Work and Energy

AP Physics Chapter 4

Work and Mechanical Energy

- **Learning Objectives:**
  - Make predictions about the changes in kinetic energy of an object based on considerations of the direction of the net force on the objects as the object moves
  - Use net force and velocity vectors to determine qualitatively whether the kinetic energy of an object would increase, decrease or remain unchanged
  - Use force and velocity vectors to determine qualitatively or quantitively whether the kinetic energy of the object would increase, decrease, or remain unchanged

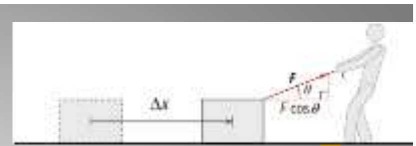
Objectives: After Work Section

- Describe **work** in terms of force and displacement, using the definition of the **scalar** product.
- Solve problems involving concept of work.
- Distinguish between the resultant work and the work of a single force.
- Define the spring constant and calculate the work done by a varying spring force.

Formula's on AP Equation Sheet

- $K = \frac{1}{2}mv^2$ Kinetic Energy
- $K = \frac{1}{2}I\omega^2$ Kinetic Rotational Energy
- $U_s = \frac{1}{2}kx^2$ Potential Spring Energy
- $U_g = mg\Delta y$ Potential Gravity Energy
- $Ug = -\frac{Gm_1m_2}{r}$ Potential Gravity btwn Masses
- $\Delta E = W = F_{\parallel}d = Fd\cos Ø$ Energy/Work
- $P=\frac{\Delta E}{\Delta t}$ Power
- $F_s = k\,|x|$ Hooke's Law for spring constant

Definition of Work



- **Work** (W) is done on an object when a *force (F)* causes a *displacement (d)* of the object
- **Three things are necessary for the performance of work:**
  1. There must be an applied force F.
  2. There must be a displacement x.
  3. The force must have a component along the displacement.
     - Work is done on an object only if it moves in the direction of the force

W = F d

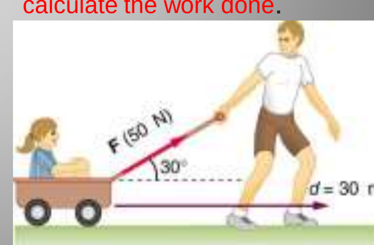
- Force units (N) × distance units (m)
- N•m are also called joules (J)
- W = ∫ F ds

Work

- **2 categories of Work**
  - Work done against another force
    - Lift something – exerted against force of gravity
  - Work done to change the speed of something
    - Stopping a car or speeding it up

- How would you calculate the work in this case?
  - What is the component of **F** in the direction of **d**?
  - Only the component of the force that is in the direction of the objects displacement does work!
    - *F* cos θ
    - W = *F*cosθd

When **F** and **Δd** are not parallel, we can use components to calculate the work done.

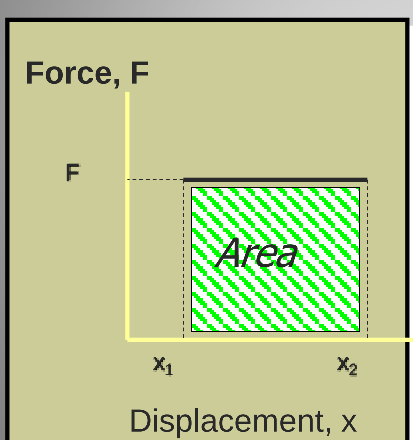


Work – Further explained

- **If the displacement is zero, no work is done by the force.**
  - Example, if you hold a heavy box without moving it, you are exerting a force (counteracting the force of gravity) but you are not doing work.
- **If the net force is zero, now work is done by the displacement (change in location) of the object.**
  - Example if a cart is sliding across a frictionless air track at a constant velocity, the net force on the cart is zero, which means no work is being done
- **If the displacement is perpendicular to the direction of the applied force, no work is done by the force.**
  - Example you can slide a very heavy object along a roller conveyor because the force of gravity is acting vertically and the object's displacement is horizontal, which means gravity is doing no work, and therefore you do nave have to do any work against gravity.

Graph of Force vs. Displacement

Assume that a constant force F acts through a parallel displacement Dx.



The area under the curve is equal to the work done.

Work = $F(x_2 - x_1)$

$$\boxed{Work = F\Delta x}$$

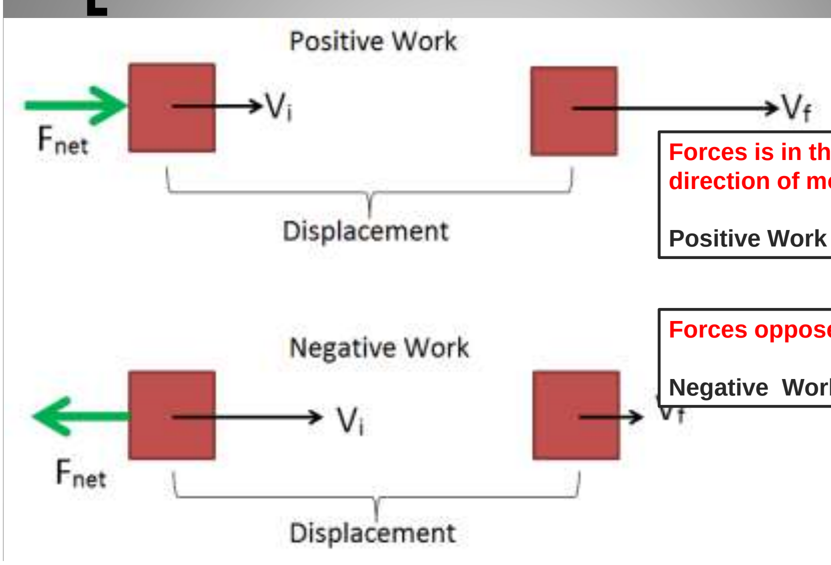
Conservative and non conservative forces

Two classes of forces

1. **Conservative** – a force that conserves energy. That is the amount of WORK done by the force changes the ENERGY by the same amount. Gravity is a great example of a conservative force, or really and field force
   1. The work done by conservative forces is path independent

1. **Non-conservative** forces do not conserve energy. Friction is an example
   1. **The work done by non-conservative forces is path dependent**
      - **Example** – dragging a box along a floor with friction across a room. You could take the shortest route or a winding one. Friction would cause more work from this longer route

positive vs negative work



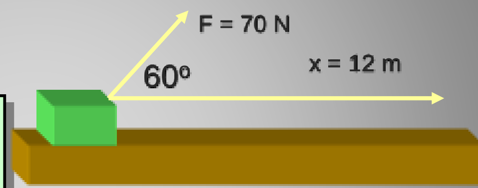
Forces is in the direction of motion

Positive Work

Forces opposes motion

Negative Work

Work of a Force at an Angle



$$Work = F_x x$$

$$Work = (F \cos \theta)\, \Delta x$$

Work = (70 N) Cos 60^0 (12 m) = 420 J

Work = 420 J

Only the x-component of the force does work!