Chapter 6

Work and Kinetic Energy

Work

- We define work by the following:

- The angle θ is the angle between the displacement and the force.

Constant Force

- If the force applied is constant then the work done becomes:

Units

- The unit for work is the joule.
- The letter J is used to represent a joule.

$$1J = 1Nm$$

Example

- A volleyball is hit over the net.
- During the collision with the ball, the athlete applies a force of 150 N to the ball over a distance of 2.0 cm.
- Determine the work done on the ball.

Solution

- The work done is given by:

Hooke’s Law

- If a spring is stretched or compressed by a small amount, the reaction force of the spring can be expressed by Hooke’s law.

- The force required to stretch or compress, by Newton’s third law, is negative the above equation.

The work done by a spring

- The work done compressing a spring can be obtained by applying the general definition of work.

Kinetic Energy

- Consider an object with a force applied to it in the x-direction.
- We can determine the motion of the object with Newton's second law.

- We rewrite the second law in terms of velocity.

- We separate variables and integrate.

- We note that the left side of the equation is the work done moving the object.
- Then:

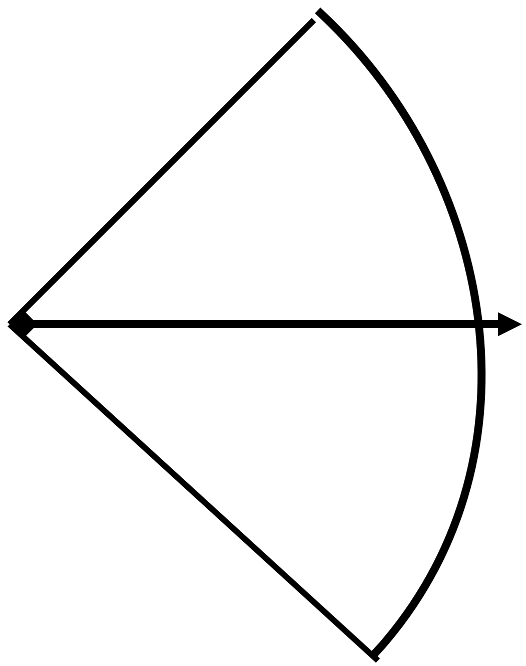
- The object has gained energy of motion, which we called kinetic energy and define as:

- The **work-energy theorem states** that the work done by the net force on a particle is equal to the change in kinetic energy.

Example

- An archer draws back a re-curve bow.
- If the draw of the bow is 1000-N and the draw length is 0.75 m, determine the maximum speed that a fired arrow would leave if its mass is 100-g.

Sketch



Free-Body Diagram

Solution

- Once again, we can treat the bow as a Hooke's law device.
- Therefore:

Solution cont.

- We can now apply the work energy theorem.
- The work done on the arrow by the bow is equal to the change in kinetic energy.

Solution cont.

- The speed of the arrow is:

Power

- As Jennifer pulled back on the projectile launching device in lab, she was doing work.
- In her attempt to cock the gun she applied a force, however small it might be, but a force none the less, through a distance.
- According to the work energy theorem she must have been storing energy in the spring of the gun.

Power

- Now consider the time it took Jennifer to cock the gun.
- 15 minutes
- Meanwhile, Cliff was able to cock the gun in only 12 minutes after 7 failed attempts.
- The energy stored each time was the same; however, something was different between the two events.

Power

- The rate at which energy was supplied to the gun was different for each case.
- This rate of energy transfer or rate of work done per unit time is called the power.
- The average power can be defined by the following:

Power

- The instantaneous power can be obtained by letting the time difference approach zero.

- We can also express the power in terms of an applied force.
- Suppose an objects velocity changes do to an applied force.
- The work done during a differential amount of displacement is:

- The power is then:

- If the force is constant then we get:

Units

- The unit of power in the mks system is the watt.

$$1W = 1J / s$$

Example

- A body-builder curls a weight bar upward in 0.4s.
- If the bar weighs 240-N and the distance lifted is 0.8 m, what is the average power developed during the lift?

Solution

- The average power developed is the change in the work per unit time.