Module 7: Work, Energy & Power

7.1 Work & Types of Energy

OBJECTIVES:

1. Define Work, Energy, and Power.
2. Identify which systems do negative, positive, and zero work.
3. Explain work-energy theorem.
4. Solve problems involving work, energy, and power.

Work

- Work, in physics, is the measure of energy transfer that occurs when an object is moved over a distance by an external force at least part of which is applied in the direction of the displacement.

$$\boldsymbol{W = \Delta E = E_f - E_o}$$

- No work is done unless the object is displaced in some way and there is a component of the force along the path over which the object is moved.

$$\bullet\ \boldsymbol{W = \vec{F} \cdot \vec{d} = |\vec{F}||\vec{d}| \cos \theta}$$

Is WORK a scalar or a vector quantity? What is the unit for work?

Work

$$1\,Joule = 1\,Newton\ * 1\,meter$$

$$\mathbf{1\,J = 1\,N * m}$$

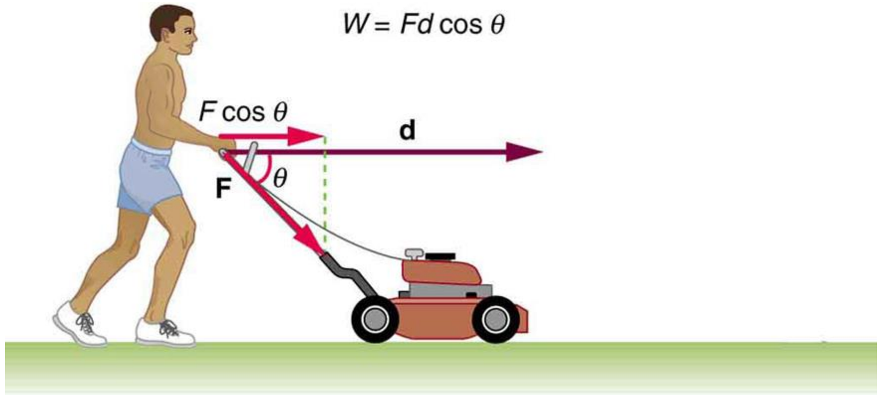
$$1\,J = 1\,\frac{kg * m}{s^2} * m$$

$$\mathbf{1\,J = 1\,\frac{kg * m^2}{s^2}}$$

http://epiphanyvideoworks.com/Science/Hughes/Units/Work&MachinesContent.htm

Work Done by a Constant Force

- **Work** is the product of a constant force along displacement; a scalar quantity; represented by **W**



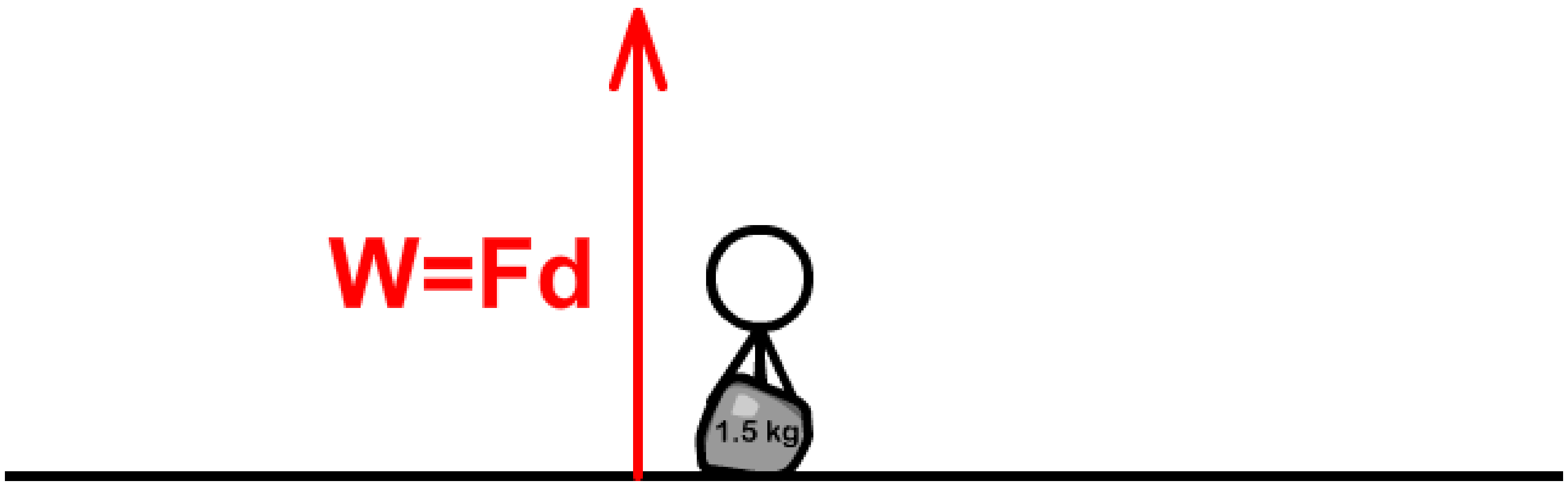
$$W = F_x \cdot d$$
$$W = F\cos\theta \cdot d$$
$$W = Fd\cos\theta$$

https://scienceres-edcp-educ.sites.olt.ubc.ca/secondary/physics/work-energy-power/

F = force in the direction of the displacement, J
θ = angle between force and displacement
d = displacement

Work Done by a Constant Force

You Do Work Storing PE



Work is done to **transform energy from one form to another.**

$W = Fd$

How many joules of work did you do? (W)

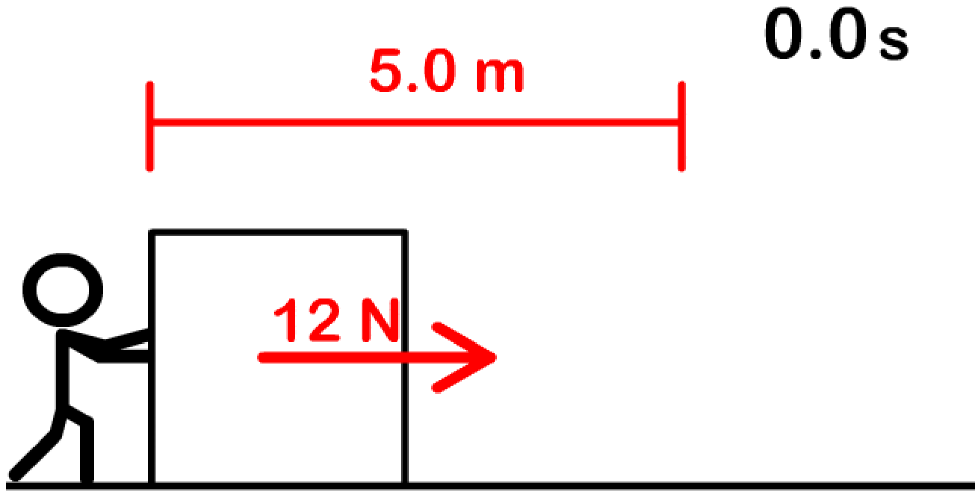
How many newton's of force did you apply in the direction of motion? (F)

How many meters did it move? (d)

WORK makes you **mad.**

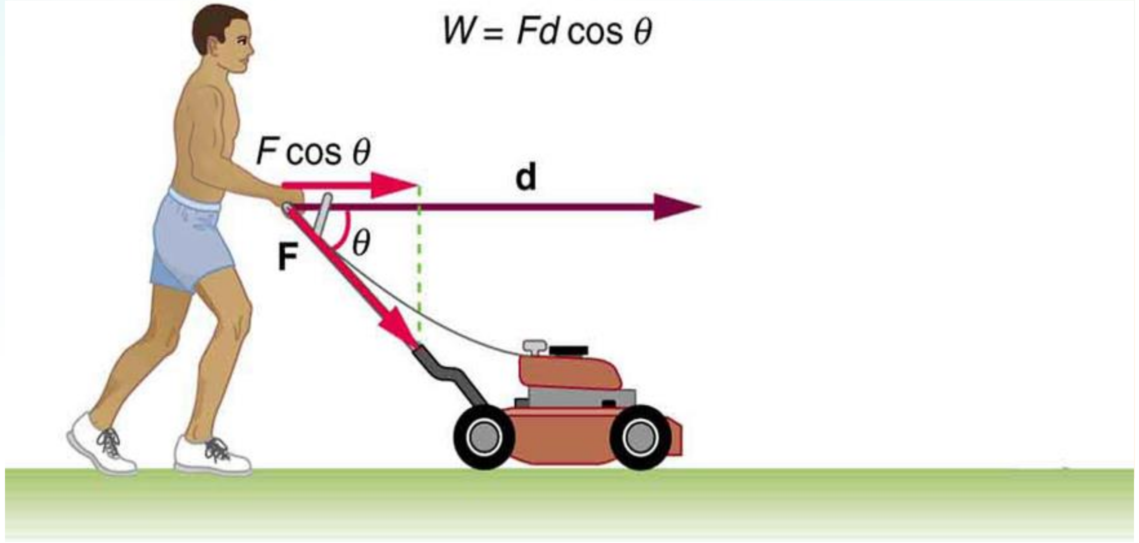
Work Done by a Constant Force

- When a force acts upon an object to cause a displacement of the object, it is said that **work** was done upon the object.
- There are three key *ingredients* to work - **force**, **displacement**, and **cause** (In order for a force to qualify as having done *work* on an object, there must be a displacement and the force must *cause* the displacement)



Example

How much work is done on the lawn mower by the person (a) if he exerts a constant force of 75.0 N at an angle 35° below the horizontal and pushes the mower 25.0 m on level ground?



Example

A 4.0-kg block is pulled across a flat surface via a rope with a 50.0N applied force to the right. A frictional force of 30.0N acts between the surface and the block. The block is pulled for a total horizontal displacement of 10.0 meters. Draw the FBD that depicts all of the forces which act upon the trashcan.

Find the following:

a) Work done by the Applied force?
b) Work done by the Frictional force
c) Work done by the Gravitational Force
d) Work done by the Normal Force
e) Net work done by all forces?

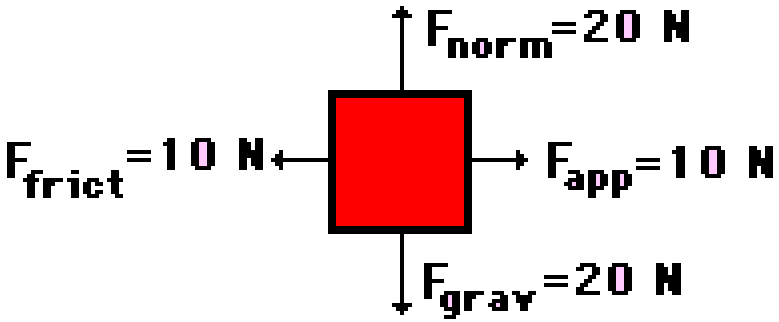
Example

David is pulling a 400.0 kg sled with a kinetic coefficient of friction of 0.15 at a constant velocity up an inclined plane with an inclination of 25.0^{o}.If the inclined plane is 60.0 m long,

a. how much work does it take to move the sled to the top of the incline?
b. How much work is done if a 30.0 m incline reaches the same height?

Example

Find the total work done on a system where in a 10-N force is applied to push a block across a frictional surface at constant speed for a displacement of 5.0 m to the right as shown by the FBD below.



Energy

Energy is the ability to do work. It is needed by an object to do work by itself alone. It is a scalar quantity

Mechanical Energy

Kinetic Energy is an energy stored by virtue of its motion

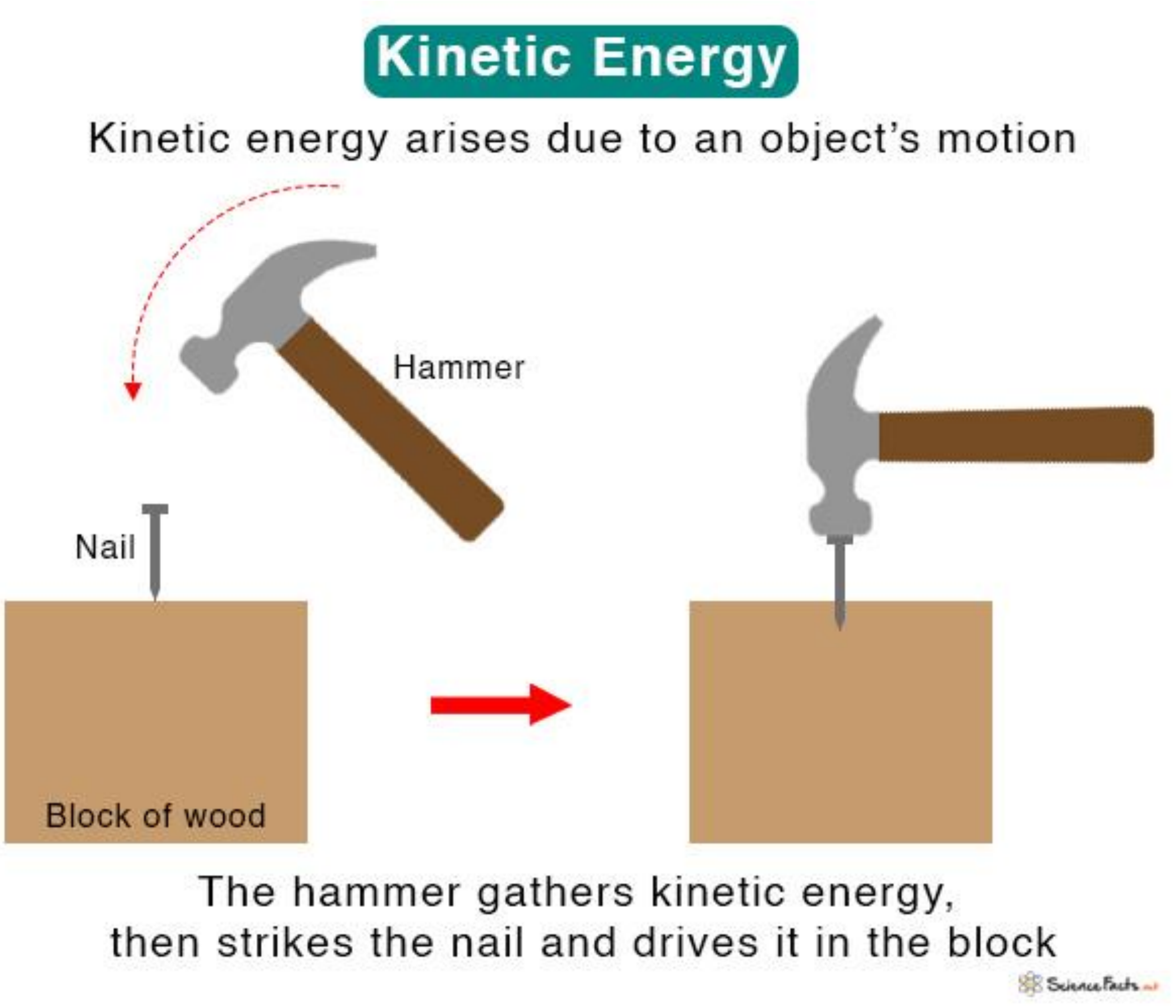
Gravitational Potential Energy is an energy stored in a body by virtue of its vertical location or height with respect to a certain reference horizontal line

Elastic Potential Energy is an energy stored in a body by the presence of an elastic material

ENERGY

POTENTIAL ENERGY	KINETIC ENERGY
Chemical Energy	Mechanical Energy
Electric Energy	Electrical Energy
Elastic Energy	Thermal Energy
Gravitational Energy	Sound Energy
	Radiant Energy

Kinetic Energy



- **The energy acquired by an object due to its motion is known as kinetic energy. The motion can be translational, rotational, vibrational, or a combination of all three.**

- ✓ Associated with a moving object
- ✓ Increases or decreases with the change in velocity
- ✓ Greater for heavier mass
- ✓ Can transform into other types of energy
- ✓ Measured in the unit of Joules

Kinetic Energy

$$\boxed{KE = \frac{1}{2}mv^2}$$

KE = kinetic energy, Joule
m = mass of the object in motion, kg
v = velocity of the object, m/s

If $v_f > v_i$ then $\Delta KE = +$ (KE is gained)
If $v_f < v_i$ then $\Delta KE = -$ (KE is lost)
If $v_f = v_i$ then $\Delta KE = 0$ (KE is conserved)

KINETIC ENERGY is the ENERGY IN MOTION

Example

Determine the kinetic energy of an 80-kg athlete running at 10 m/s?

Example

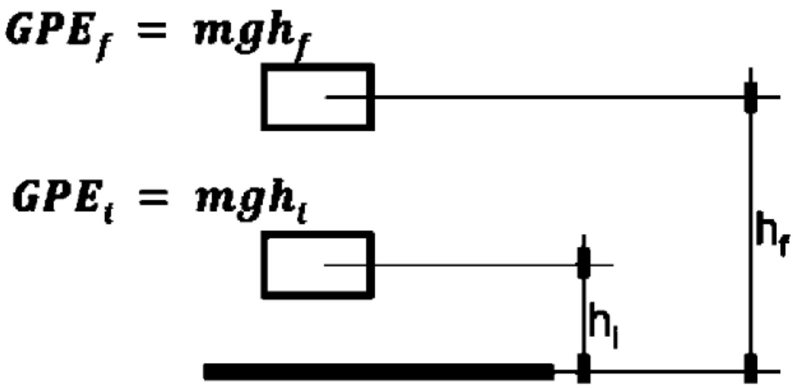
The Chicxulub crater in Yucatán, one of the largest impact craters on Earth, is believed to have been formed by an asteroid traveling at 22 km/s and releasing $4.2 \times 10^{23}\,J$ of kinetic energy upon impact. What was its mass?

Example

In nuclear reactors, thermal neutrons of 1.68×10^{-27} kg travel at about 2.2 km/s. What is the kinetic energy of such a neutron?

Gravitational Potential Energy

$$\boxed{PE_g = mgh}$$



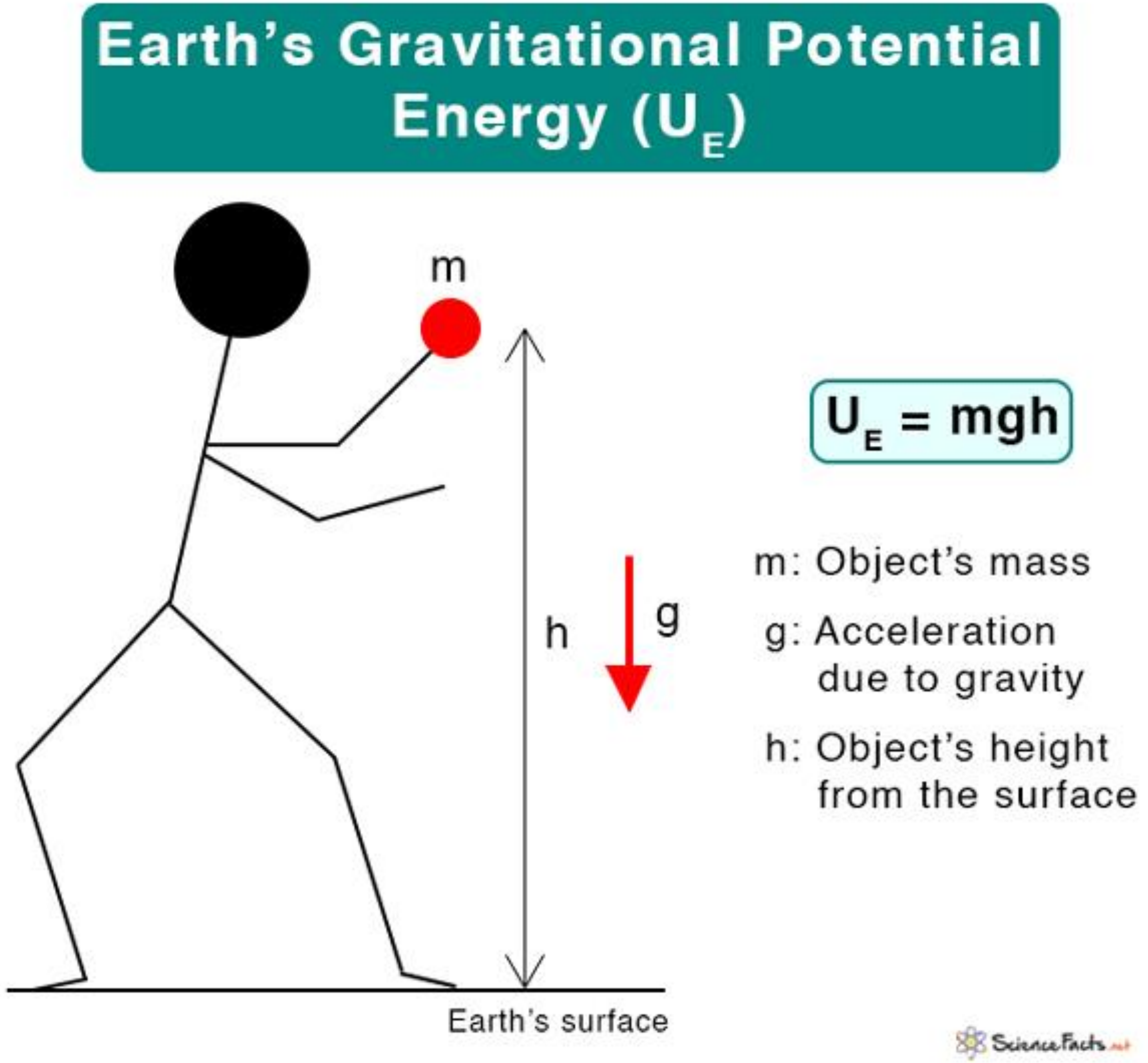
PE_g = GPE = gravitational potential energy, J

m = mass of the object in motion, kg

g = acceleration due to gravity, g = 9.8 m/s^2

h = height of the object from a reference point, m

POTENTIAL ENERGY is the ENERGY IN POSITION



POTENTIAL ENERGY is the ENERGY IN POSITION

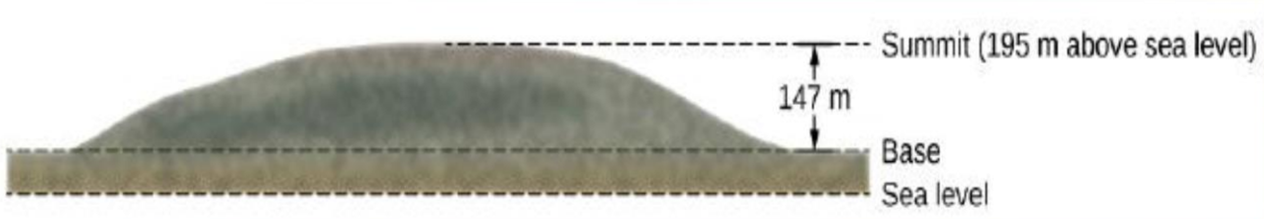
Example

The summit of Great Blue Hill in Milton, MA, is 147 m above its base and has an elevation above sea level of 195 m. A 75-kg hiker ascends from the base to the summit. What is the gravitational potential energy of the hiker-Earth system with respect to zero gravitational potential energy at base height, when the hiker is

(a)at the base of the hill,

(b)at the summit, and

(c)at sea level, afterward?



Example

Work-Energy Theorem

When work is done on a system and the only change in the system is in its speed, the net work done on the system equals the change in kinetic energy of the system.

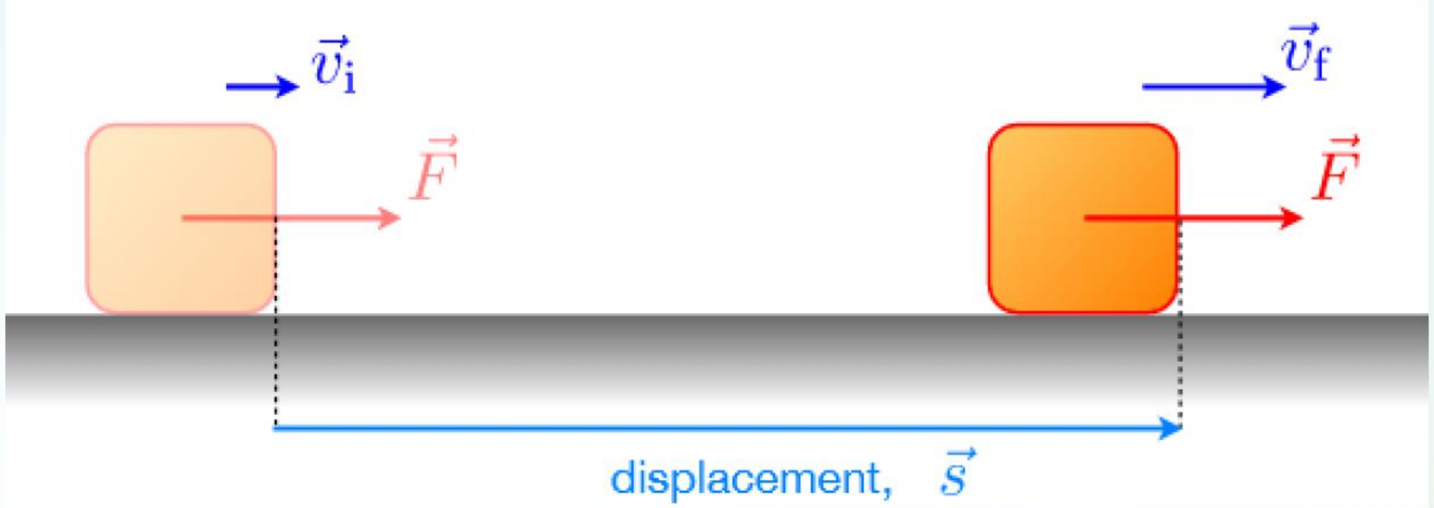
$$\boldsymbol{W = \Delta KE}$$

Work-Energy Theorem & Power

$$W = \Delta KE = KEf - KEi = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$$

W = work
ΔKE = change in kinetic energy

KE_i = initial kinetic energy
KE_f = final kinetic energy



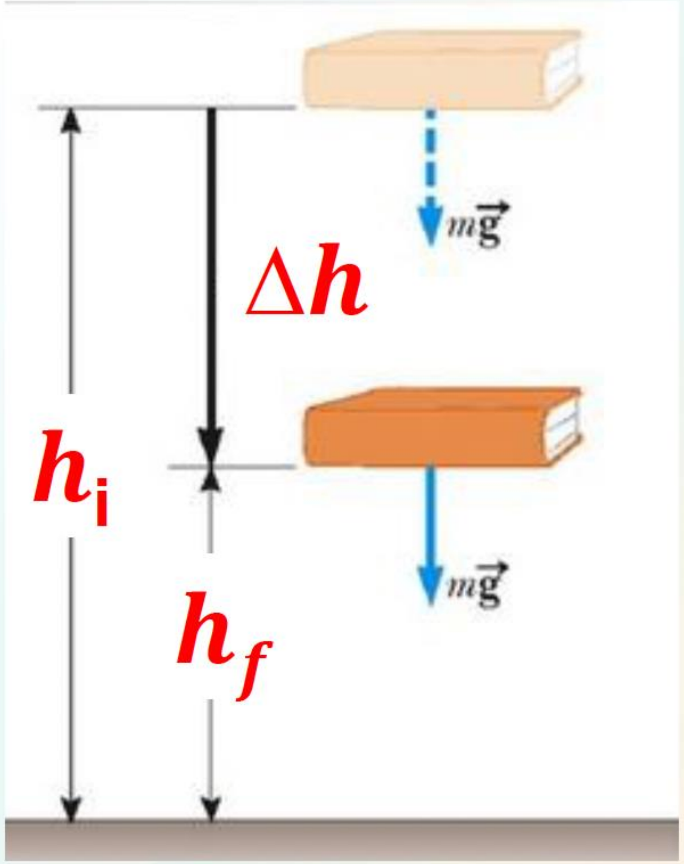
https://docplayer.net/21740443-Physics-111n-work-energy.html

Work-Energy Theorem & Power

$$W = \Delta PEg = PEgf - PEgi = mgh_f - mgh_i$$

W = work
ΔPE_g = change in potential energy

PE_{gi} = initial potential energy
PE_{gf} = final potential energy



https://www.slideshare.net/shubhendraojha/work-energy-and-power

Example

Using energy considerations, calculate the average force a 60.0-kg sprinter exerts backward on the track to accelerate from 2.00 to 8.00 m/s in a distance of 25.0 m, if he encounters a headwind that exerts an average force of 30.0 N against him.

Example

A constant 10-N horizontal force is applied to a 20-kg cart at rest on a level floor. If friction is negligible, what is the speed of the cart when it has been pushed 8.0 m?

Power

$$P = \frac{work}{t} = \frac{E}{t}$$

- **The rate of doing work**, in watt
- The rate at which energy is transferred or transformed
- It is work or energy divided by the time
- One watt means one joule of work in one second
- Conversion: 1 horsepower (HP) = 746watts

POWER makes you mad over time.

Power

$$\text{Power} = \frac{\text{Work}}{\text{Time}} = \frac{\text{Force} \bullet \text{Displacement}}{\text{Time}}$$

$$\text{Power} = \text{Force} \bullet \frac{\text{Displacement}}{\text{Time}}$$

$$\boxed{\text{Power} = \text{Force} \bullet \text{Velocity}}$$

Example

An escalator is used to move 20 students every minute from the first floor of the FEU-TECH Building to the second floor. The second floor is located 5.20 meters above the first floor. The average student's mass is 54.9 kg. Determine the power requirement of the escalator in order to move this number of students in this amount of time.

Example

A woman is pulling her luggage with a 25 N force at an angle of 55°. What is her power output if it takes her 15 seconds to pull the suitcase 20m forward?

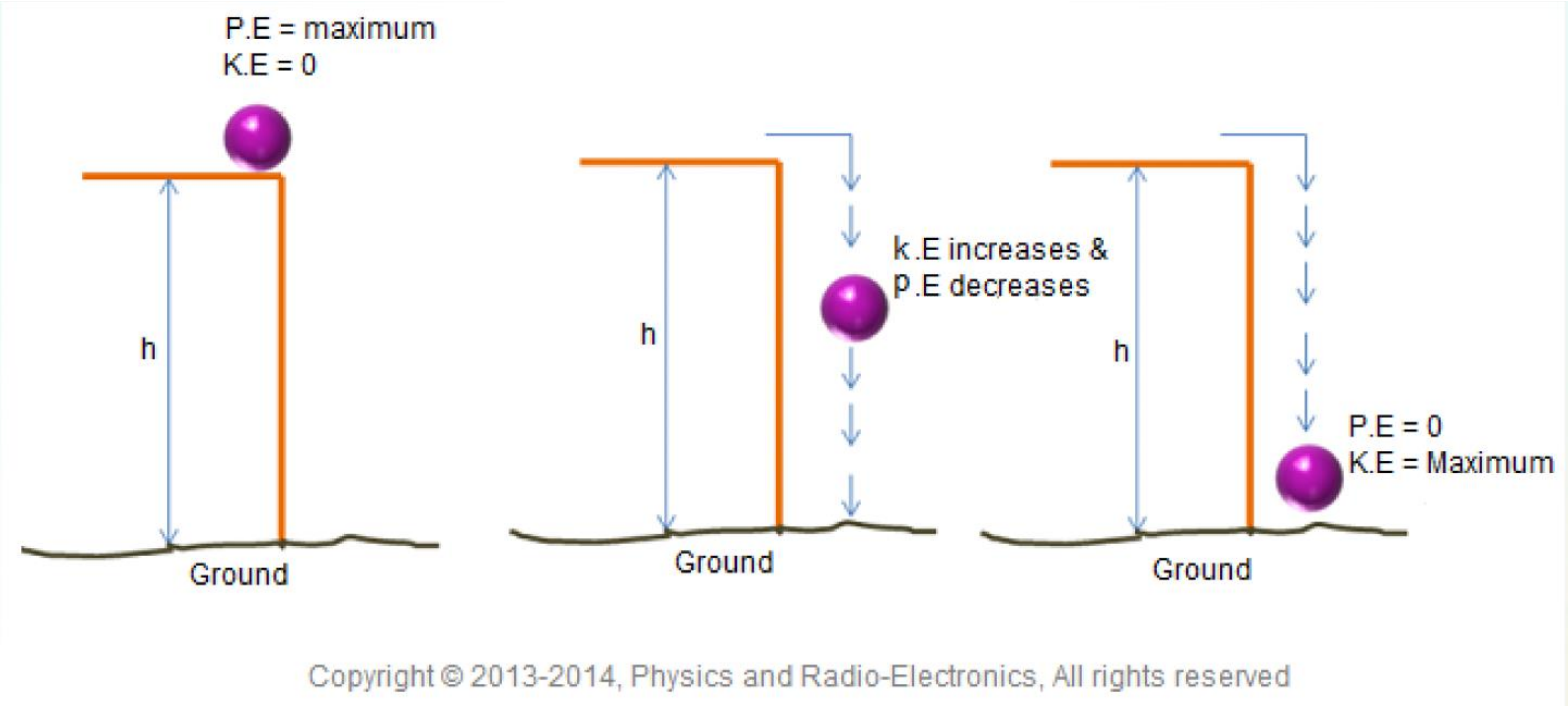
Conservation of Energy

<u>LAW OF CONSERVATION OF ENERGY</u>

Energy cannot be created nor destroyed, but energy can change from one form into another.

- $\Delta E = \Delta U_g + \Delta KE = W$
- For an isolated system, W = 0, or the total energy of an isolated system remains constant (is conserved).
- $\Delta E = \Delta U_g + \Delta KE = W = 0$ (isolated system)
- Conservation of Energy... final = initial

Conservation of Energy



Conservation of Energy

- Energy conservation means that the sum of the KE and the PE of an object is always the same.

$$\boxed{E = KE + PE_g}$$

$$\boxed{E = \frac{1}{2}mv^2 + mgh}$$

- When energy is transferred, one body loses energy, whereas another gains it.

$$\boxed{\text{Total energy before} = \text{Total energy after}}$$

Conservation of Energy

- At maximum height, speed is zero. Hence, all E is converted to PE_g

$$\boxed{E = PE_g = mgh_{max}}$$

- At minimum height, speed is maximum. Hence, all E is converted to KE

$$\boxed{E = KE = \frac{1}{2}mv^2_{max}}$$

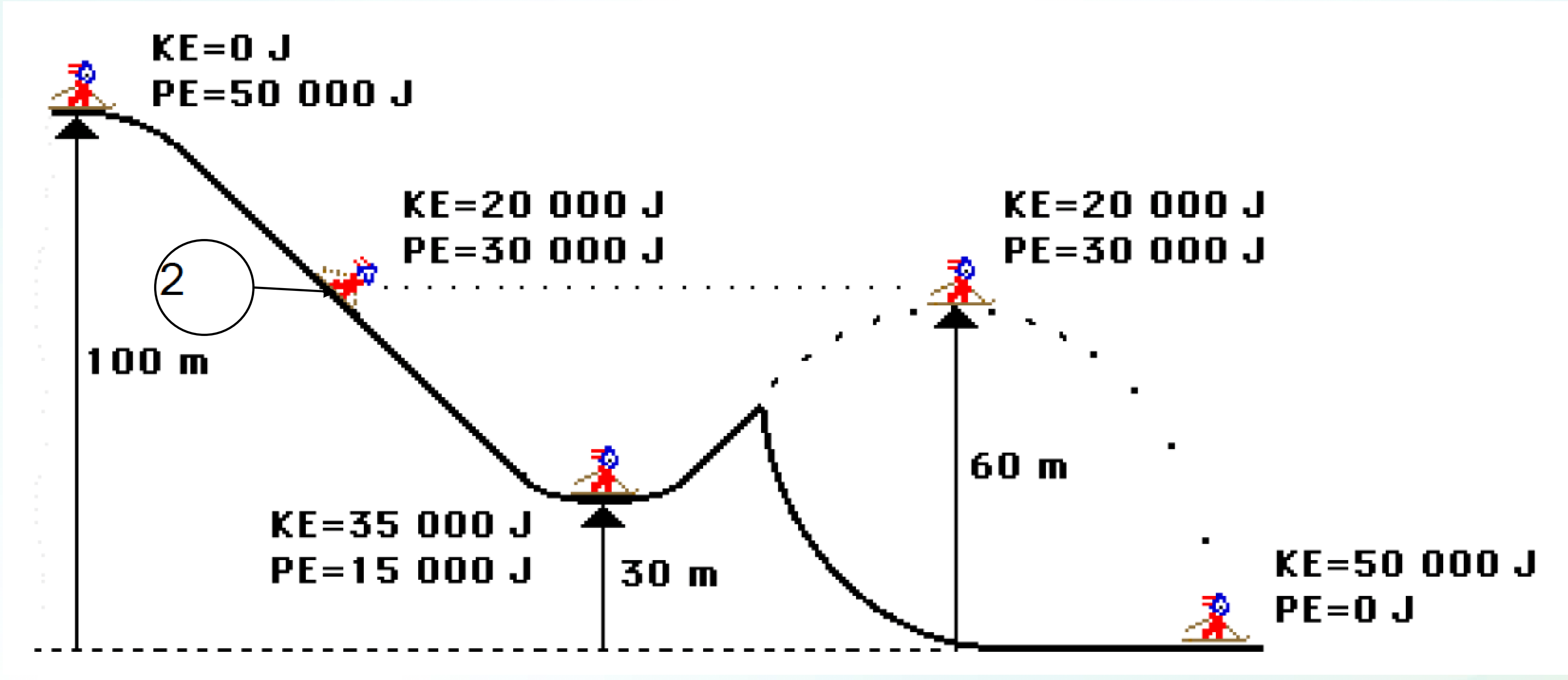
- Where $E = KE_{max} = PE_{gmax}$ then

$$\boxed{v = \sqrt{2gh}}$$

Example

Find the following, with the skier having mass 60 kg:

a. Height of the skier at point 2
b. Speed at point 2
c. Mechanical energy at point 2



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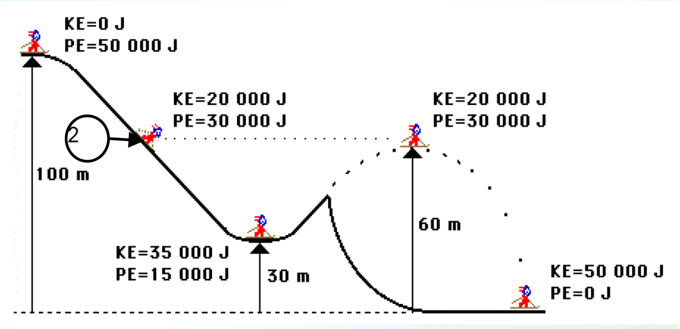

Example

A heavy ball is hanging from a 4.5m cable, and it is released from a height of 16.5 m off the ground and then falls to its lowest point which is 15 m off the ground. What is the speed of the ball at its lowest position?

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Got any questions???

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