Al-Mustaqbal University

Department of Optics Techniques

Medical and optical physics 1

First stage

Assist. Lec. Hala Mohammed Subhi

➢ Lecture 4

Work, Power and Energy

Introduction:

Energy, work, and power are three interconnected concepts in physics. However, did you know that we use these concepts daily? Energy, a necessary component of life, is found in everything we eat. Eating provides our bodies with the energy needed to regulate internal functions such as repairing cells or body tissue, building muscle, and maintaining homeostasis. We may not know it but energy is always present as it allows our bodies to do "work" and provides the "power" needed for us to function properly. Therefore, let us use this example as a starting point in understanding work, energy, and power, and introduce definitions and examples that help expand our knowledge on the topic.

There are several good examples of work that can be observed in everyday life - a horse pulling a plow through the field, a father pushing a grocery cart down the aisle of a grocery store, a freshman lifting a backpack full of books upon her shoulder, a weightlifter lifting a barbell above his head, an Olympian launching the shot-put, etc. In each case described here there is a force exerted upon an object to cause that object to be displaced.

<u>Work definition</u>

is the amount of energy transferred due to an object moving some distance because of an external force.

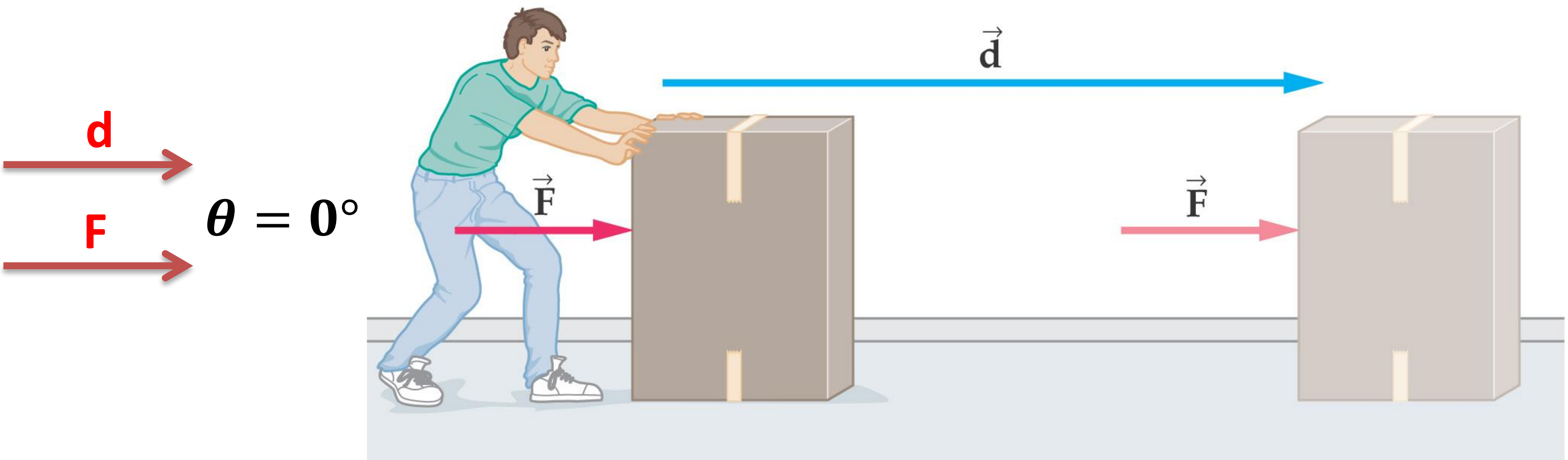
Work Equation: Mathematically, work can be expressed by the following equation:

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

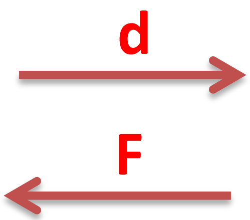
where **F** is the force, **d** is the displacement, and the angle (**θ**) is defined as the angle between the force and the displacement vector.

There are three cases of angle in the Work law:

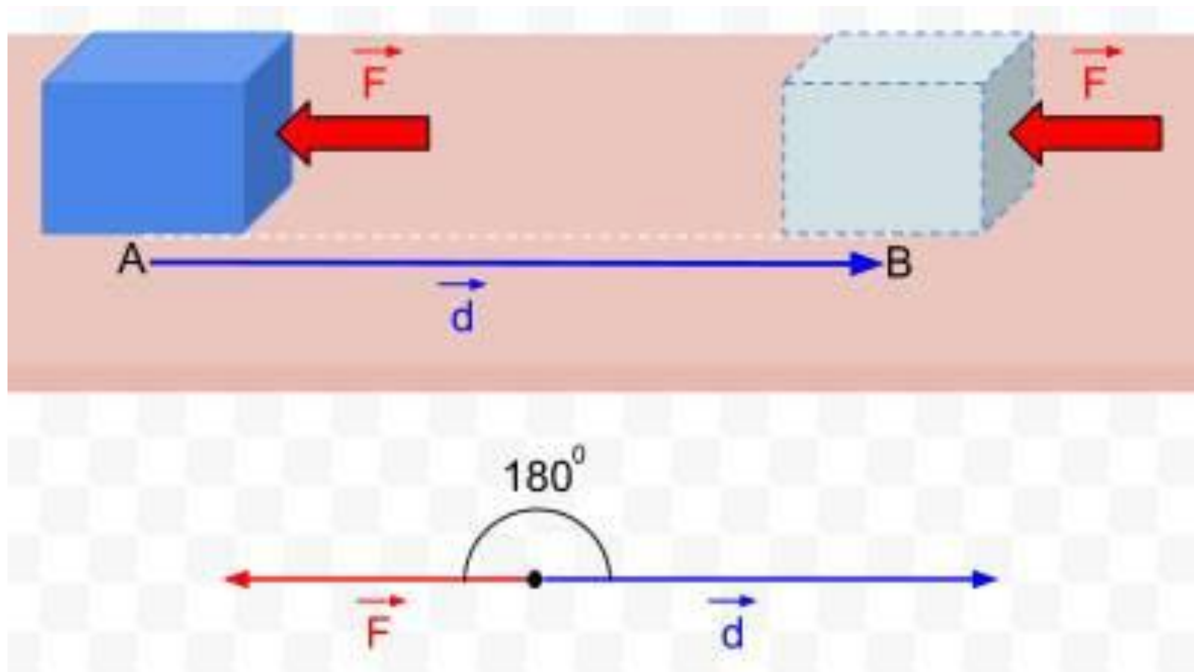
1- A force acts rightward upon an object as it is displaced rightward. In such an instance, the force vector and the displacement vector are in the same direction. Thus, the angle between F and d is 0 degrees.



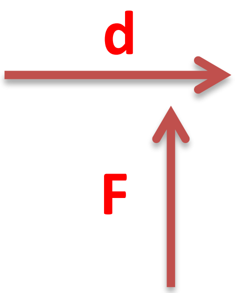
2- A force acts leftward upon an object that is displaced rightward. In such an instance, the force vector and the displacement vector are in the opposite direction. Thus, the angle between F and d is 180 degrees.



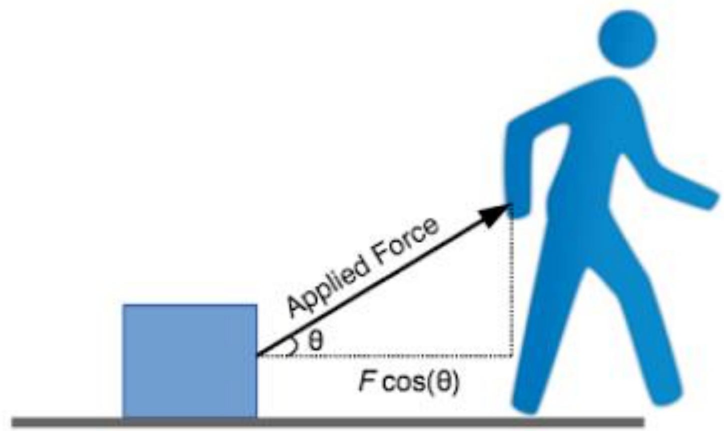
$$\theta = 180°$$



3- A force acts upward on an object as it is displaced rightward. In such an instance, the force vector and the displacement vector are at right angles to each other. Thus, the angle between F and d is 90 degrees.

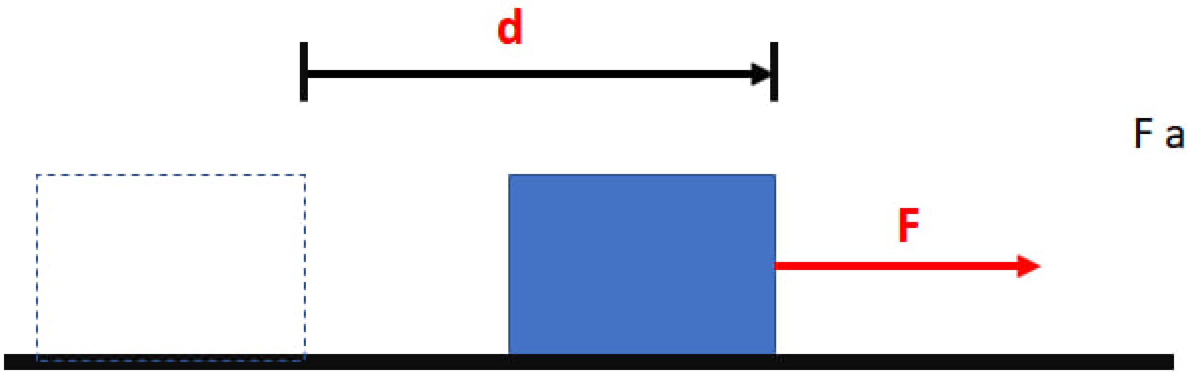


$$\theta = 90°$$



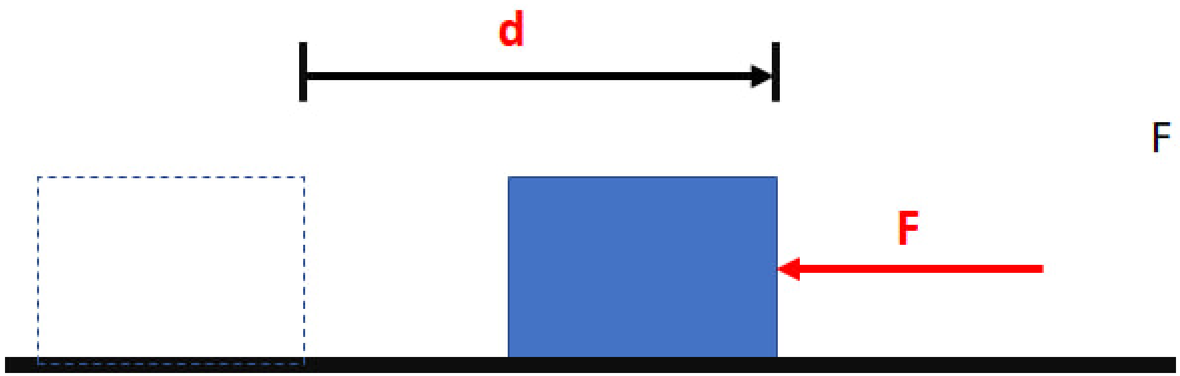
Units of Work: The standard unit used to measure work done in physics is the joule, which has the symbol J. In mechanics, 1 joule is the energy transferred when a force of 1 Newton is applied to an object and moves it through a distance of 1 meter.

1 Joule = 1 Newton * 1 meter



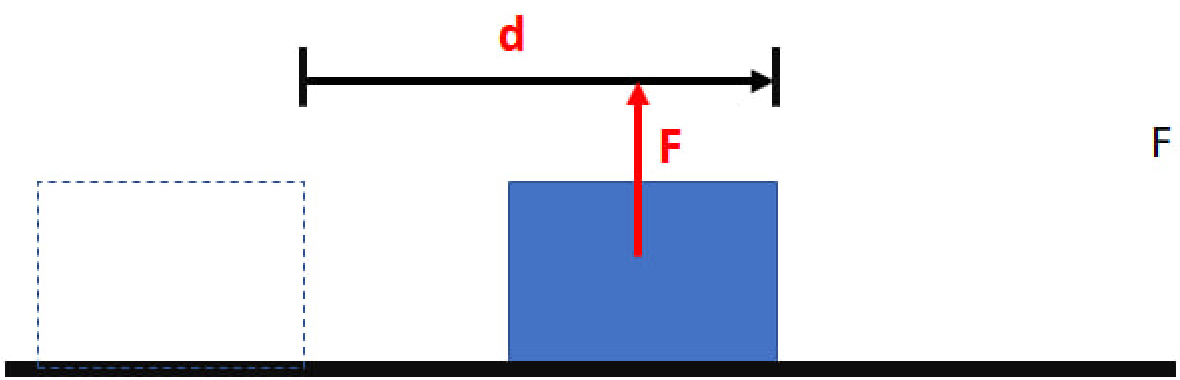
F and d are in the same direction:

$$W = +F \cdot d$$



F and d are in opposite directions:

$$W = -F \cdot d$$

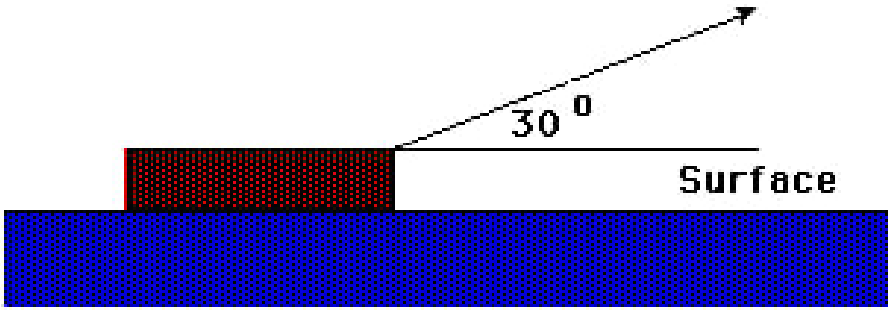


F and d are perpendicular:

$$W = 0$$

Example:

A force of 50 N acts on the block at the angle shown in the diagram. The block moves a horizontal distance of 3.0 m. How much work is done by the applied force?



Solution:

W = F . d . cos Ɵ

W = (50 N) * (3 m) * cos (30°) = 129.9 Joules

Example:

How much work is done by an applied force to lift a 15-Newton block 3.0 meters vertically at a constant speed?

Solution:

W = F . d

W = (15 N) * (3 m) = 45 Joules

Power definition :

Power: is the amount of energy transferred or converted per unit time. Power is a scalar quantity. Mathematically, it is computed using the following equation.

$$P = \frac{Work}{time} \rightarrow \frac{W}{t}$$

Where, **P** is the power, **W** is the work done and **t** is the time taken.

Power has a SI unit of watts, denoted by W.

Another Formula for Power:

The expression for power is work/time. And since the expression for work is force*displacement, the expression for power can be rewritten as (force*displacement)/time. Since the expression for velocity is displacement/time, the expression for power can be rewritten once more as force*velocity. This is shown below.

$$Power = \frac{Work}{time} = \frac{force\,.displacement}{time}$$

$$\text{Power} = \text{force}\ \frac{displacement}{time}$$

$$\boldsymbol{Power = force\,.velocity}$$

<u>Prove that:</u>

$$P = Fv\ cos\theta$$

Example:

A garage hoist lifts a truck up 2 meters above the ground in 15 seconds. Find the power delivered to the truck. [Given: 1000 kg as the mass of the truck]

First we need to calculate the work done, which requires the force necessary to lift the truck against gravity:

F = mg = 1000 x 9.81 = 9810 N.

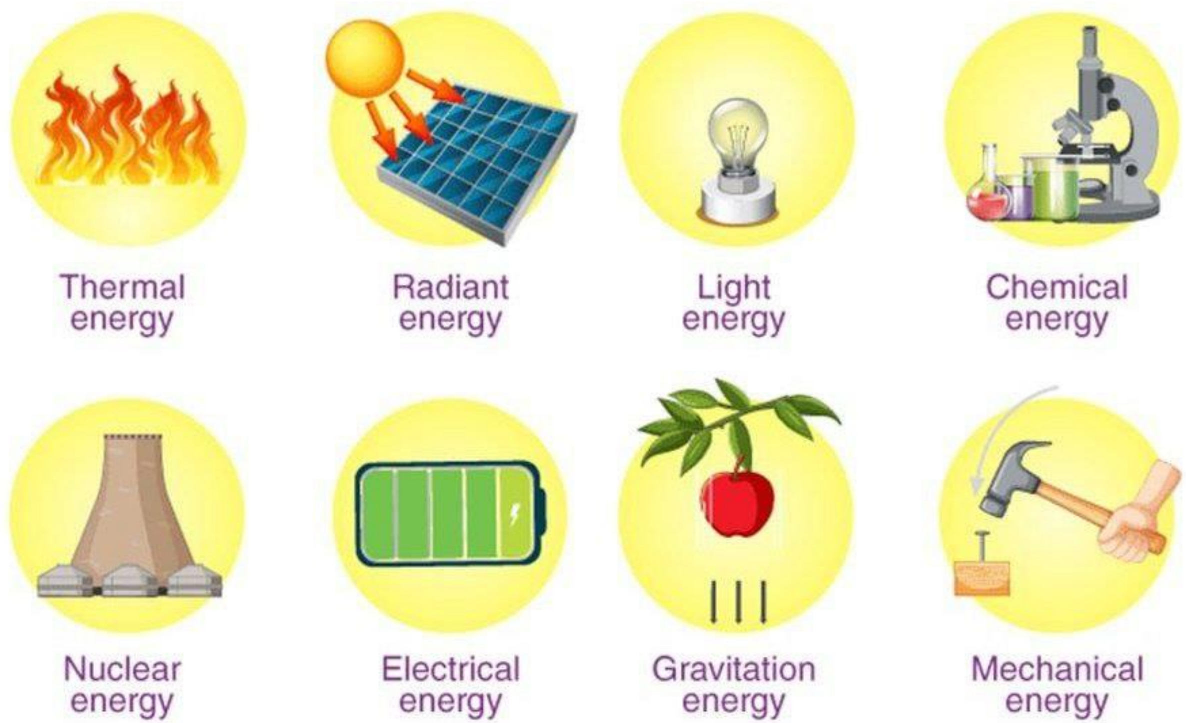
W = F . d = 9810N x 2m = 19620 Nm = 19620 J.

The power is $P = \frac{W}{t} = \frac{19620}{15} = 1308\ \frac{J}{s} = 1308$ W.

Energy definition :

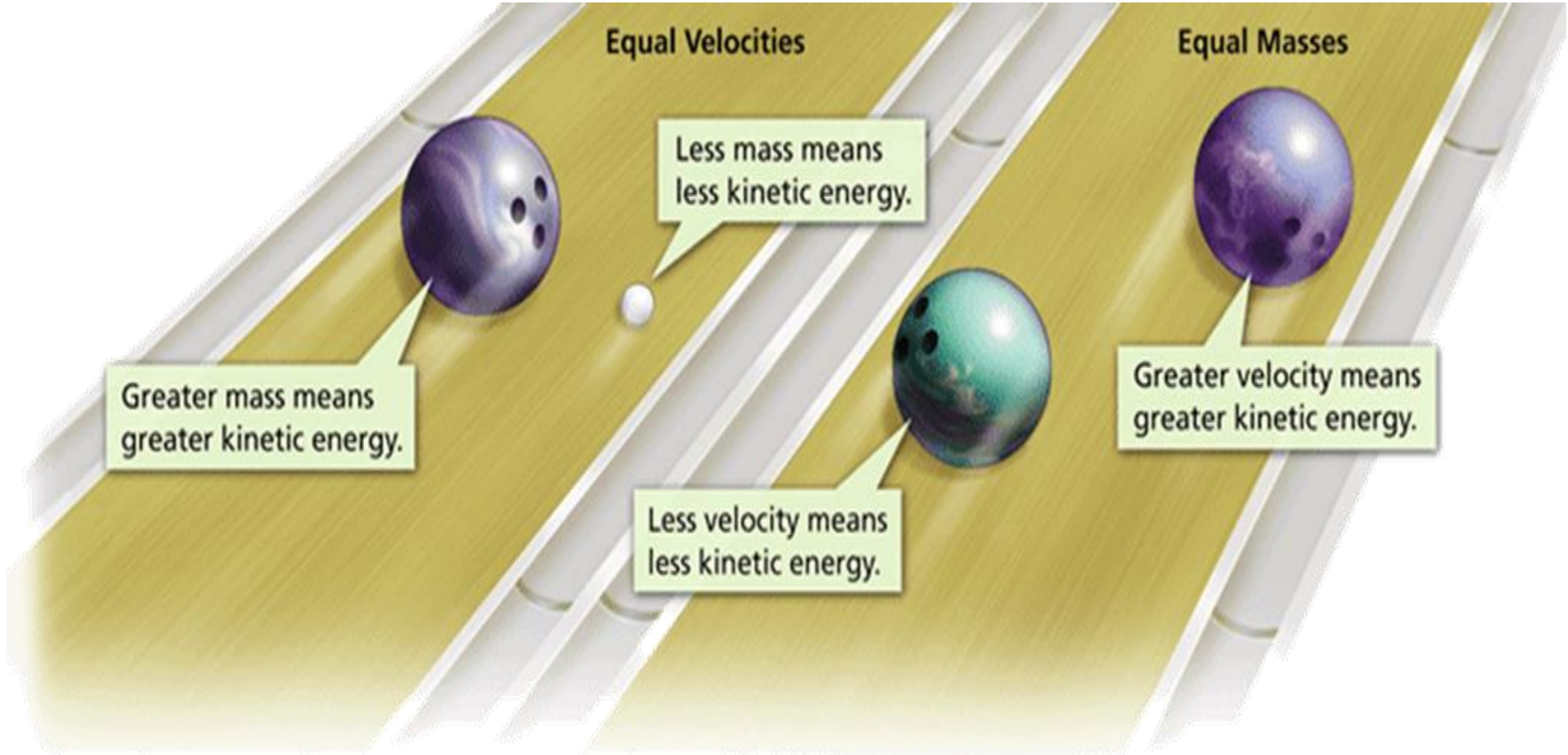
We can define energy as the capacity to do work. There are various forms of energy. Energy is a scalar quantity whose SI unit is the joule (J). Energy is found in many things, and thus there are different types of energy. All forms of energy are either kinetic or potential.

Types of energy



Kinetic Energy:

Kinetic Energy is energy associated with the state of motion of an object. The amount of Kinetic energy is dependent on the mass and speed of an object. Kinetic Energy increases as mass and velocity increase.



Kinetic energy is calculated by: $KE = \frac{1}{2} m v^2$

Formula	Represents	Units
$KE = \frac{1}{2}mv^2$	KE = Kinetic energy	Joules (J)
	m = mass	kilogram (kg)
	v = velocity	Meter/second (m/s)

Example: A 1200 kg automobile is traveling at a velocity of 100 m/s northwest. What is the kinetic energy of the automobile?

Solution:

$$KE = \frac{1}{2} m v^2$$

$$= \frac{1}{2} (1200) (100)^2$$

$$\therefore KE = 6000000 \, J$$

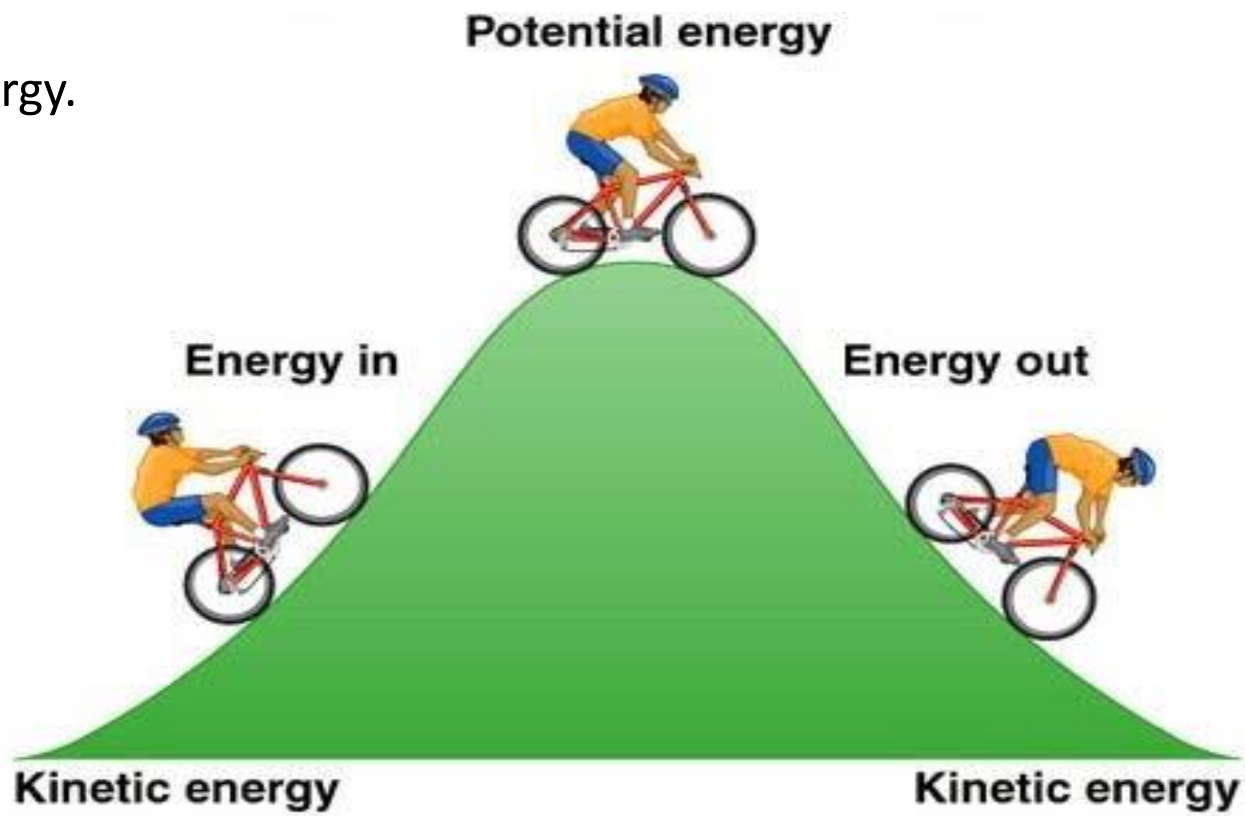
Potential Energy:

potential energy, stored energy that depends upon the relative position of various parts of a system.

Types of Potential Energy:

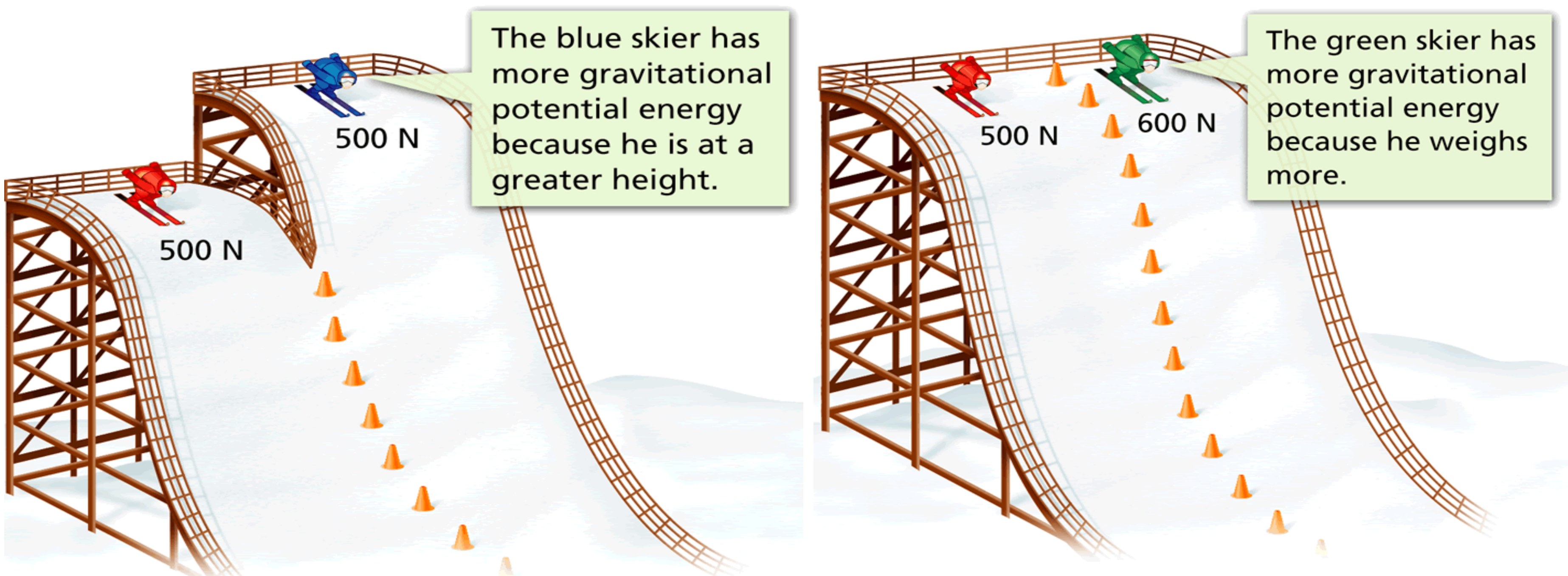
1- Gravitational Potential Energy.

2- Elastic Potential Energy.



Gravitational potential energy : Gravitational potential energy is the energy stored in an object as the result of its vertical position or height.

- Gravitational Potential Energy increases as weight and height increase.



Gravitational Potential energy is calculated by: $GPE = mgh$

Formula	**Represents**	**Units**
GP$E = mgh$	PE = Potential energy	Joules (J)
	m = mass	(kg)
	g = Acceleration due to gravity	(m/S^2)
	h = Height	(m)

Example: A 2 kg ball is lifted to a height of 5 meters above the ground. What is its gravitational potential energy?

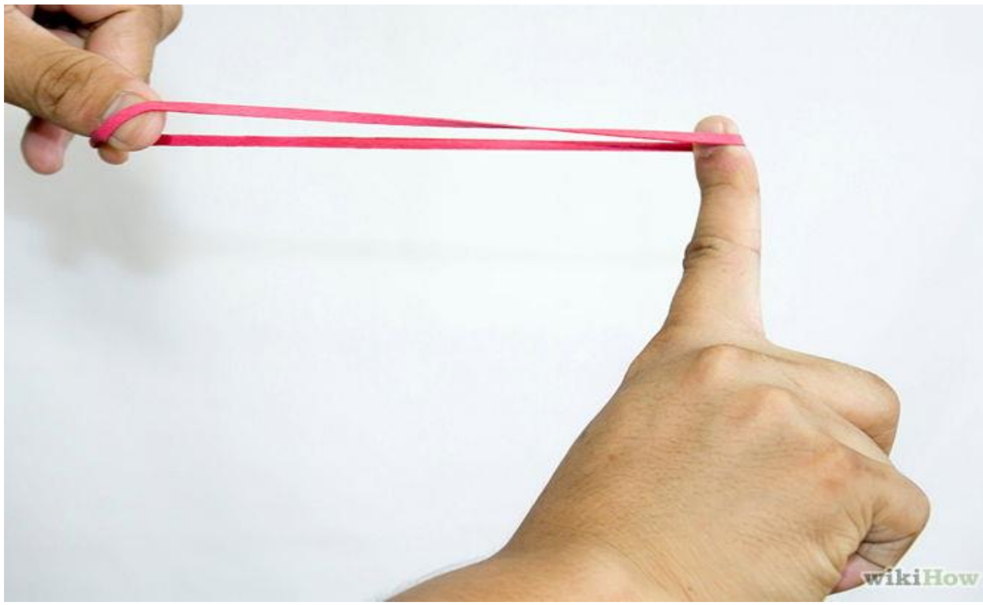
Solution:

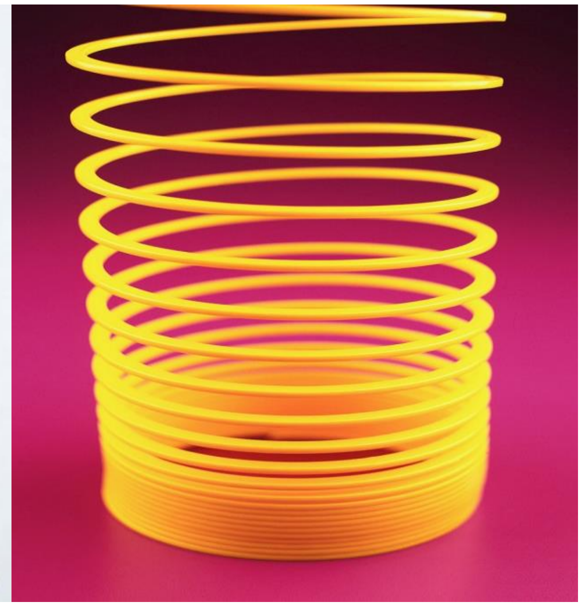
GPE= m g h

GPE= 2 kg x 9.81 m/S^2 *x 5 m*

GPE= 98.1 J

Elastic potential energy: is the energy stored within an object due to its ability to be stretched or compressed. Pulling back a rubber band.





For certain springs, the amount of force is directly proportional to the amount of stretch or compression (x); the constant of proportionality is known as the spring constant (k).

$$EPE = \frac{1}{2}K.x^2$$

<u>Mechanical Energy :</u> It is the sum of potential energy and kinetic energy that is the energy associated with the motion & the position of an object, known as Mechanical energy. Thus, we can derive the formula of mechanical energy as :

Mechanical Energy = Kinetic Energy + Potential Energy

Mechanical Energy = $\frac{1}{2}m\,v^2 + mgh$

The Law of Conservation of Energy

Energy can neither be created nor destroyed; rather, it transforms from one form to another. Although, it may be transformed from one form to another. If you take all forms of energy into account, the total energy of an isolated system always remains constant. All the forms of energy follow the law of conservation of energy. In brief, the law of conservation of energy states that :

In a closed system, i.e., a system that is isolated from its surroundings, the total energy of the system is conserved.