# What is Energy

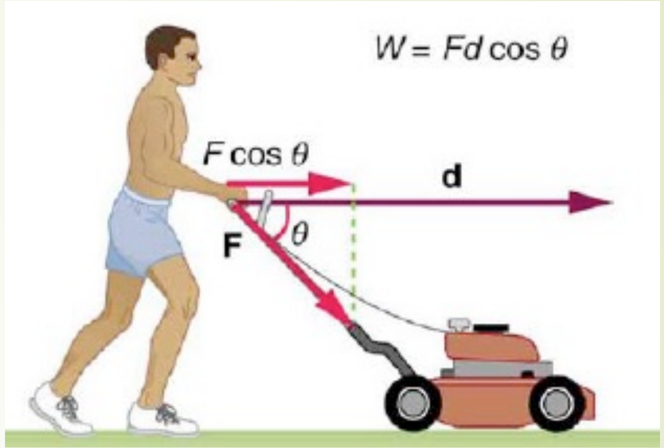
**Objective: Learning about the different forms of energy. Explore mechanical energies and associated conservation principle.**

Key concepts:

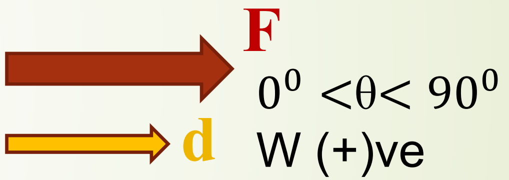
- ❖ Work and Energy
- ❖ Kinetic energy
- ❖ Gravitational potential energy
- ❖ Conservation of energy
- ❖ Power and Efficiency

# Concept of Work

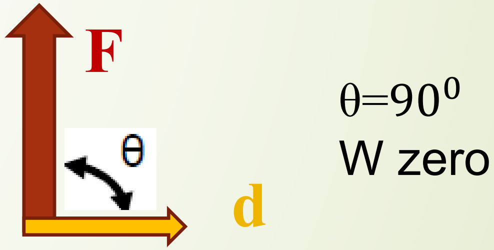
Work tells you how much energy it takes to push something and make it move.




- Work is *done on* an object (a mass) *by* the force components acting on the object that are parallel to the displacement of the object.
- Work, W = Force x Distance x cosθ = Fd cosθ



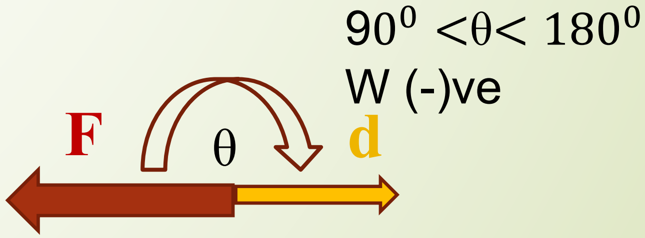

- SI Units of Work and Energy: Joules (J)




- Work is a scalar! (no direction - but it can have a sign)

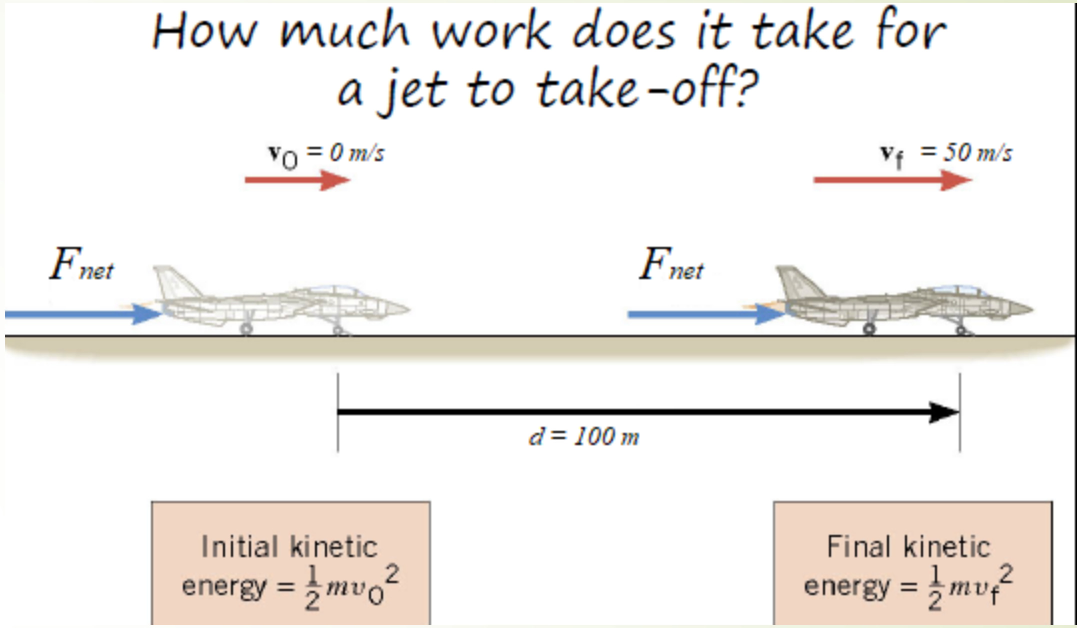
• The work is positive if **F** and d point in the same direction.

• The work is negative if **F** and d point in opposite directions.



# Work-Energy Theorem

Example: Suppose you are taking off in a jet of 10000 kg. If the 125 kN force acts on the probe through a displacement of 100 m, what is the work done.




Solution:

$W = Fnet * d = (125000\ N)*(100m)$

$W = 12.5$ MJ

From Kinematics,

Recall: $v_f^2 = v_0^2 + 2\,a\,(x - x_0) \Rightarrow v_f^2 - v_0^2 = 2\,a\,d$

$\Rightarrow \quad a = \dfrac{v_f^2 - v_0^2}{2d}$

Since, $W = Fnet * d = (ma) * d$

$W = \frac{1}{2} m\, v_f^2 - \frac{1}{2} m v_0^2 = K.E_{final} - K.E_{inital} = \Delta K.E.$ *(Work-Energy Theorem)*

where, Kinetic Energy = $K.E. = \frac{1}{2} m v^2$ *(***K.E. has a ______________ relationship with v.)*

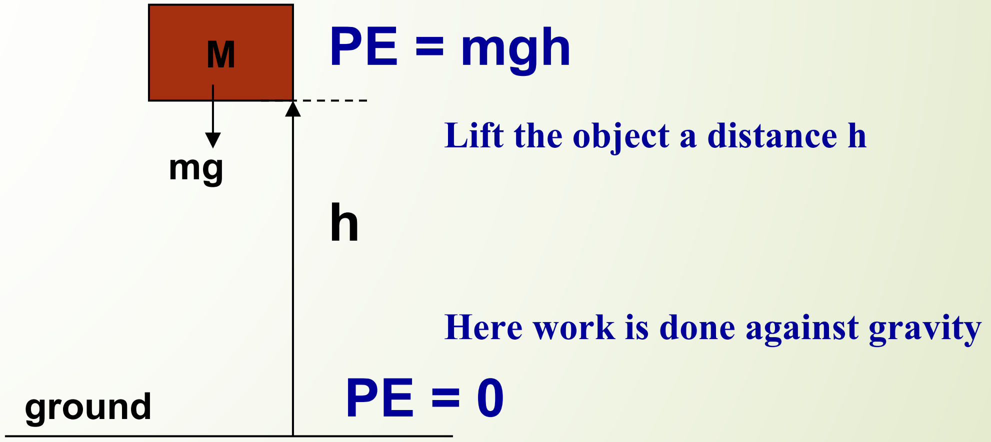
$W = \frac{1}{2} * 10000kg * (\frac{50m}{s})^2 = 12.5$ MJ *(By using, Work-Energy Theorem)*

# Mechanical Energy

*Potential energy, P.E.* $=mgh$
*Because of objects position*

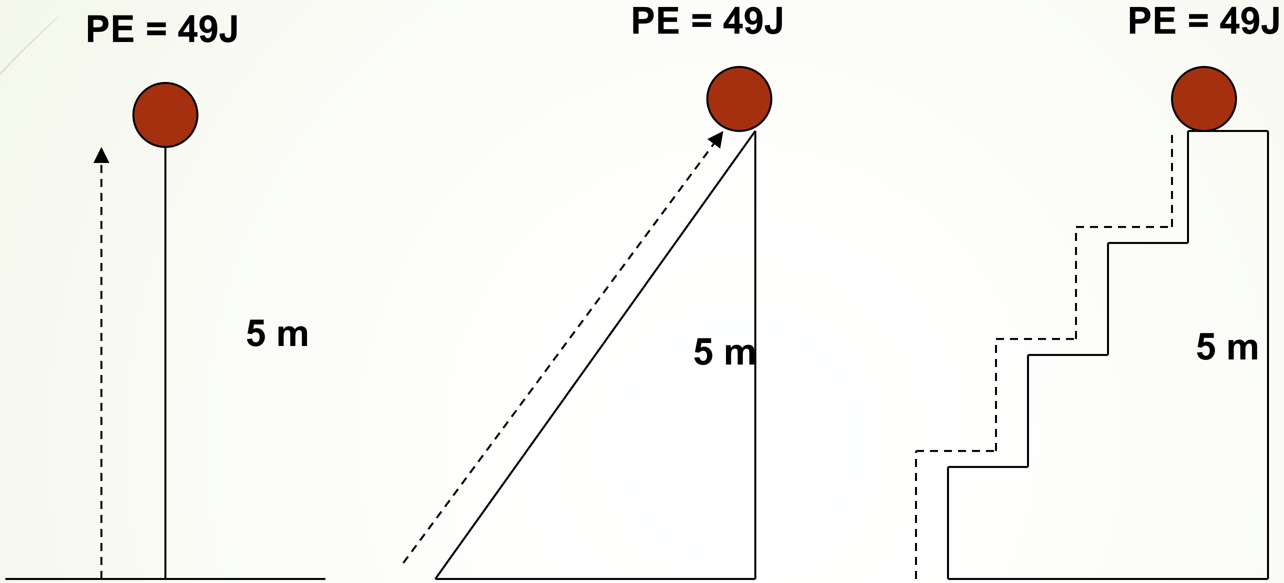
*Kinetic energy, K.E.* $=\frac{1}{2}mv^2$
*Because of objects motion*

- Gravitational potential energy: $P.E. = mgh$
- Work done by gravity is: $W_{grav} = -mgh \Rightarrow W_{grav} = -\Delta\, P.E.$
- There are various kinds of potential energy.
- Most important kind - gravitational potential energy.




**If speed doubles* → *K.E. increases by __________ times*
**If mass doubles* → *P.E. increases by __________ times*

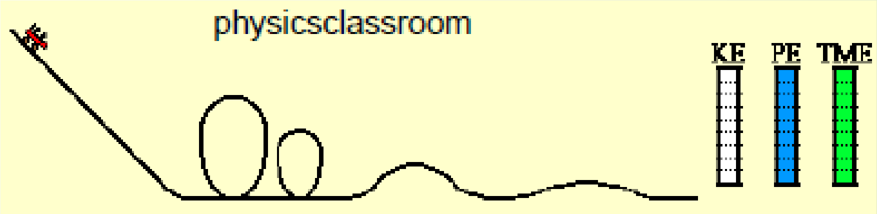
# Conservative Forces and Gravitational Potential Energy




*For a mass of 1 kg lifted to 5m*
*$PE = 1kg \times 9.8\ m/s^2 \times 5m = 49\ J$*

- *The height which matters here is the height (5m). The work done by gravity is independent of the path taken!*
- *Gravity, spring/elastic force are examples of "**Conservative Force**"*
- *Conservative force can used to create P.E. (stored energy),* $W_c = -\Delta\, P.E$
- *Try the "**Roller-Coaster**" Model.*

****P.E. has a ____________ relationship with h.*



# Different forms of Energy & Conservation of Energy

- **Kinetic Energy** = Energy of motion
- **Potential Energy** = Energy of position
- **Thermal Energy** = Kinetic Energy of the random motion of molecules
- **Chemical Energy** = Potential Energy of the bonds between atoms
- **Nuclear Energy** = Potential Energy of the particles inside the atomic nucleus

***Conservation of Energy****: Energy cannot be created or destroyed. It may be transformed from one form into another or transferred from one object to another, but the total amount of energy never changes.*

# Conservation of Mechanical Energy

A ***Non-conservative force*** is one for which the work depends on the path taken. Friction, air-resistance, viscosity, tension… etc adds or removes energy from the system.

- Since, both Conservative & Non-conservative forces can change K.E.

*We can write,* $\Delta\, K.E. = W_{net} = W_C + W_{NC}$

*Since,* $\Delta\, P.E. = -W_C \quad \Rightarrow \; W_{NC} = \Delta\, K.E. + \Delta\, P.E.$

*Total Mechanical Energy,* $E = P.E. + K.E.$

*Therefore,* $W_{NC} = \Delta\, E = E_f - E_o \Rightarrow E_f = E_o + W_{NC}$

- *When considering mechanical energies of a system:*

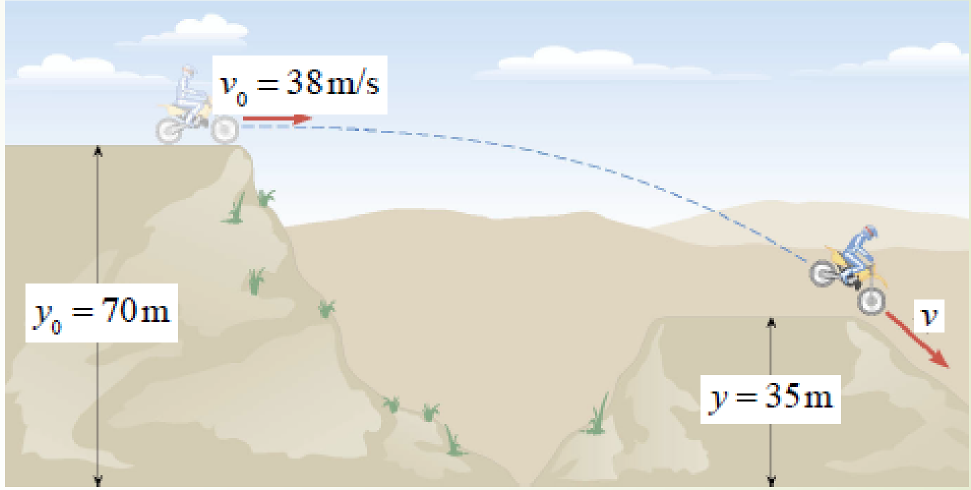
$$KE_f + PE_f = KE_o + PE_o + W_{NC}$$

- *In absence of Non-conservative forces, total mechanical energy is **conserved!***

$$KE_f + PE_f = KE_o + PE_o\,;\; (W_{NC} = 0)$$

# Conservation of Mechanical Energy

Example: A motorcyclist leaps across the canyon by driving horizontally off a cliff with 38.0 m/s. Ignoring air resistance, find the speed with which the cycle strikes the ground on the other side.




Solution: Only a conservative force-gravity is present, so the total mechanical energy should be conserved

$$\Rightarrow E_f = E_o \; (Since, W_{NC} = 0)$$

$$\Rightarrow \; \text{mg}y_f + \frac{1}{2} mv_f^2 = \text{mg}y_o + \frac{1}{2} \; mv_o^2$$

$$\Rightarrow \; 2\text{g}y_f + \; v_f^2 = 2\text{g}y_o + v_o^2$$

$$\Rightarrow \; v_f^2 = 2\text{g}(y_o - y_f) + v_o^2 = 2(9.8\, m/s^2)(35\text{ m}) + (38\, m/s)^2$$

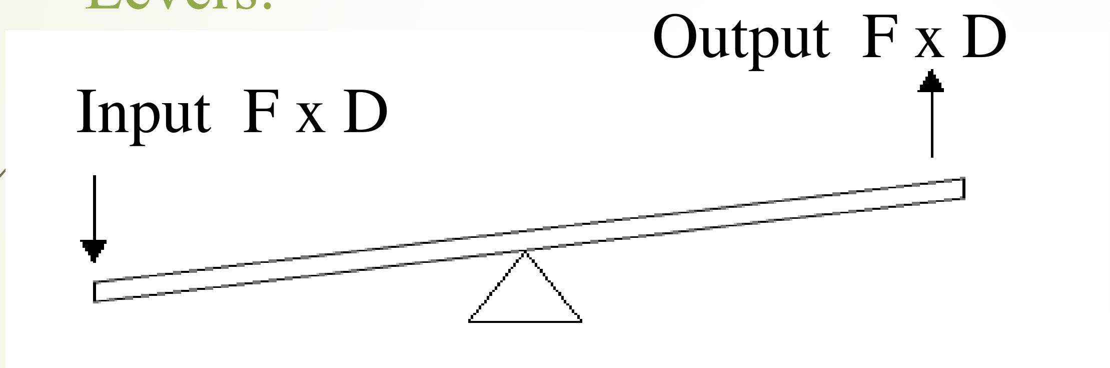
$$\Rightarrow v_f = 46.2\, m/s$$

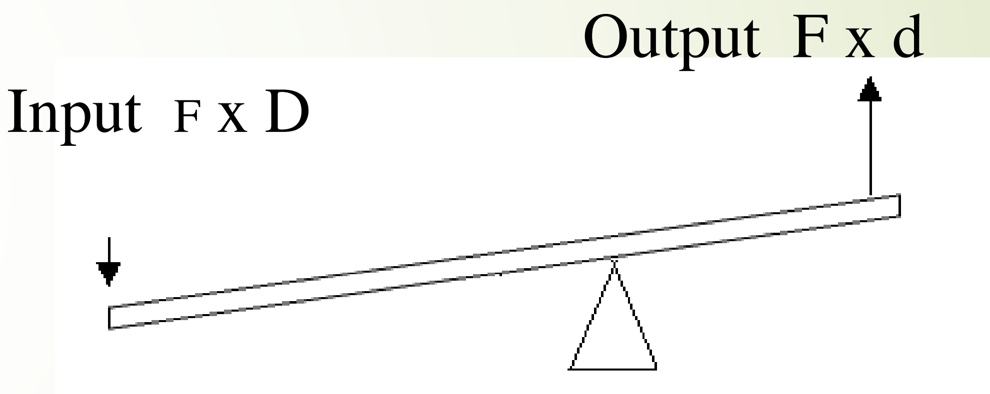
# Machines - devices to multiply forces

(Force x Distance)input = (Force x Distance)output

Work Input = Work Output

Levers:




**Equal** distance means **equal** force

**Smaller** distance means **bigger** force

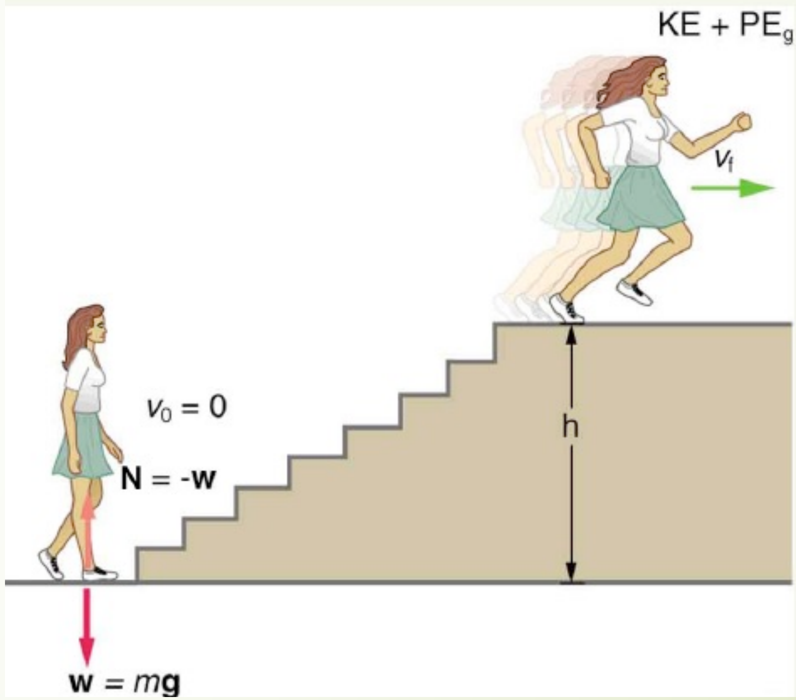
***Energy is conserved:*** A machine can multiply force but cannot increase energy!

# POWER

Power is the RATE at which energy is changed from one form to another.

$$\text{Power} = \frac{\text{Work done}}{\text{time interval}}$$

$$\text{watts(W)} = \frac{\text{Joule}}{\text{s}} = \text{Js}^{-1}$$




**1000 W = 1 kW**
**1000 kW = 1 MW**
**746 W = 1 Mechanical Horsepower**

Power tells you how quickly work gets done.

# Efficiency

*Efficiency* is how much work gets done for the amount of energy used. Machines that do more work given the same energy input are more efficient.

$$\text{Efficiency} = \frac{\text{Work done}}{\text{Energy used}} = \frac{\text{Energy out}}{\text{Energy in}}$$

**80% efficient** → $\frac{\text{80J output}}{\text{100J input}}$

*100% efficient systems are not practical*

# Efficiency

**Example:** 100 J of energy input for a machine, 98 J of work done.

$$\text{Efficiency} = \frac{\text{work done}}{\text{energy used}} = \frac{98\text{J}}{100\text{J}} = 0.98 \text{ or } 98\%$$

Where did the other 2J or energy go?

The lower the efficiency, the more energy is "wasted" as heat.

The "graveyard" (or final form of energy) is "heat".

# Energy Sources

Sun - the most powerful energy source

All natural power sources we have today originated from sun e.g. wind, hydro, thermal etc.

Solar power – sunlight is directly transformed into electricity

Wind power - turn into electricity using wind turbines

Hydro power – water is used to turn turbines and produce electricity

Nuclear power – stored energy in plutonium and uranium can be used to produce electricity

***Energy is needed for all living things***