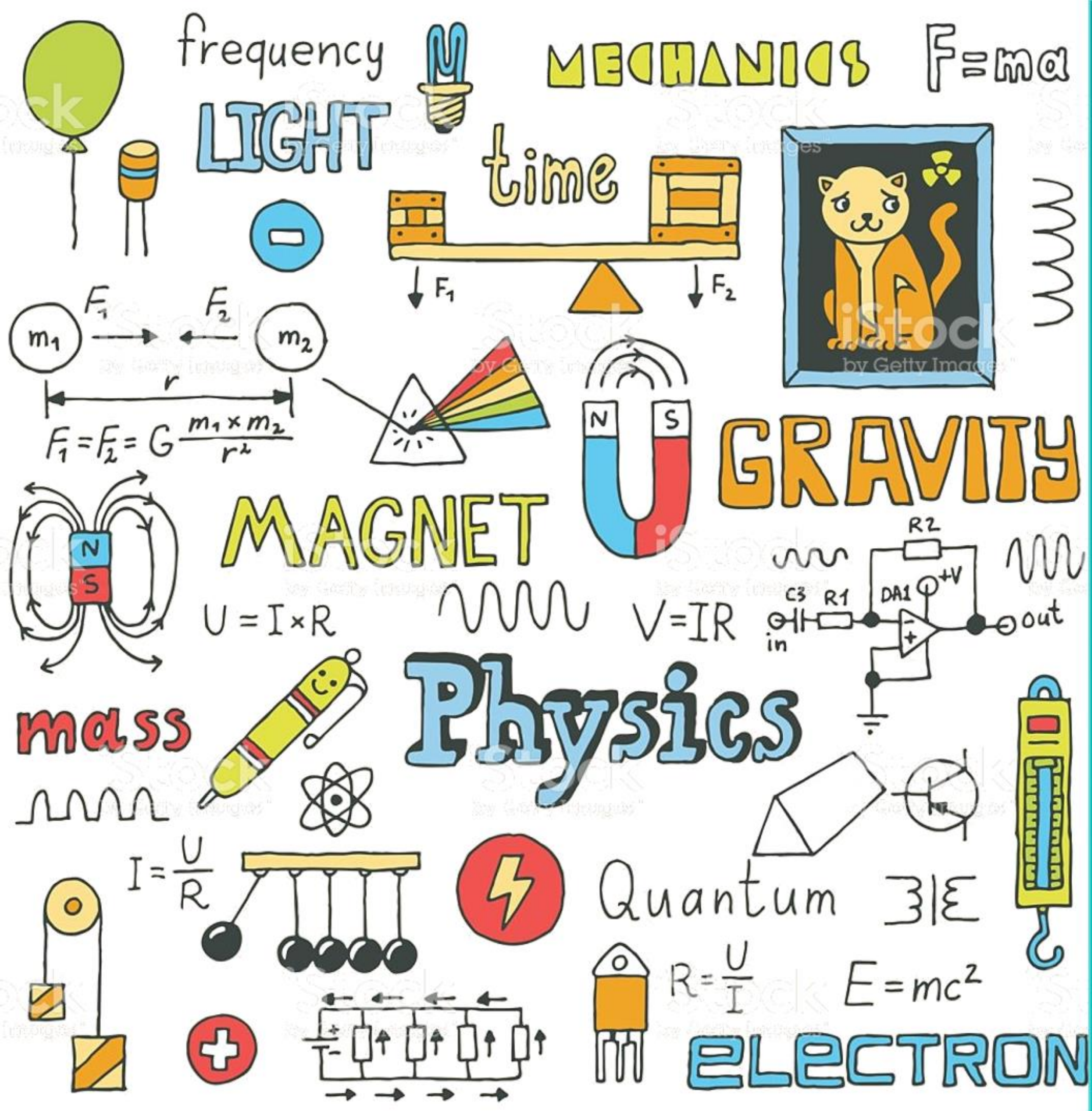

Physics

L5

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What are we going to talk about today?

Ch6 : Work, Energy, and Power

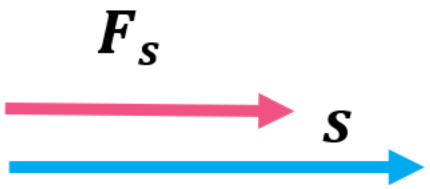
- 6.1 Work
- 6.2 Kinetic Energy
- 6.3 Potential Energy and Conservative Forces
- 6.6 Solving Problems Using Work and Energy.
- 6.9 Power

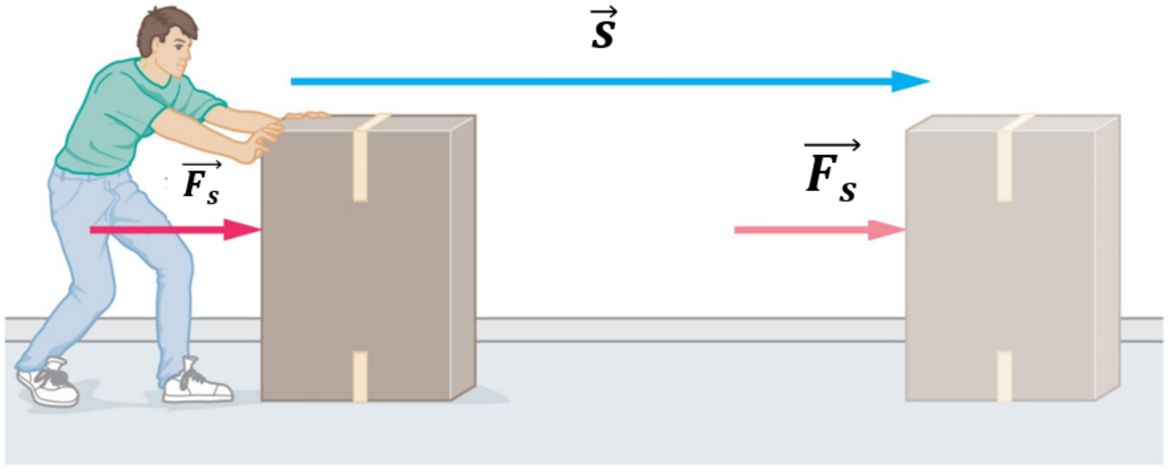
On a wind farm at the mouth of the River Mersey in Liverpool, England, the moving air does work on the blades of the windmills, causing the blades and the rotor of an electrical generator to rotate. Energy is transferred out of the system of the windmill by means of electricity.

What is a Work?

- The work done by a constant force $\vec{F_s}$ is defined as the product of the force component on the direction of the displacement and the displacement $\vec{s}$:

$$W = |\vec{F_s}||\vec{s}|$$



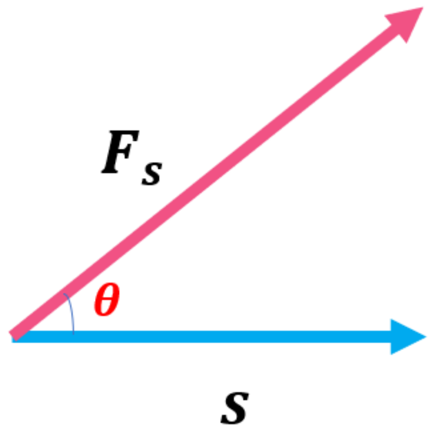


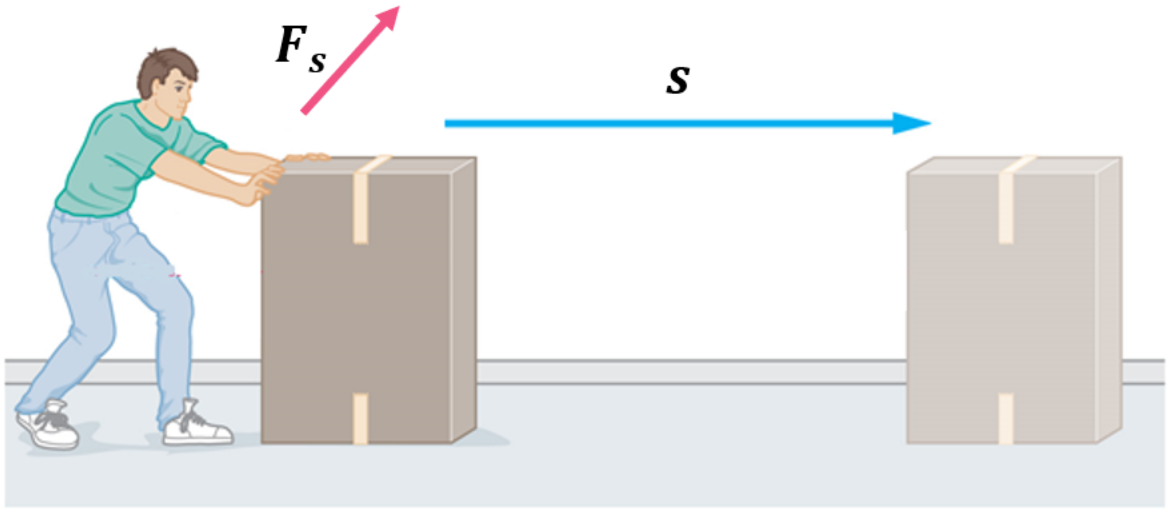
- Work is a scalar quantities.
- The dimension of work is $[W] = M\frac{L^2}{T^2}$
- The S.I unit of work is the Joule (J). Where $1J = 1Kg\,\frac{m^2}{s^2} = 1\,N.m$

6.1 Work

- If the force and the displacement make an angle θ, then $F_s = F\cos\theta$, and the work can be written as

$$W = |\vec{F}||\vec{s}|\cos\theta$$

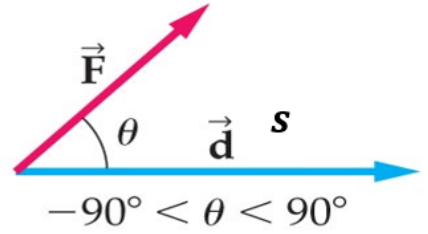
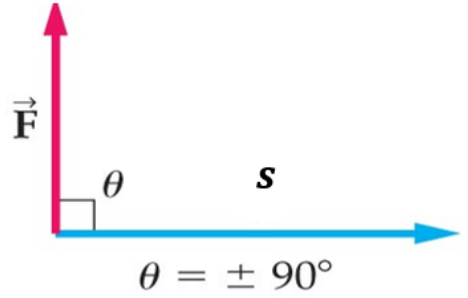
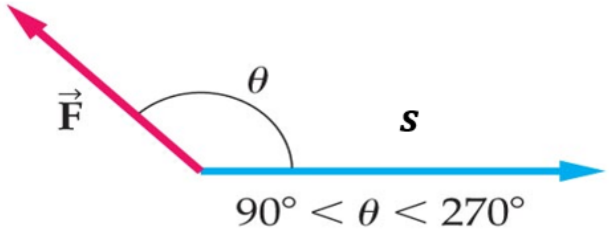




- Note that no work is produced by the component of the force perpendicular to the direction of motion, then $W = 0$ (When $\theta = 90°$)

6.1 Work

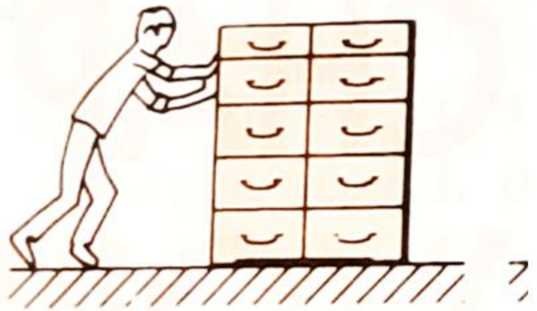
Work can be positive, negative, or zero dependent on θ:

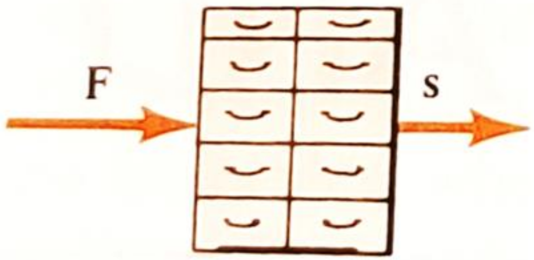
(a) Positive work: Work is positive if the force has a component in the direction of motion.	
(b) Zero Work : Work is zero if the force has no component in the direction of motion.	
(c) Negative Work: Work is negative if the force has a component opposite the direction of motion.	

Example 6.1 P 140:

A 600 N force is applied by a man to a dresser that moves 2 m . Find the work done if the force and displacement are:

(a) **parallel.** (**Ans: 1200 J**)



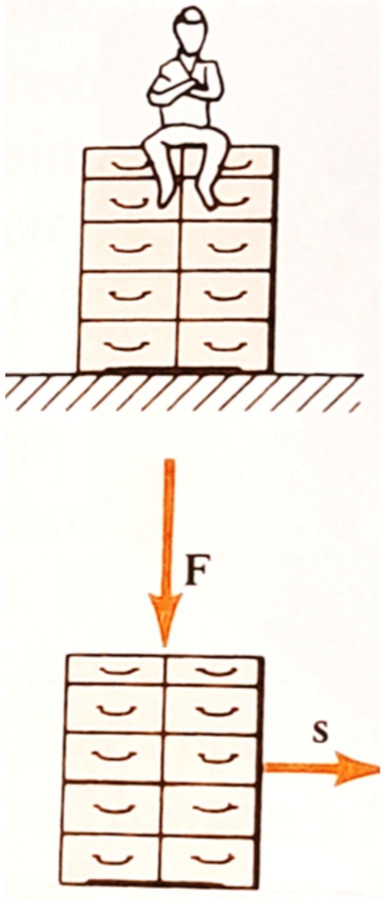


(a)

Example 6.1 P 140:

A 600 N force is applied by a man to a dresser that moves 2 m . Find the work done if the force and displacement are:

(b) at right angles. (Ans: 0)

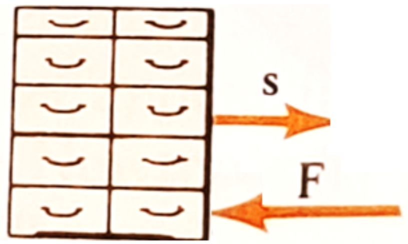


(b)

Example 6.1 P 140:

A 600 N force is applied by a man to a dresser that moves 2 m . Find the work done if the force and displacement are:

(c) oppositely directed. (Ans: –1200 J)



Example 6.2 P 140:

A horse pulls a barge along a canal with a rope in which the tension is 1000 N . The rope is at an angle of 10^0 with the towpath and the direction of the barge.

(a) **How much work is done by the horse in pulling the barge 100 m upstream at a constant velocity?** (Ans: $9.85 \times 10^4\ J$)

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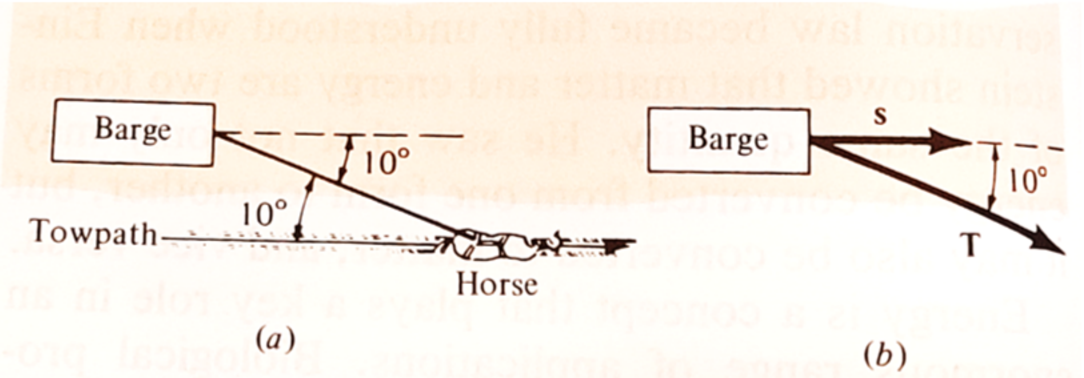


Example 6.2 P 140:

A horse pulls a barge along a canal with a rope in which the tension is 1000 N . The rope is at an angle of 10^0 with the towpath and the direction of the barge.

(b) What is the net force on the barge?

Ans: Since the barge moves at constant velocity, the sum of all the forces on it must be zero

.

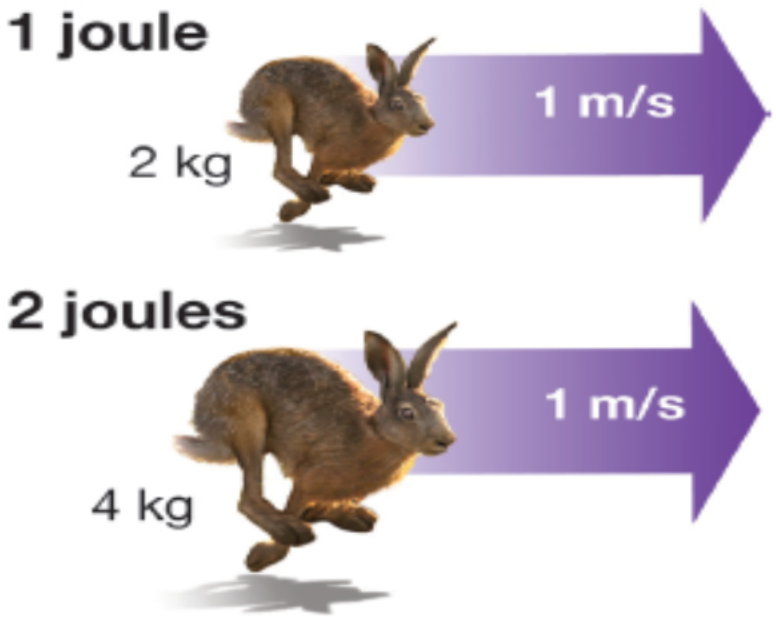
6.2 Kinetic Energy

The kinetic energy of an object is a measure of the work an object can do by virtue of its motion.

If an object of mass, m moves with a velocity v, then the kinetic energy, K is given by the following equation:

$$K = \frac{1}{2}mv^2$$

Example: what is its kinetic energy?



- Kinetic energy is a scalar quantity.
- The dimension of work is $[K] = M\frac{L^2}{T^2}$
- The S.I unit of kinetic energy is the Joule (J).

The work–energy principle

The change in the kinetic energy of an object (final kinetic energy minus the initial kinetic energy) is equal to the total work (W) done on it by all the acting forces.

$$\Delta k = k_f - k_i = W$$

- If the work is positive $W > 0$, the Kinetic energy increases $k_f > k_i$.
- If the work is negative $W < 0$, the Kinetic energy decreases $k_f < k_i$.
- if the total work done by all the forces is zero $W = 0$ the kinetic energy remains constant $k_f = k_i$.

6.2 Kinetic Energy

Example 6.3 P 142:

A woman pushes a car, initially at rest, toward a child by exerting a constant horizontal force of magnitude 5 N through a distance of 1 m

(a) **How much work is done on the car?** (**Ans: 5 J**)

Example 6.3 P 142:

A woman pushes a car, initially at rest, toward a child by exerting a constant horizontal force of magnitude 5 N through a distance of 1 m

(b) What is its final kinetic energy? (**Ans: 5 J**)

Example 6.3 P 142:

A woman pushes a car, initially at rest, toward a child by exerting a constant horizontal force of magnitude 5 N through a distance of 1 m

(c) If the car has a mass of 0.1kg what is its final speed? (Ans: 10 m/s)

Example 6.4 P 142:

In the preceding example the woman releases the toy car with a kinetic energy of 5J. It moves across the floor and reaches the child who stops the car by exerting a constant force *F'* opposite to its motion. The car stops in 0.25 m. Find *F'* if no work is done on the car by frictional forces. (**Ans: 20 N**)

6.3 Potential Energy and Conservative Forces

We can define a potential energy that accounts for energy "stored" by doing work

- **Gravitational Potential Energy**:

Suppose we threw an apple up of mass m from a height of h_i to a height of h_f the work done by gravity on the apple is :

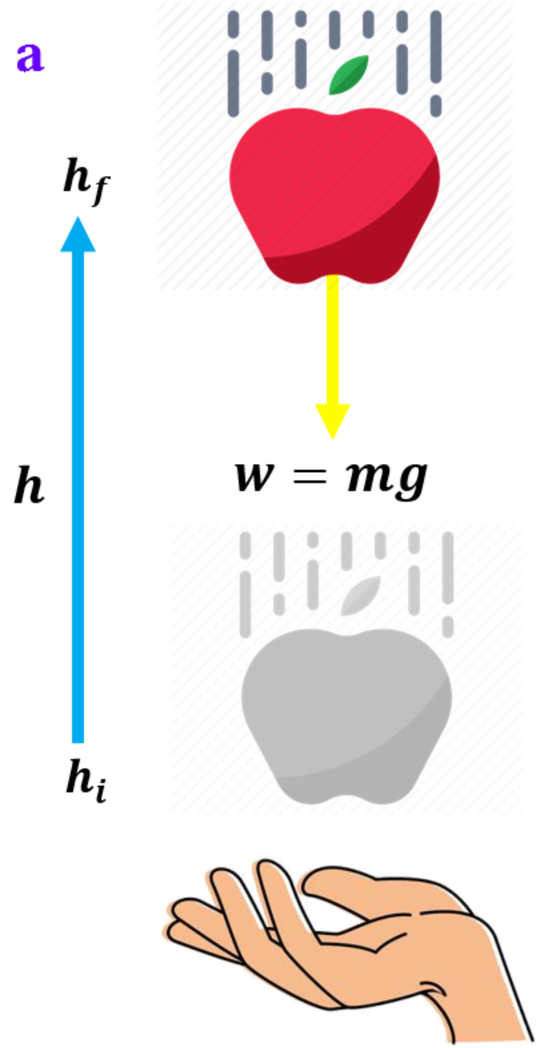
$$W_g = F_s s$$
$$= - mg\,(h_f - h_i)$$

We can define a gravitational potential energy U as

$$\boxed{U = mgh}$$

The change in potential energy when an object of mass is raised from an initial height h_i to a height h_f is opposite to the work done by the gravitational force:

$$\boxed{W_g = -\Delta U = U_i - U_f}$$



6.3 Potential Energy and Conservative Forces

To say that energy is conserved means that energy can never be created or destroyed—it can only be transformed from one form to another.

Total mechanical energy:

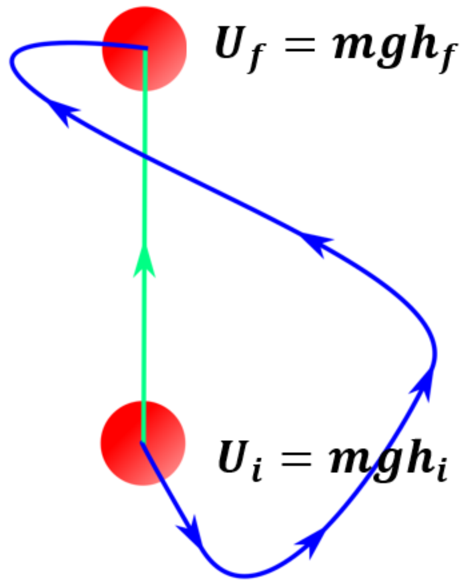
An object can have both kinetic and potential energy at the same time. The sum of an object's potential and kinetic energies is called the object's mechanical energy.

$$E = U + K$$

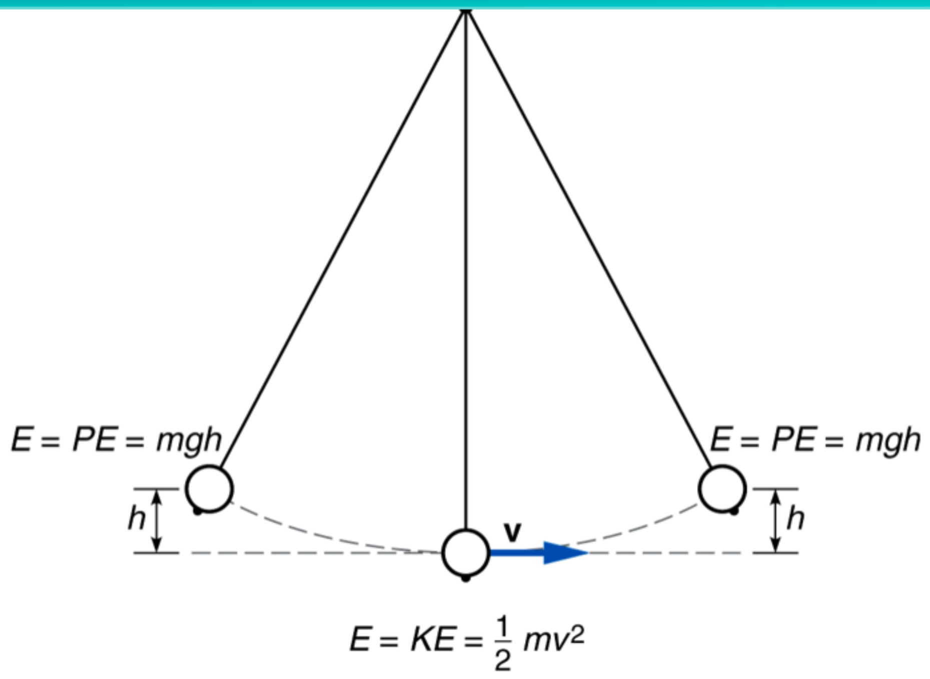
Conservative Force:

A conservative force is one, like the gravitational force, for which work done by or against it depends only on the starting and ending points of a motion and not on the path taken.

When only conservative forces act on and within a system, the total mechanical energy is constant. ($E_f = E_i$).



6.3 Potential Energy and Conservative Forces



Conservative Force:

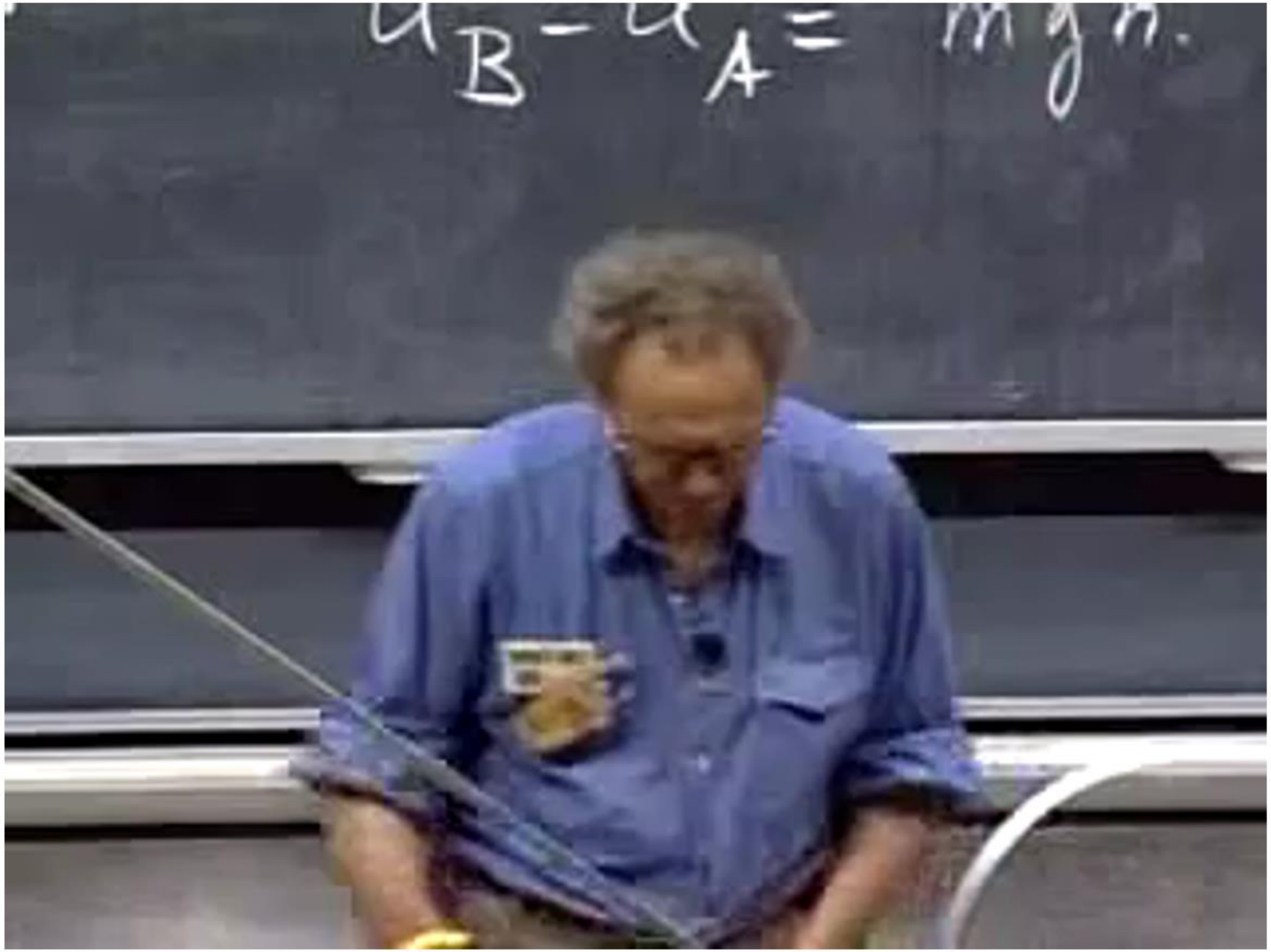
1. If the work done by the applied forces is zero ($W_a = 0$) and only the gravitational force is doing work, the mechanical energy is constant or conserved $\Delta E = E_f - E_i = zero$, then :

$$U_f + K_f = U_i + K_i$$

2. if the work done by the applied forces is nonzero ($W_a \neq 0$) he mechanical energy is not conserved $\Delta E = W_a$:

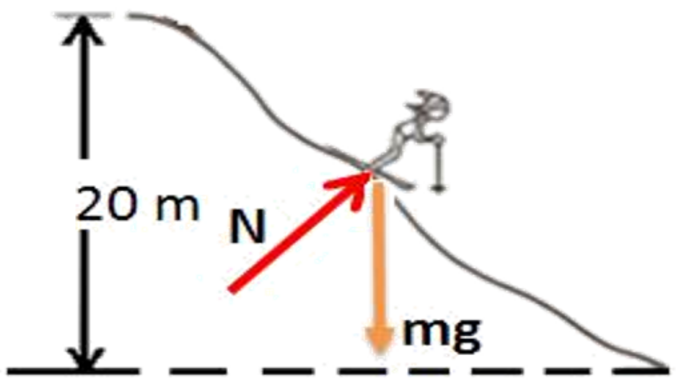
$$(U_f + K_f) - (U_i + K_i) = W_a$$

https://www.youtube.com/watch?v=mhIOylZMg6Q



Example 6.5 P 144:

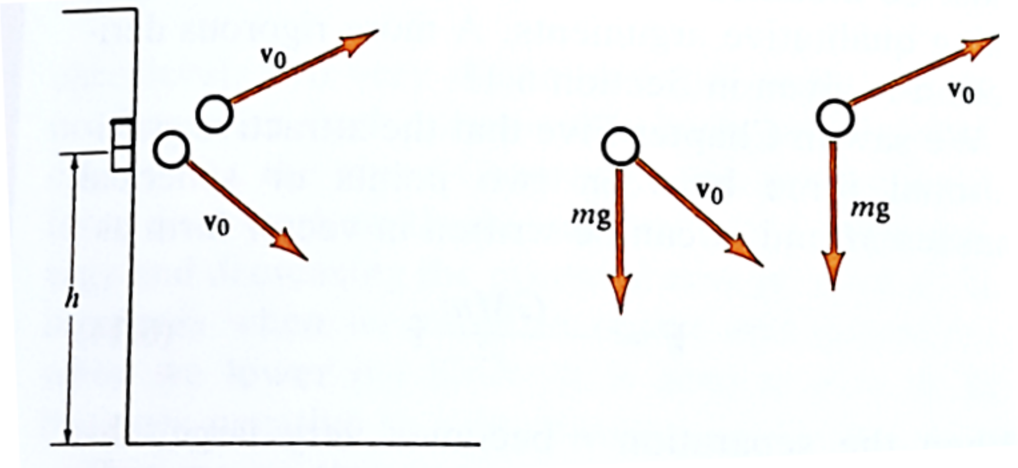
A woman skis from rest down a hill 20 m height. If friction is negligible, what is her speed at the bottom of the slope? (**Ans: 19.8m/s**)



6.6 Solving Problems Using Work and Energy

Example 6.8 P 147:

Two identical balls of mass m are thrown from a window a height h above the ground. The initial speed of each ball is $v_\circ$, but they are thrown in different directions . What is the speed of each ball as it strikes the ground? (Ans: $\sqrt{v_\circ^2 + 2gh}$)



6.9 Power

When a system develops work ΔW during a period of time Δt , the average power is defined as :

$$\mathcal{P}_{av} = \frac{W}{\Delta t}$$

The instantaneous power $\mathcal{P}$ is found by considering smaller and smaller time interval, so

$$\mathcal{P} = \frac{dW}{dt}$$

- The power is expressed in joule per second (J/s) in the SI system, which is called Watt (W)
- Energy Is often sold by electrical utilities by the kilowatt hour (KWh). This is 1 kilowatt of power for 1 hour. In terms of S.I. units,

$$1\ KW\ h = \left(10^3 W\right)(3600s) = 3.6 \times 10^6 J$$

6.9 Power

Example 6.14 P 152:

A 70 kg man runs up a flight of stairs 3m high in 2 s .

(a) How much work does he do against gravitational forces? (**Ans: –2060 J**)

(b) What is his average power output? (**Ans: –1030 W**)