WORK, POWER & ENERGY

Work

- An applied force acting over a displacement.
  - The force being applied must be parallel to the displacement for work to be occurring.

$$Work = Force \times displacement$$

Units: Newton•meter (Joule)

ft · lbs (horsepower)

Work = F x d

To calculate work done on an object, we need:

The *Force*

- The *average* magnitude of the force
- The direction of the force

The *Displacement*

- The magnitude of the change of position
- The direction of the change of position

+ Work

- Positive work is performed when the direction of the force and the direction of motion are the same
  - ascent phase of the bench press
  - Throwing a ball
  - push off (upward) phase of a jump

- Work

- Negative work is performed when the direction of the force and the direction of motion are the *opposite*
  - descent phase of the bench press
  - catching
  - landing phase of a jump

Work Summary

- If the product of two vectors is a scalar value.
- If force is a vector, displacement is a vector, then work must be a scalar.

Work performed climbing stairs

- Work = Fd
- Force
  - Subject weight
    - From mass, ie 65 kg
- Displacement
  - Height of each step
    - Typical 8 inches (20cm)
- Work per step
  - 650N x 0.2 m = 130.0 Nm
- Multiply by the number of steps

Energy

- Energy (E) is defined as *the capacity to do work (scalar)*
  - Many forms
    - No more created, only converted
    - chemical, sound, heat, nuclear, mechanical

Units: Newton•meter (Joule)

ft · lbs (horsepower)

Types of Energy

- Kinetic Energy (KE):
  - energy due to motion
- Potential Energy (PE):
  - energy due to position or deformation

Kinetic Energy

Energy due to motion reflects the mass velocity of the object.

Any object in motion has kinetic energy.

$$KE = 1/2\ mv^2$$

Kinetic Energy

There are many forms of kinetic energy:

- Vibrational
  - (the energy due to vibrational motion)
- Rotational
  - (the energy due to rotational motion)
- Translational
  - (the energy due to change in position).

Kinetic Energy

- The amount of WORK the object could do as a result of its MOTION

If the Wnet of an object is + than the object SPEEDS UP.

If the Wnet of an object is - than the object SLOWS

If the object SPEEDS UP than the kinetic energy INCREASES.

If the object SLOWS DOWN than the KE DECREASES.

If the Wnet of an object is + than the KE INCREASES.

If the Wnet on an object is - than the KE DECREASES

Potential Energy

Two forms of PE:

- Gravitational PE:
  - energy due to an object's position relative to the earth
- Strain PE:
  - due to the deformation of an object

Gravitational PE

- The energy is stored as the result of the GRAVITATIONAL ATTRACTION OF THE EARTH for the object.
    - Affected by the object's
        - weight = mg
    - elevation (height) above reference point
        - ground or some other surface

GPE = mgh

Gravitational PE

There is a direct relation between gravitational potential energy and the MASS AND HEIGHT of an object.

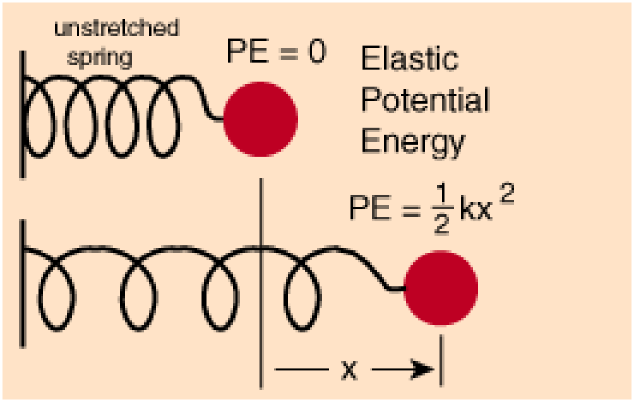
- More massive objects have GREATER gravitational potential energy.
- The higher that an object is elevated, the GREATER the gravitational potential energy.

GPE

- Zero height is an arbitrarily assigned position that most people agree upon.
- Typically, the GROUND is considered to be a position of zero height.

Elastic PE

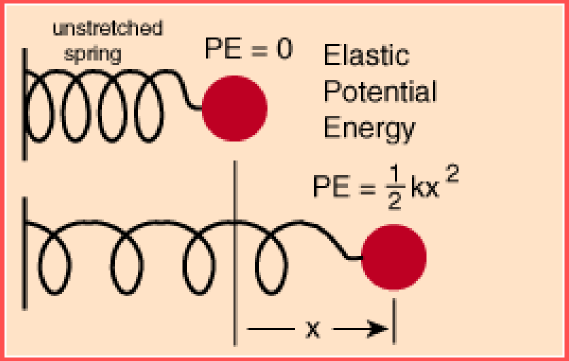
- capacity for doing work as a result of a stretched spring or other elastic deformation



PEe = 1/2 kΔx^2

$PEe = 1/2\ k\Delta x^2$

- Δx^2 = change in length or deformation of the object from its undeformed position
  - greater deformation = greater SE
- k = spring constant (stiffness) of material



Elastic PE

- The amount of Elastic PE stored in such a device is related to the amount of stretch of the device
  - The more stretch, the more stored energy.
  - The more compression, the more force that is required to compress it further.

Equilibrium Position

If a spring is not stretched/compressed.

Then there is no Elastic Potential Energy stored in it.

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There is 0 PE if a spring is in equilibrium position.

Work - Energy Relationship

- The work done by an external force acting on an object causes a change in the mechanical energy of the object

$$W = \Delta Energy$$

Work - KE Relationship

- If only KE is found in the system then:
  - Mass doesn't change in a system

$$W = \Delta KE$$

$$W = \frac{1}{2}m{v_f}^2 - \frac{1}{2}m{v_i}^2$$

$$Fd = \frac{1}{2}m\left(v_f - v_i\right)^2$$

Work - KE Relationship

- It means that if work acts on an object it will undergo
  - A change in speed

    and
  - A change in Kinetic Energy.
- The net work done on an object is equal to the change in kinetic energy of the object.

Work - PE Relationship

- If only PE is found in the system then:
  - Mass doesn't change in a system

$$W = \Delta PE$$

$$W = mgh_f - mgh_i$$

$$Fd = mg(h_f - h_i)$$

Work - PE Relationship

- Suppose you lift a mass upward at a constant speed, $\Delta v = 0$ & $\Delta K=0$.
    - It is known that when an object is lifted above the ground it has POTENTIAL ENERGY
- If an object is lifted at a constant speed, the applied force equals the weight of the object you are lifting.

Work - Energy Relationship

- Two energy forms interact, and work is the change in all energy
- Combining the two relationships:

$$Fd = \Delta Energy$$

$$Fd = \Delta KE + \Delta PE$$

$$Fd = \frac{1}{2}m\left(v_f - v_i\right)^2 + mg(r_f - r_i)$$

Work - Energy Relationship

Since,

WORK
KINETIC ENERGY
POTENTIAL ENERGY

are expressed in JOULES,

they are EQUIVALENT TERMS!

Conservation of Energy

- In physics, the law of conservation of energy states that the total energy of an isolated system cannot changeit is said to be conserved over time.
  - Energy can be neither created nor destroyed, but can change form.
    - For instance chemical energy can be converted to kinetic energy in the explosion of a stick of dynamite.

Mechanical Energy (ME)

- Mechanical energy is the energy that is possessed by an object due to its motion or due to its position.
  - ME can be either:
    - kinetic energy (energy of motion)
    - potential energy (stored energy of position)

Not considered ME:

- Chemical Energy
- Thermal Energy

Conservation of ME

- The principle of the conservation of mechanical energy states:
  - The total mechanical energy in a system remains constant as long as the only forces acting are conservative forces.

Conservation of ME

- Total ME is constant throughout a reaction:

$$ME_i = ME_f$$

$$KE_i + PE_i = KE_f + PE_f$$

$$\frac{1}{2}mv_i^2 + mgh_i = \frac{1}{2}mv_f^2 + mgh_f$$

Conservation of ME

- Friction must be ignored for the equation of Conservation of Mechanical Energy (ME) to be true.
  - Friction causes thermal energy.

Power

- The rate of doing work
  - Work = Fd

$$Power = Work / time$$

$$Power = Fd / t$$

$$Power = Force * velocity$$

Units of Power

- Units of Power: Watt
  - 1 watt is equal to 1 joule per second

    1 W = 1 J/s
- 1 horsepower = 745.699872 watts