinetic energy.

**Example 2** A 30,000kg train is coasting at a constant velocity of 100m/s. Superman applies an opposing force to the train, causing it to slow down and come to rest in a distance of 50m. How much force did Superman apply? Ignore the effects of friction.

Critical thinking

* What are all the forces acting on the train? Do all of the forces do work?
  + Superman’s applied force (opposite the direction of motion) does negative work
  + Gravity force (down, perpendicular to the direction of motion) does NOT do work
  + Normal force (up, perpendicular to the direction of motion) does NOT do work
* What happens to the speed of the train? How does this affect the train’s kinetic energy?
  + The train slows down and stops
  + The final velocity is 0m/s; therefore, the final kinetic energy is 0J.
* Out of the variables, W, F, D, Ki, Kf, m, vi, vf which ones do I have and which ones can I get?
  + Have: m, vi, vf, Kf, D
  + Can get: Ki, W, F

Ki = (1/2)m(vi)2 = (1/2)(30,000kg)(100m/s)2 = 150,000,000J or 1.5×108J

Kf = (1/2)m(vf)2 = (1/2)(30,000kg)(0m/s)2 = 0J

The kinetic energy decreases by 150,000,000J

W = Kf – Ki

W = 0J – 150,000,000J

W = -150,000,000J

-(FA)(D) = -150,000,000J

-(FA)(50m) = -150,000,000J

-FA = -3,000,000N

FA = 3,000,000N

Superman applies a force of 3,000,000N to bring the train to a stop.