Potential Energy and Energy Conservation

- Work
- Kinetic Energy
- Work-Kinetic Energy Theorem
- Gravitational Potential Energy
- Elastic Potential Energy
- Work-Energy Theorem
- Conservative and
- Non-conservative Forces
- Conservation of Energy

Definition of Work W

- The work, *W*, done with a constant force on an object is defined as the product of the force component in the displacement direction and the magnitude of displacement

$$W \equiv (F\cos\theta)\Delta x$$

  - F is the magnitude of the force
  - Δ x is the magnitude of the object's displacement
  - θ is the angle between $\vec{\mathbf{F}}$ and $\Delta\vec{\mathbf{x}}$

Work Done by Multiple Forces

- If you apply more than one force to an object, the total work equals the algebraic sum of the work done by the individual forces

$$W_{\text{net}} = \sum W_{\text{by individual forces}}$$

  - work is a scalar, so
  - this is the algebraic sum

$$W_{net} = W_g + W_N + W_F = (F\cos\theta)\Delta r$$

Kinetic Energy and Work

- Kinetic energy associated with the motion of an object
- $$KE = \frac{1}{2}mv^2$$
- Scalar quantity with the same unit as work
- Work is related to kinetic energy

$$\frac{1}{2}mv^2 - \frac{1}{2}mv_0{}^2 = (F_{net}\cos\theta)\Delta x$$

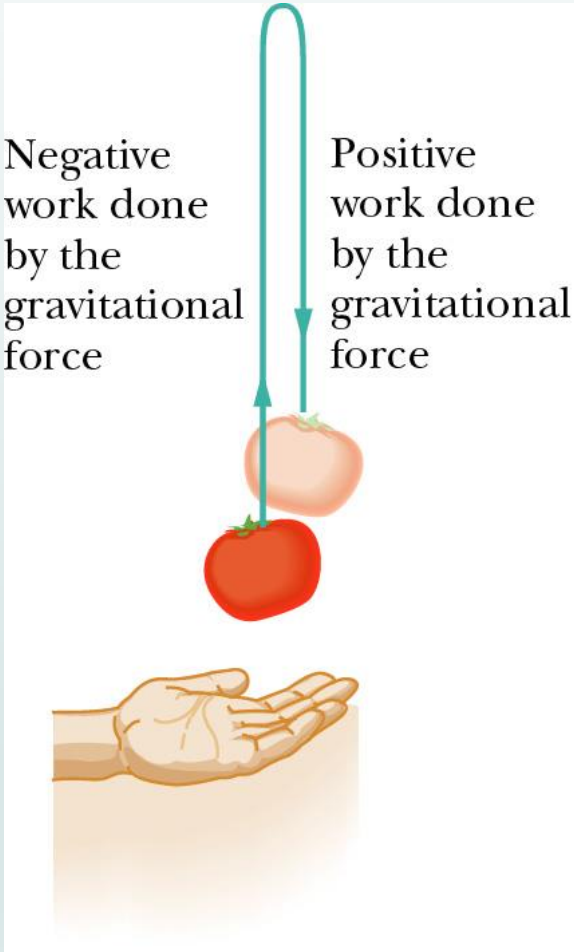
$$W_{net} = KE_f - KE_i = \Delta KE$$

Work done by a Gravitational Force

- Gravitational Force
  - Magnitude: mg
  - Direction: downwards to the Earth's center
- Work done by Gravitational Force

$$W = F\Delta r\cos\theta = \vec{\mathbf{F}}\cdot\Delta\vec{\mathbf{r}}$$

$$W_g = mg\Delta r\cos\theta$$



Potential Energy

- Potential energy is related to object position
- Gravity Potential Energy is the energy associated with a relative position relative to a objects near Earth's surface

- The gravitational potential energy

$$\boxed{PE \equiv mgy}$$

  - m is the mass of an object
  - g is the acceleration of gravity
  - y is the vertical position of the mass relative the surface of the Earth
  - SI unit: joule (J)

Figure 8.2 Physics for Scientists and Engineers 6th Edition, Thomson Brooks/Cole © 2004; Chapter 8

- For each problem a location should be chosen where the gravitational potential energy is zero
  The choice is arbitrary because the change in potential energy is significant
  Select a suitable location for zero reference height
  Often the surface of the Earth
  there may be another point proposed by the problem
  Once the location is selected, the problem must remain constant for the whole

Work and Gravitational Potential Energy

- PE = mgy
- $$W_g = F\Delta y \cos\theta = mg(y_i - y_f)\cos 0$$
  $$= -mg(y_f - y_i)$$
- Units of Potential Energy are the same as those of Work and Kinetic Energy

$$W_{gravity} = PE_i - PE_f$$

Figure 8.2
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Extended Work-Energy Theorem

- The work-energy theorem can be extended to include potential energy:

$$\boxed{W_{net} = KE_f - KE_i = \Delta KE}$$

$$W_{gravity} = PE_i - PE_f$$

- If we only have gravitational force, then $W_{net} = W_{gravity}$

$$KE_f - KE_i = PE_i - PE_f$$

$$\boxed{KE_f + PE_f = PE_i + KE_i}$$

- The sum of the kinetic energy and the gravitational potential remains constant at all times and hence a conserved quantity

Extended Work-Energy Theorem

- We denote the total mechanical energy by

$$E = KE + PE$$

- Since $$KE_f + PE_f = PE_i + KE_i$$

- Total mechanical energy is conserved and always remains the same

$$\frac{1}{2}mv_i^2 + mgy_i = \frac{1}{2}mv_f^2 + mgy_f$$

Platform Diver

- A diver of mass m drops from a board 10.0 m above the water's surface. Neglect air resistance.
- (a) Find is speed 5.0 m above the water surface
- (b) Find his speed as he hits the water

Platform Diver

- (a) Find is speed 5.0 m above the water surface

$$\frac{1}{2}mv_i^2 + mgy_i = \frac{1}{2}mv_f^2 + mgy_f$$

$$0 + gy_i = \frac{1}{2}v_f^2 + mgy_f$$

$$v_f = \sqrt{2g(y_i - y_f)}$$

$$= \sqrt{2(9.8m/s^2)(10m - 5m)} = 9.9m/s$$

- (b) Find his speed as he hits the water

$$0 + mgy_i = \frac{1}{2}mv_f^2 + 0$$

$$v_f = \sqrt{2gy_i} = 14m/s$$

Spring Force

- Involves the *spring constant*, k
- Hooke's Law gives the force

$$\vec{F} = -k\vec{x}$$

  - F is in the opposite direction of x, always returning to the equilibrium point.
  - K, the material it is made of, the thickness of the telescope, and so on. It depends.

Potential Energy in a Spring

- Elastic Potential Energy:
  - SI unit: Joule (J)
  - related to the work required to compress a spring from its equilibrium position to some final, arbitrary, position x

$$PE_s = \frac{1}{2}kx^2$$

- Work done by the spring

$$W_s = \int_{x_i}^{x_f}(-kx)dx = \frac{1}{2}kx_i^2 - \frac{1}{2}kx_f^2$$

$$W_s = PE_{si} - PE_{sf}$$