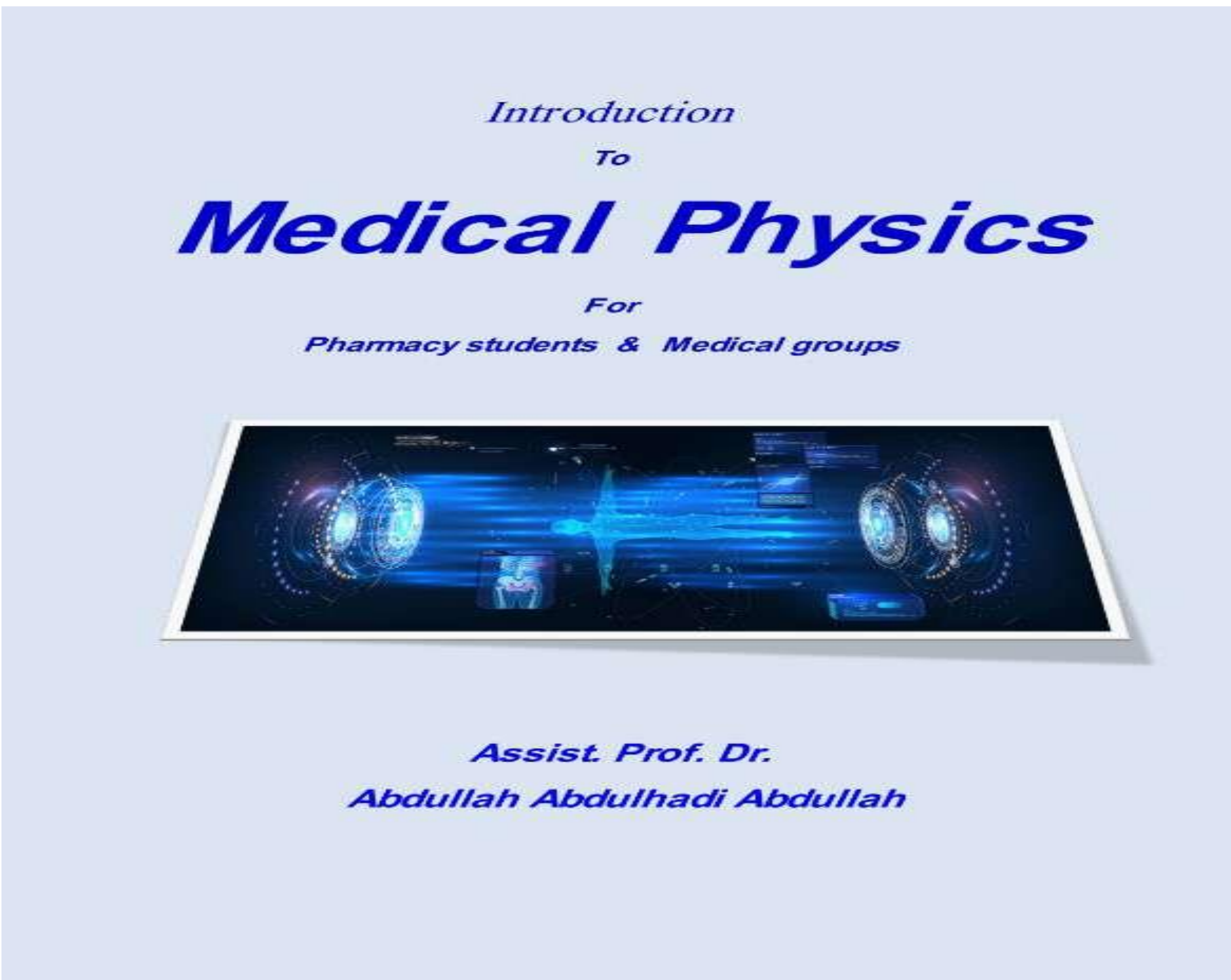
CHAPTER ONE

FUNDAMENTAL CONCEPT



Assist.Prof.Dr
Abdullah A. Abdullah

1.1 Terminology.

What is the concept of medical physics?

Medical Physics is the application of physics to medicine. It uses physics concepts and procedures in the prevention, diagnosis, and treatment of disease. Medical Physics fulfils a key role in medicine, in biological and medical research.

The examples of medical physics are Ultrasound, Magnetic Resonance, Computed Tomography, Nuclear Medicine, X-rays, and Radiation Therapy.

(From the discovery and the medical use of the X-rays, the development of CT machine, MRI machine, PET machine, accelerators for radiotherapy).

Radiological physics involved with the one of radiation in diagnosis and treatment of disease.

Radiation protection also known as radiological protection, The protection of people from harmful effects of exposure to ionizing radiation, and the means for achieving this Exposure can be from a source of radiation external to the human body or due to internal irradiation caused by the ingestion of radioactive contamination.

1.2 Modeling.

To understanding a physical phenomenon we simplify it by selecting its main features by similar things. For example: the film by retina, the eye by camera. This kind of selection is called modeling it is not complete replacement. The flow of blood is represented by the flow of electricity. In medical field the heart rate (R) is a function of the power produced by the body (p) and can be modulated mathematically by the term function as:

$$R = f\,(p)$$

In medical field the term Feedback occurs when outputs of a system are routed back as inputs as part of a chain of cause-and-effect that forms a circuit or loop. The system can then be said to feed back into itself. There are two kind of it.

1. Negative feedback: the kind of increasing in one side and decreasing in another. For example when calcium in blood drops too low the body release some calcium from the bone to increase the level in the blood.
2. Positive feedback: can occur when the two changes in the same direction. Like growing in weight means increasing in cell numbers.

1.3 Measurement.

Measurement, the process of associating numbers with physical quantities and phenomena.

International system (SI) units or metric units; the basic units are: meter, Kilogram, second, ampere, Kelvin and candle. In medicine nonstandard units are used. For example: for blood pressure, millimeter of mercury instead of dynes per square centimeter. Measurements in the body involve the time can be dividing into two groups:

Repetitive measurements such as pulse, non-repetitive measurements such as removing foreign substance from the blood by the kidney.

1.4 Units.

Standardized quantity of a physical property, used as a factor to express occurring quantities of that property.

The **units of measurement** are the units that are used to represent physical quantities like length, mass, temperature, current, area, volume, intensity, etc.

Any other quantity of that kind can be expressed as a multiple of the unit of measurement.

The International System of Units (SI) is the modern form of the metric system and is the most widely used system of measurement, based on the International System of Quantities It comprises a coherent system of units of measurement built on seven base units. Which are the second, meter, kilogram, ampere, kelvin, mole, candela, and a set of twenty prefixes to the unit names and unit symbols that may be used when specifying multiples and fractions of the units.

Table 1: Basic SI units.

Base Quantity	Unit	Symbol
Length	meter	M
Mass	kilogram	Kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

Table 2: Standard prefix.

Standard prefixes for the SI units of measure

Multiples	Name		deca-	hecto-	kilo-	mega-	giga-	tera-	peta-	exa-	zetta-	yotta-
	Symbol		da	h	k	M	G	T	P	E	Z	Y
	Factor	10^0	10^1	10^2	10^3	10^6	10^9	10^{12}	10^{15}	10^{18}	10^{21}	10^{24}
Fractions	Name		deci-	centi-	milli-	micro-	nano-	pico-	femto-	atto-	zepto-	yocto-
	Symbol		d	c	m	μ	n	p	f	a	z	y
	Factor	10^0	10^{-1}	10^{-2}	10^{-3}	10^{-6}	10^{-9}	10^{-12}	10^{-15}	10^{-18}	10^{-21}	10^{-24}

Note: 10^{-6} kg is 1 µkg as 1 mg.

1.5 Physical quantities.

A property of a material or system that can be quantified by measurement. Can be expressed as the combination of a magnitude and a unit. For example, the physical quantity mass can be quantified as n kg where n is magnitude and kg is the unit.

Physical quantities are divided into two groups:

1. Base quantity: contains of length, mass, time, electrical current, temperature, quantity of matter & luminous intensity.
2. The quantity which derived from base quantity. Like force, energy, pressure.

The fundamental unites:

The kilogram: Base unit of mass in the metric system, formally the International System of Units (SI), having the unit symbol kg.

The Meter: base unit of length in the International System of Units. The SI unit symbol is m. The length of the path travelled by light in a vacuum in 1299,792,458 of a second.

The second: The second (abbreviation: sec) is the base unit of time in (SI), One second is the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of ground state of the Cs_{133} atom.

The Ampere: The base unit of electric current in SI. Having the unit symbol A.

Examples:

1. What is the mass of 4.54 gm in milligram & in kilograms?

   Solution: $1gm = 10^3$ milligrams

   $4.54\ gm = 4.54\times10^3 = 4540$ milligrams

   $1gm = 10^{-3}$ kilograms

   $4.54\ gm = 4.54\times10^{-3}$ kilograms = 0.00254 kilograms.

2. Express 1228 km/h in meter per second?

   Solution: 1 km = 1000 m = 10^3 m.

   1h = 60min, 1min=60 sec

   1h = 60×60 = 3600 sec.

$$1228\ km/h = 1228\times10^3\ \frac{m}{h} = 1228\times10^3\ \frac{m}{3600s} = 341.11\ m/s$$

3. What is the volume of 1.55 cm^3 in cubic millimeters and in cubic meters?

   Solution: 1cm= 10 mm

   $1cm^3 = 1cm\times 1cm\times1cm = 10mm\times 10mm\times 10mm = 1000mm^3$

   So: $1cm^3 = 10^3\ mm^3$

$$1.55\ cm^3 = 1.55\times10^3\ mm^3 = 1550\ mm^3$$

As the same 1cubic centimeters = 10^{-6} cubic meters

$$1.55\ cm^3 = 1.55 \times 10^{-6}\ m^3 = 0.00000155\ m^3$$

1.6 Mechanics & Motion of the body

In physics, a **force** is an influence that can cause an object to change its velocity, i.e., to accelerate, meaning a change in speed or direction, unless counterbalanced by other forces. *Magnitude and direction* of a force are both important, force is a vector quantity. The SI unit of force is the newton (N), and force is often represented by the symbol **F**.

Effects of Force

Whenever a Force is applied to any object, it tends to change its shape, size, speed, or direction. It changes the motion of an object. Motion is the movement of a body. Here are some of the effects that force has on its objects:

1. It changes the direction of an object.
2. It can make a body at rest move.
3. It can change the speed of an object by either increasing or decreasing it.
4. It can stop a moving object.
5. It can change the shape or size of an object.

Formula of force:

Force can be explained by the product of mass (m) and acceleration (a). The equation for the formula of Force can be expressed in the form given below:

$$F = ma$$ *Newton 2nd law*

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Abdullah A. Abdullah

Fundamental forces in nature.

There are four fundamental forces of nature, and they govern everything that happens in the universe. Modern physics attempts to explain every observed physical phenomenon by these fundamental interactions.

Four fundamental forces:

1. Gravity.
2. The weak force.
3. Electromagnetism.
4. The strong force.

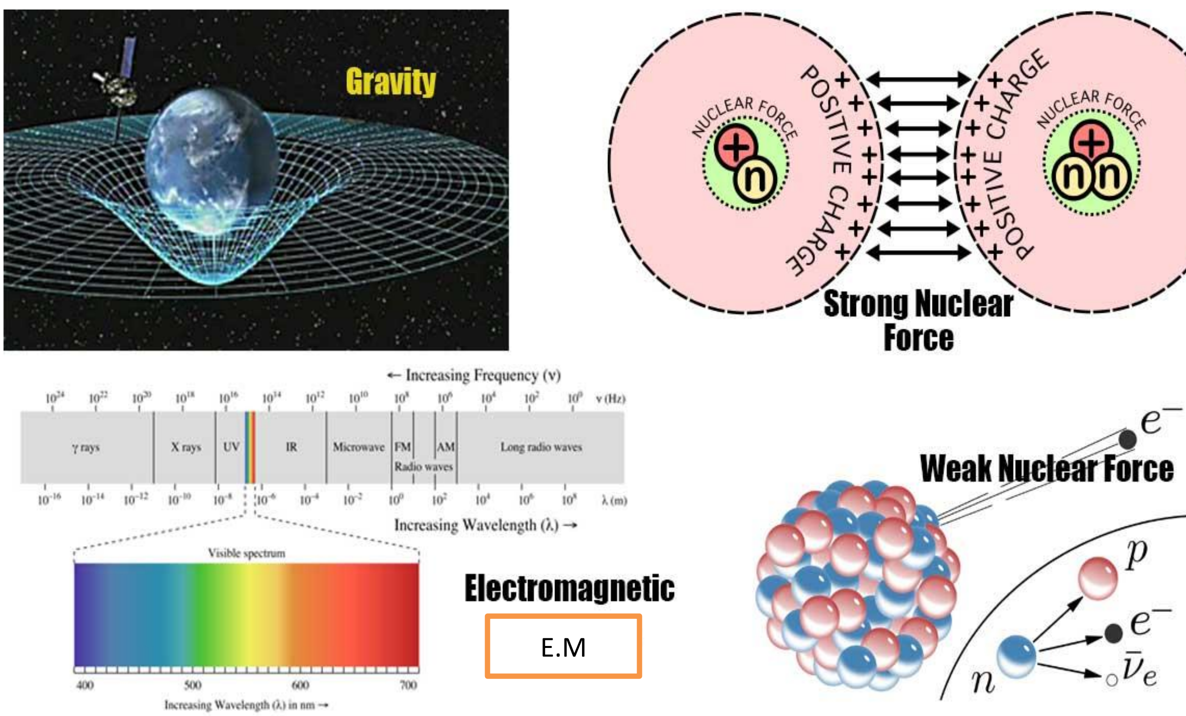

Fig.1: fundamental interactions.

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Abdullah A. Abdullah

Gravity:

A fundamental interaction which causes mutual attraction between all things that has mass.

Isaac Newton was the first to propose the idea of gravity, the force of attraction between two bodies is proportional to the product of their masses and inversely proportional to the square of the distance between them.

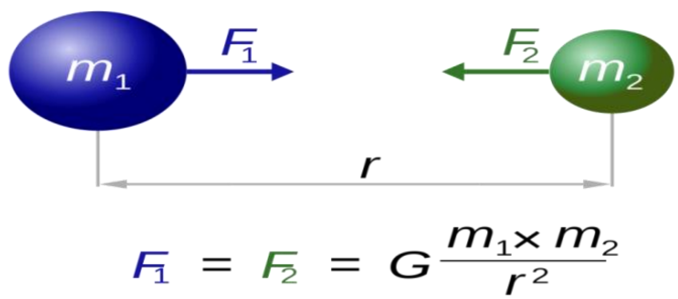

Fig 2: The gravitational force.

Where: F is the gravitational force between the bodies of masses m_1&m_2.

G is gravitational constant = $6.67430 \times 10^{-11}\ m^3 \cdot kg^{-1} \cdot s^{-2}$

Albert Einstein suggested, through his theory of general relativity, that gravity is not an attraction or a force. Instead, it's a consequence of objects bending space-time.

Weak force: also called the weak nuclear interaction is responsible for particle decay. This is the literal change of one type of subatomic particle into another. So, for example, a neutrino that strays close to a neutron can turn the neutron into a proton while the neutrino becomes an electron.

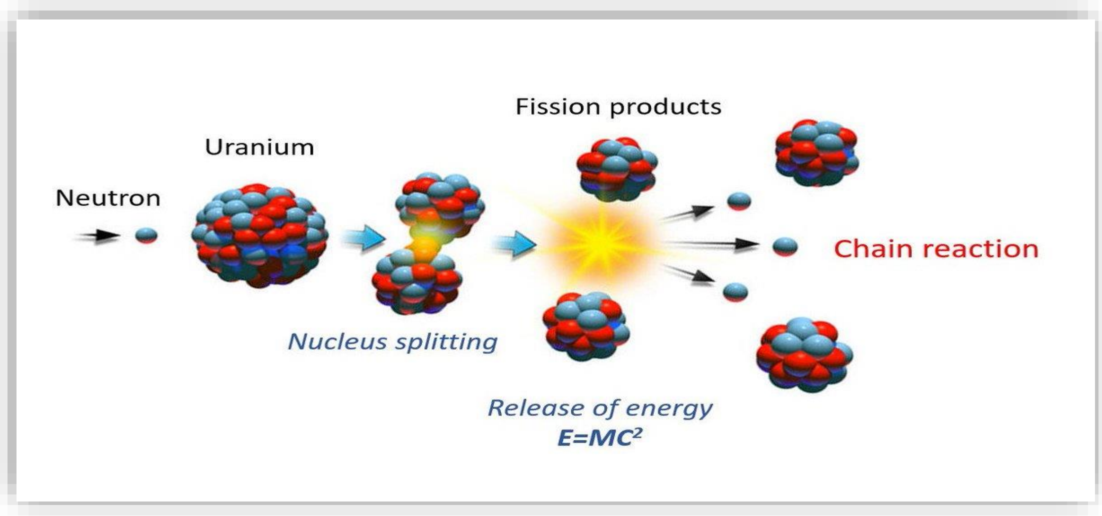

Fig 3: weak force.

Electromagnetic force: consists of two parts, the electric force and the magnetic force. We described these forces as separate from one another, but researchers later realized that the two are components of the same force.

Acts between charged particles, like negatively charged electrons and positively charged protons. Opposite charges attract one another, while like charges repel. The greater the charge, the greater the force. This force can be felt from an infinite distance.

The electric component acts between charged particles whether they're moving or stationary, creating a field by which the charges can influence each other. But once set into motion, those charged particles begin to display the second component, the magnetic force.
The particles create a magnetic field around them as they move. So when electrons zoom through a wire to charge your computer or phone or turn on your TV, for example, the wire becomes magnetic.

Coulomb's law: quantifies the amount of force between two stationary, electrically charged particles. The electric force between charged bodies at rest is conventionally called electrostatic force

$$F_e = K_e \frac{q_1 \, q_2}{r^2}$$

Where:

Fe is the force. Ke is the coulombs constant (8.9×10^9 $N.m^2.C^{-2}$). q_1&q_2 Signed magnitudes of the charges. r is the distance between the charges.

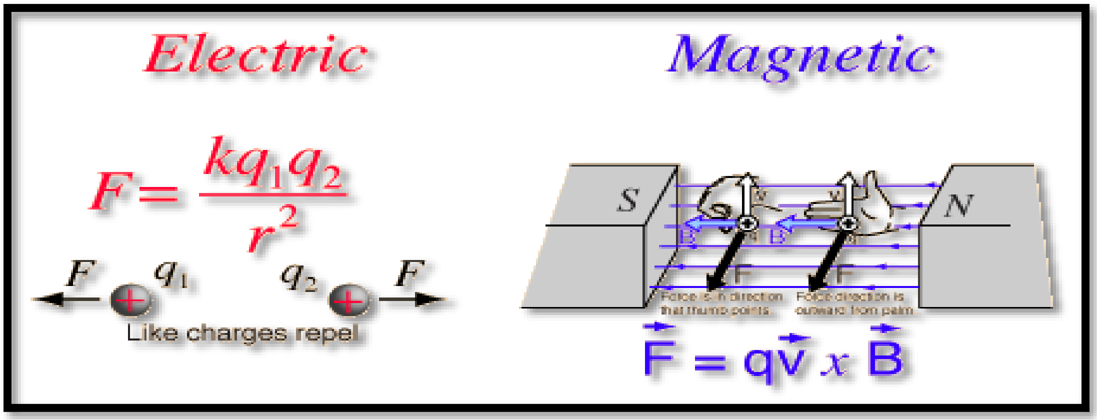

Fig 4: electrical force & magnetic force.

Strong nuclear force: is the strongest of the four fundamental forces of nature. And that's because it binds the fundamental particles of matter together to form larger particles. The force that holds protons and neutrons together. It also holds them all together in a nucleus and is responsible for the energy released in nuclear reactions.

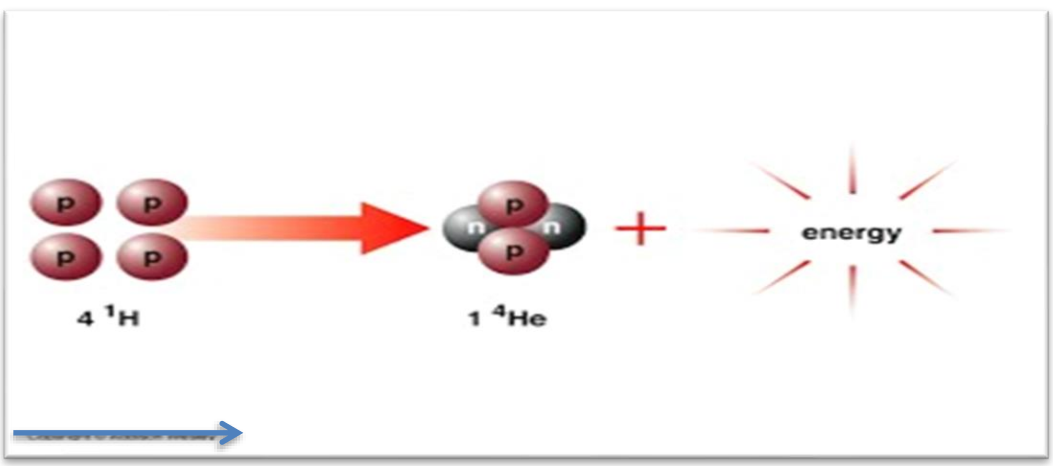

Fig 5: nuclear force.

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Abdullah A. Abdullah

Types of force.

There are a variety of types of forces. Types were placed into two broad category headings on the basis of whether the force resulted from the contact or non-contact of the two interacting objects.

Table 3: Types of forces.

Contact Forces	***Action-at- Distance Forces***
Frictional Force	Gravitational Force
Tensional Force	Electrical Force
Normal Force	Magnetic Force
Air Resistance Force	
Applied Force	
Spring Force	

1.7 Work, Mass and Energy.

Work: 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.

The work is calculated by multiplying the force by the amount of movement of an object. W = F. d

A force of 10 newton's, that moves an object 3 meters, does 30 n-m of work. A newton-meter is the same thing as a joule, so the units for work are the same as those for energy – joule.

1 joule = (1 newton) (1meter) = 1 n. m

Work done = force × distance moved in the direction of the force.

$$W= \Delta E = F\times d$$

W= work done (j).ΔE= energy transferred (j).F= force (N).d=distance in direction of force.

If the force F acts in angle with the direction of movement then the component of that force in the direction of displacement will acts:

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Abdullah A. Abdullah

W= f. d cos θ

Example 1: A force of 50 N acts on the block at the angle 30 degree. The block moves a horizontal distance of 3.0 m. How much work is done by the applied force?

Answer:

$W = F \times d \times \cos(\theta)$.

$W = (50\ N) \times (3\ m) \times \cos(30\ degrees) = 129.9$ Joules

Example2: Apply the work equation to determine the amount of work done by the applied force in each of the three situations described below.

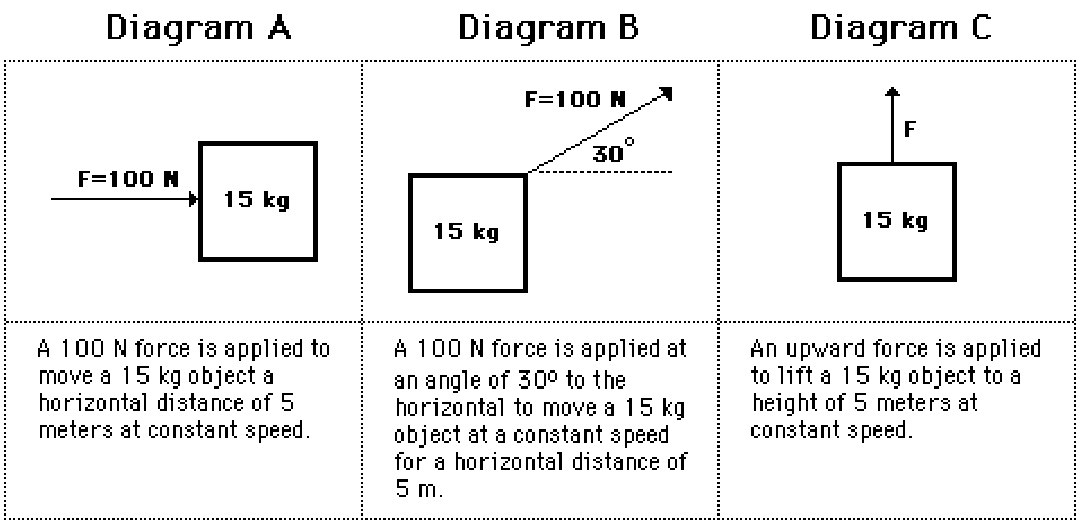

Diagram A Answer:

$W = (100\ N) \times (5\ m) \times \cos(0\ degrees) = 500\ J$

The force and the displacement are given in the problem statement. The force and the displacement are both rightward. Since F &d are in the same direction, the angle is 0 degrees.

Diagram B Answer:

$W = (100\ N) \times (5\ m) \times \cos(30\ degrees) = 433\ J$

The force and the displacement are given in the problem statement. It is said that the displacement is rightward. It is shown that the force is 30 degrees above the horizontal. Thus, the angle between F and d is 30 degrees.

Diagram C Answer:

$W = (147\ N) \times (5\ m) \times \cos(0\ degrees) = 735\ J$

The displacement is given in the problem statement. The applied force must be 147 N since the 15-kg mass (F_{grav} =147 N) is lifted at constant speed. Since F & d are in the same direction, the angle is 0 degrees.

Mass and weight:

Mass (m) of an object is a measure of the object's inertial property, or the amount of matter it contains.

$$F = ma \qquad a \text{ is acceleration.}$$

Weight (w) of an object is a measure of the force exerted on the object by gravity, or the force needed to support it.

$$W = mg \qquad g = 9.8 m/s^2 \text{ gravitational acceleration}$$

The difference between *mass & weight* is that mass is the amount of matter in a material, while weight is a measure of the force of gravity acts upon that mass.

Newton's laws of motion are three laws that describe the relationship between the motion of an object and the forces acting on it. These laws, which provide the basis for Newtonian mechanics, can be paraphrased as follows:

1. A body remains at rest, or in motion at a constant speed in a straight line, unless acted upon by a force.
2. The net force on a body is equal to the body's acceleration multiplied by its mass or, equivalently, the rate at which the body's momentum changes with time.
3. If two bodies exert forces on each other, these forces have the same magnitude but opposite directions.

1.7 Motion.
In physics, change with time of the position or orientation of a body. Motion along a line or a curve is called translation. Motion that changes the orientation of a body is called rotation.

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In both cases all points in the body have the same velocity (directed speed) and the same acceleration (time rate of change of velocity). The most general kind of motion combines both translation and rotation.

1) Straight line (linear motion).
The equation of a straight line is usually written this way: **y = mx + b**
where:

m is the slope or gradient of the line. $m = \frac{\Delta y}{\Delta x} = \frac{y2-y1}{x2-x1}$

b is the y-intercept of the line.
x is the independent variable of the function *y* = *f*(*x*).
y is dependent variable.

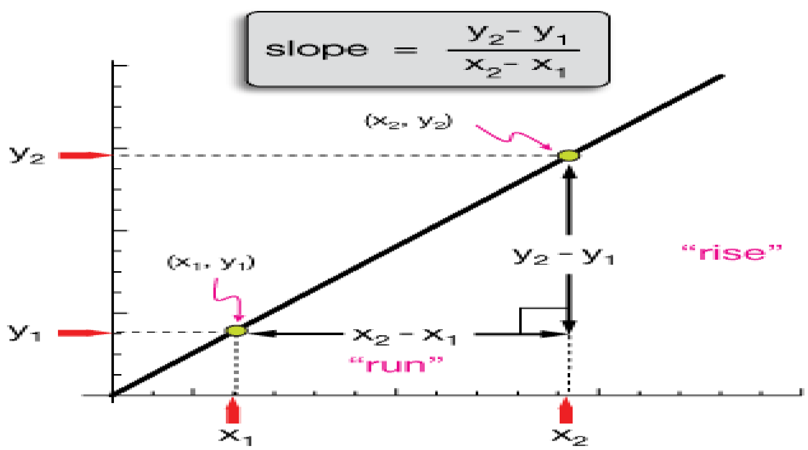

Fig 6: the slope of straight line.

a- Displacing time and average velocity.

Displacement is the vector difference between the ending and starting positions of an object.
Velocity is the rate at which displacement changes with time. It is a vector.

The average velocity over some interval is the total displacement during that interval, divided by the time.

$$V_{av} = \frac{displacement}{change\ in\ time} = \frac{\Delta d}{\Delta t}$$

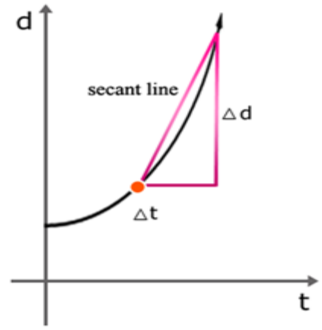

Fig7: the average velocity

b- Instantaneous velocity.

The velocity of an object in motion at a specific point in time. Or specific point along the path. We use the velocity at very short time intervals:

$$V = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$$

Note: Instantaneous velocity cannot be negative

c- Average velocity & average speed.

Average velocity = $v_{avg} = \frac{displacement}{time} = \frac{\Delta x}{\Delta t}$

Average speed = $\frac{total\ distance}{time} = \frac{D}{\Delta t}$

Example 3: A car travels distance of 70 km in 2 hours. What is the average speed?

Solution: average speed = $\frac{total\ distance}{time} = \frac{70km}{2hrs}$ = 35 km/hr.

Example 4: A boy walks 10 km east in 2 hours & then 2.5 km west in 1 hour. Calculate the total average velocity of the body?

Solution: V = $\frac{10-2.5}{2+1} = \frac{7.5}{3}$ = 2.5 km/hr.

Note: velocity with direction, but speed without direction.

d- Average acceleration.
The change of velocity by time interval during changes.

$$a = \frac{\Delta v}{\Delta t} = \frac{v2 - v1}{t2 - t1}$$

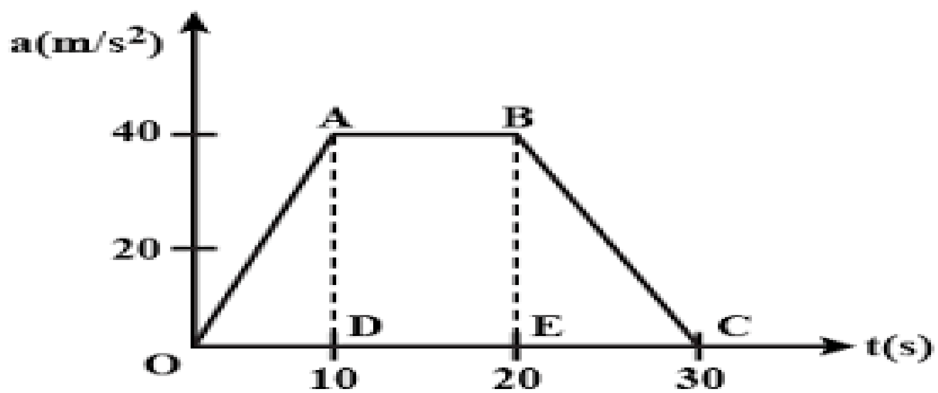

Fig 8: Time acceleration graph.

2) Nonlinear motion.

a- Pendulum

A pendulum is a weight suspended from a pivot so that it can swing freely. When a pendulum is displaced sideways from its resting, equilibrium position, it is subject to a restoring force due to gravity that will accelerate it back toward the equilibrium position. When released, the restoring force acting on the pendulum's mass causes it to oscillate about the equilibrium position, swinging back and forth. This is Called simple harmonic motion.

The **period (T)** is the time for one complete cycle, a left swing and a right swing. The period depends on the length of the pendulum and also to a slight degree on the amplitude, the width of the pendulum's swing.
The **frequency (F)** is the number of times the pendulum swings back and forth per second.
Frequency and period are inversely related that is, $T = 1/f$. if the angle of displacement is small, the period is given by:

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$$T = \frac{1}{f} = 2\pi\sqrt{\frac{l}{g}}$$

Where g is the gravitation acceleration and l is the length of the pendulum arm.

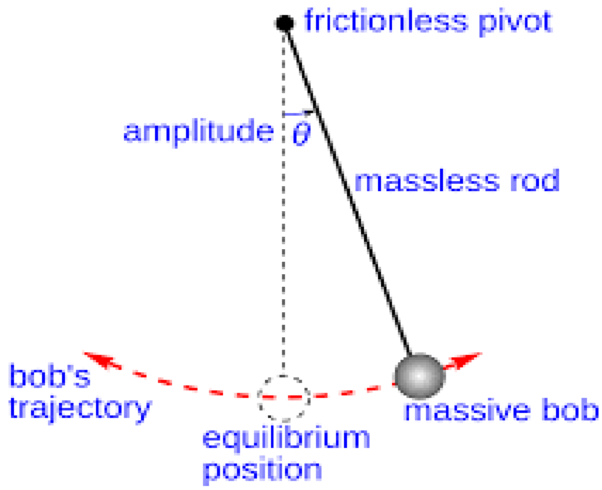

Fig 9: simple pendulum.

b - Centrifuge:

Is a laboratory device that is used for the separation of fluids, gas or liquid, based on density. Separation is achieved by spinning a vessel containing material at high speed; the centrifugal force pushes heavier materials to the outside of the vessel.

The centrifuge works using the sedimentation principle, where the centrifugal acceleration causes denser substances and particles to move outward in the radial direction. At the same time, objects that are less dense are displaced and move to the center. In a laboratory centrifuge that uses sample tubes, the radial acceleration causes denser particles to settle to the bottom of the tube, while low-density substances rise to the top.

Fig 10: Show blood centrifugal machine.

Stokes law: The force that retards a sphere moving through a viscous fluid is directly proportional to the velocity of the sphere, the radius of the sphere, and the viscosity of the fluid.

The force of viscosity on a small sphere moving through a viscous fluid is given by:

$$F_d = 6 \pi a \eta v$$

Where:
F_d is the frictional force – known as **Stokes' drag** – acting on the interface between the fluid and the particle.
η is the viscosity .
a is the radius of the spherical object
v is the flow velocity relative to the object.

In SI units: F_d is given in newton's . **η** in Pa· s, ***a*** in meters, and ***v*** in m/s.

When the particle moving at constant speed, the retarding force (F_d) is in equilibrium with the difference between the download gravitational force and upward buoyant force.

Examples.

Ex1: find the gravitational force between two mass of 0.01 kg and 0.5kg, if the distance between center- to- center is 0.05m?

Solution: $F = G \frac{m1 \times m2}{r^2} = 6.67 \times 10^{-11} \frac{(0.01)\times(0.5)}{(0.05)^2} = 1.3 \times 10^{-10}$ N

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Ex 2: A worker applies a constant horizontal force with magnitude 40 N to a box with mass 20 kg resting on level floor with negligible fraction. What is the acceleration of the box?

Solution: $\sum F.s = F = 40N$

$$F = m\,a \longrightarrow a = \frac{\sum F.s}{m} = \frac{40N}{20kg} = 2\ \frac{kg.m/s^2}{kg} = 2m/s^2$$

Ex 3: What the weight of mass of 1kg & 3 kg respectively?

Solution: W = mg

For 1 kg $1.0\ kg \times 9.8\ m/s^2 = 9.8\ N$

For 3 kg $3.0\ kg \times 9.8\ m/s^2 = 29.4\ N$

Ex 4: a car of 2.49×10^4 N weight traveling in x-direction makes fast stop, the x-direction of the net force acting its 1.83×10^4 N. What is bits acceleration?

Solution: $W = mg \longrightarrow m = w/g$

$$m = \frac{2.49 \times 10^4}{9.8} = 2540\ kg.$$ Car mass.

$$F = ma \longrightarrow a = F/m$$

$$a = \frac{1.83 \times 10^4}{2540} = 7.2\ m/s^2$$

Ex 5: a 40 kg person walking at 1m/s bumps into a wall and stops in distance of 2.5 cm in about 0.05 sec. What is the force developed on impact?

Solution: $F = \frac{\Delta(mv)}{\Delta t}$

$$F = \frac{40}{0.05} = 800\ Kg.\ m/\ s^2 = 800\ N$$ where: (1 N = 1 Kg. m/ s^2)

Ex 6:

a) A person walking at 1 m/sec hits his head on a steal beam and stops in 0.5 cm after 0.01 sec. if the mass of the head is 4 kg. What is the force developed?

Solution: $F = \frac{\Delta(mv)}{\Delta t}$

$F = \frac{4}{0.01} = 400$ Kg. m/ s^2 = 400 N where: (1 N = 1 Kg. m/ s^2)

b) If the steel beam has 2 cm of padding and Δt is increased to 0.04 sec, what is the force developed?

Solution: $F = \frac{\Delta(mv)}{\Delta t}$

$F = \frac{4}{0.04} = 100$ Kg. m/ s^2 = 100 N

Must read &Solve Examples

1.8 Concept of thermodynamics:

Thermodynamics is the study of the relations between heat, work, temperature, and energy. The laws of thermodynamics describe how the energy in a system changes and whether the system can perform useful work on its surroundings.

What is a system boundary and surrounding?

In thermodynamics, a 'system' is a specific amount of matter or a region in space chosen for study. The 'surroundings' are everything external to the system. The 'boundary' real or imaginary wall separates the system from its surroundings, and can be fixed or movable. The system and the surroundings together make up the Universe.

System + Surroundings = Universe

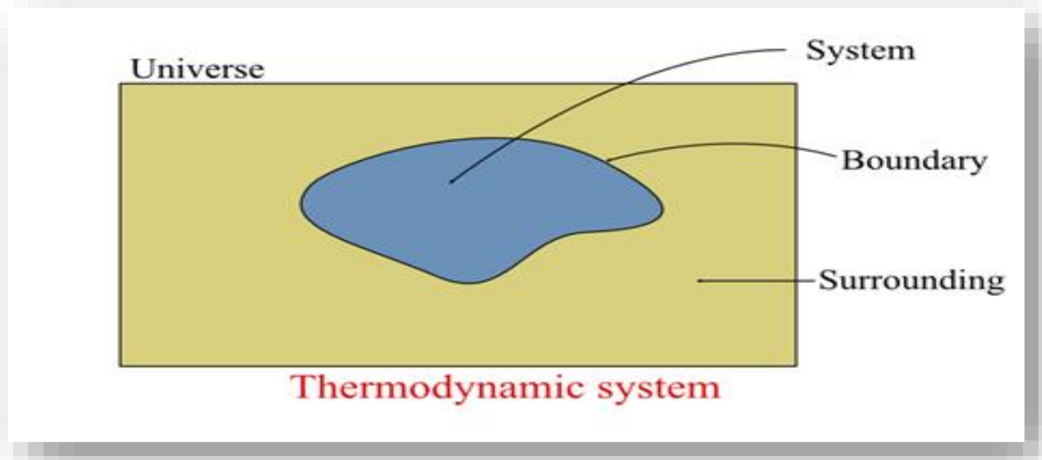

Fig 11: Thermodynamic system & classification.

Thermodynamic systems are classified as:

Open System

If the thermodynamic system has the capacity to exchange both matter and energy with its surroundings, it is said to be an open system.

A steam turbine, a pool filled with water, where the water can enter or leave the pool.

Closed System

A system which has the ability to exchange only energy with its surroundings and cannot exchange matter is known as a closed system.

A cylinder in which the valve is closed is an example of a closed system. When the cylinder is heated or cooled, it does not lose its mass.

Isolated System

A system which cannot exchange matter or energy with the surroundings is known as an isolated system. The zeroth law of thermodynamics states that thermodynamic processes do not affect the total energy of the system.

Reactants are present in a thermos flask or an insulated vessel, where neither energy nor matter is exchanged with the environment.

In the table and figure below, you can see which system allows energy and which doesn't:

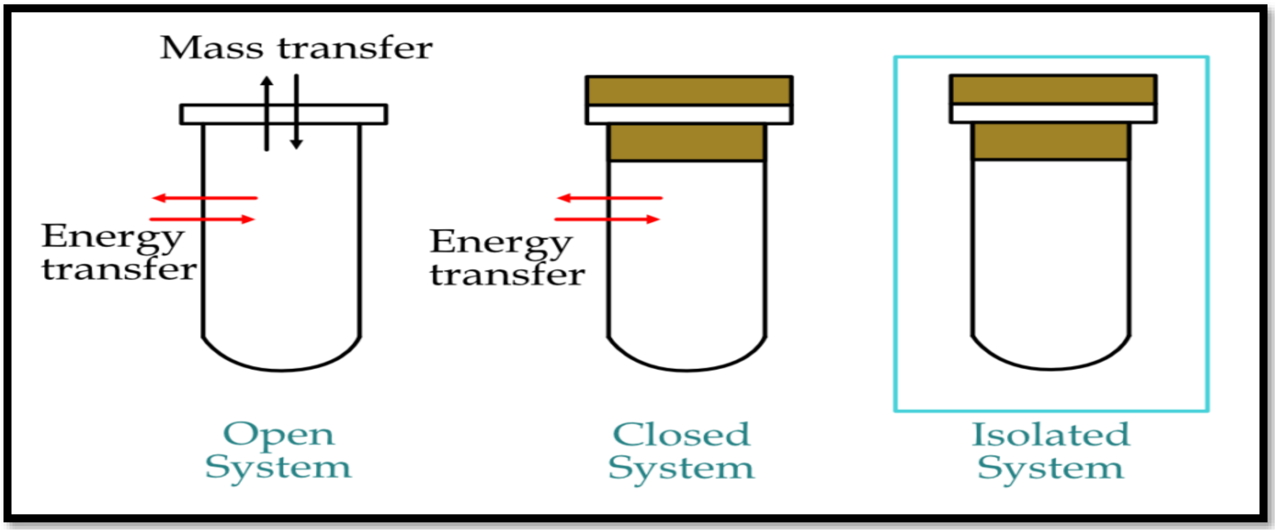

Fig 12: Types of thermodynamic systems.

Type of system	Matter	Energy
Open system	Yes	Yes
Closed system	No	Yes
Isolated system	No	No

Table 4: Type of System with matter & energy.

State zeroth law of thermodynamics.

The Zeroth law of thermodynamics states that "if two thermodynamic systems are in thermal equilibrium with a third system separately, then they are in thermal equilibrium with each other.

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In other words, we can say that if system A is in thermal equilibrium with system B and system B is also in thermal equilibrium with system C, then system A and system C are also in thermal equilibrium.

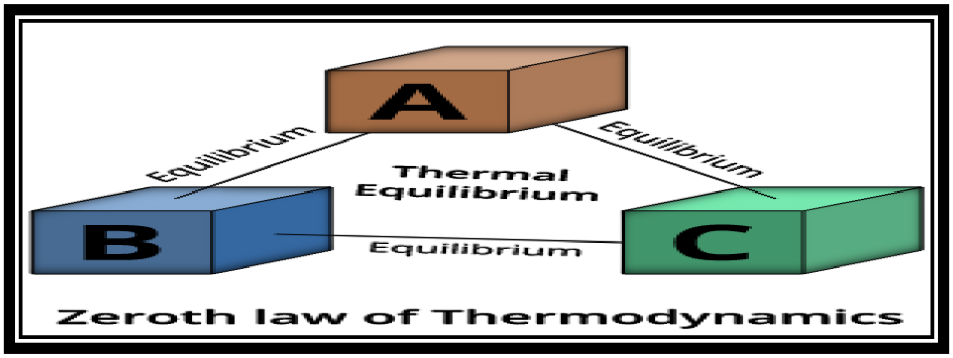

Fig 13: The zeroth law.

Energy: In physics, energy is the quantitative property that must be transferred to an object in order to perform work on, or to heat, the object. Energy is a conserved quantity. It is the capacity to do work or the ability to cause change.

Conservation of energy principle: In physics, the law of conservation of energy states that the total energy of an isolated system cannot change—it is said to be conserved over time. Energy can be neither created nor destroyed, but can change form.

The first law of thermodynamics is the application of the conservation of energy principle to heat and thermodynamic processes:

The first law of thermodynamics for a closed system or fixed mass was expressed $\Delta E = Q – W$

The first law of thermodynamics defines the internal energy (E) as equal to the difference of the heat transfer (Q) into a system and the work (W) done by the system.

$E_2 - E_1 = Q – W$………….. (1)

Q = net heat transfer across system boundaries ($=\Sigma Q_{in} – \Sigma Q_{out}$).

W = net work done in all forms ($=\Sigma W_{out} – \Sigma W_{in}$).

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ΔE = net change in total energy.

The total energy E of a system is considered to consist of 3 parts:

$\Delta E_{tot} = \Delta U + \Delta E_{kin} + \Delta E_{pot}$ ………… (2)

Substitute Eq 2 in Eq 1. We get:

$Q - W = \Delta U + \Delta E_{kin} + \Delta E_{pot}$ ………… (3)

Where:

ΔU= change in internal energy = $m (u_2 - u_1)$.

ΔE_{kin}= change in kinetic energy = $\frac{1}{2} m (v_2^2 - v_1^2)$.

ΔE_{pot} = change in potential energy=$mg (z_2 - z_1)$.

In SI base units: joule = J = $kg\ m^2\ s^{-2}$

Limitations of first law of thermodynamics**:**

1. This law permits the flow of heat from hot body to cold body & vice versa. But in reality, the heat flows from hot body to cold body only. Thus, this law does not indicate the direction of heat flow.
2. It does not tell us the quantum of energy which will change from one form to another form.

The Second law of thermodynamics states that any spontaneously occurring process will process will always lead to an escalation in the entropy of the universe.

The law explains that the entropy in an isolated system always increases. An isolated system's entropy will never decrease over time. Any isolated system spontaneously evolves towards thermal equilibrium - the state of maximum entropy of the system. Thus, the second law of thermodynamics is also known as the law of Increased Entropy.

Note:

In some cases where the system is in thermodynamics equilibrium or going through a reversible process, the total entropy of a system and its surrounding remains constant.

The entropy of the universe is increasing continuously. The entropy becomes zero on zero kelvins.

Mathematically, 2nd law of thermodynamics is represented as:

$\Delta S_{universe} > 0$ $\Delta S_{universe}$ the change in the entropy of the universe.

The third law of thermodynamics states that the entropy of a perfect crystal at a temperature of zero Kelvin (absolute zero) is equal to zero.

At a temperature of zero Kelvin, the following phenomena can be observed in a closed system-

1. The system does not contain any heat.
2. All the atoms and molecules in the system are at their lowest energy points.

There are four types of thermodynamic process :

Adiabatic Process -A process where no heat transfer into or out of the system occurs.

Isochoric Process - A process where no change in volume occurs.

Isobaric Process - A process where no change in pressure occurs.

Isothermal Process - A process where no change in temperature occurs.

Thermodynamic Properties:

1. **Intensive Property -** Intensive properties are properties that do not depend on the quantity of matter. Pressure and temperature are intensive properties.

2. **Extensive property -** Extensive properties are properties that depend on the size or quantity of matter. Volume, Energy and Enthalpy are extensive properties.

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Note:

Enthalpy is the measurement of energy in a thermodynamic system.

Mathematically, Enthalpy = Internal energy + Pressure × Volume

$$H = U + PV$$

Entropy is a thermodynamic quantity whose value depends on the physical state or condition of a system. It is a thermodynamic function used to measure the randomness or disorder.

Mathematically, Entropy = Heat / Temperature

$$S = Q / T$$

Unit of Enthalpy	**Joule**
Unit of Entropy	**Joule / Kelvin**

Thermodynamic Equilibrium:

1. **Thermal Equilibrium -** When the temperature is same throughout the entire system, the system is considered to be in Thermal Equilibrium.
2. **Mechanical Equilibrium -** When there is no change in pressure at any point of the system, the system is considered to be in Mechanical Equilibrium.
3. **Chemical Equilibrium -** When the chemical composition of a system does not vary with time, the system is considered to be in Chemical Equilibrium.
4. **Phase Equilibrium -** When the mass of each phase reaches an equilibrium level in a two-phase system, the system is considered to be in Phase Equilibrium.

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Thermal Equilibrium	Temperature does not change with time
Mechanical Equilibrium	Pressure does not change with time
Chemical Equilibrium	Molecular structure does not change with time
Phase Equilibrium	Mass of each phase is unchanging with time

Power: the rate of doing work or of transferring heat. The amount of energy transferred or converted per unit time. It is a scalar quantity.

$$P = \frac{w}{t} = \frac{\Delta E}{t}$$

P=Power (watt).W= Work done (J). ΔE=Energy transferred (J).t=Time (s).

In SI base units: power is the joule per second (J/s), known as the watt (W).

The expression for power is work/time. 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.

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

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

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

Note:

This new equation for power reveals that a powerful machine is both strong (big force) and fast (big velocity). A powerful car engine is strong and fast.

Use your understanding of work and power to answer the following questions.

1. Two physics students, Ali and Ahmed, are in the weightlifting room. Ali lifts the 100-pound barbell over his head 10 times in one minute; Ahmed lifts the 100-pound barbell over his head 10 times in 10 seconds. Which student does the most work? Which student delivers the most power? Explain your answers.

Answer:

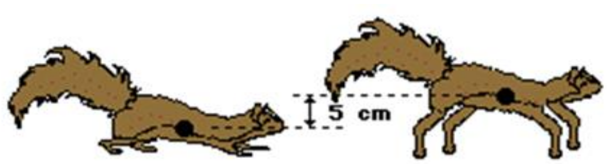
Ahmed and Ali do the same amount of work. They apply the same force to lift the same barbell the same distance above their heads. Yet, Ahmed is the most "power-full" since he does the same work in less time. *Power and time are inversely proportional.*

2. During a physics lab, Jack and Jill ran up a hill. Jack is twice as massive as Jill; yet Jill ascends the same distance in half the time. Who did the most work? Who delivered the most power? Explain your answers.

Answer:

Jack does more work than Jill. Jack must apply twice the force to lift his twice-as-massive body up the same flight of stairs. Yet, Jill is just as "power-full" as Jack. Jill does one-half the work yet does it one-half the time. The reduction in work done is compensated for by the reduction in time.

3. A tired squirrel (mass of approximately 1 kg) does push-ups by applying a force to elevate its center-of-mass by 5 cm in order to do a mere 0.50 Joule of work. If the tired squirrel does all this work in 2 seconds, then determine its power.



Answer:

The tired squirrel does 0.50 Joule of work in 2.0 seconds. The power rating of this squirrel is found by:

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P = W / t = (0.50 J) / (2.0 s) = 0.25 Watts

4. When doing a *chin-up*, a physics student lifts her 42.0-kg body a distance of 0.25 meters in 2 seconds. What is the power delivered by the student's biceps?

Answer:

To raise her body upward at a constant speed, the student must apply a force which is equal to her weight (mass* acceleration). F=W= m*g $g = 9.8\ m/s^2$

The work done to lift her body is:

W = F * d = (411.6 N) * (0.250 m) = 102.9 J

The Power is the work/time ratio which is:

(102.9 J) / (2 seconds) = 51.5 Watts (rounded)

5. Your household's monthly electric bill is often expressed in kilowatt-hours. One **kilowatt-hour** is the amount of energy delivered by the flow of l kilowatt of electricity for one hour. Use conversion factors to show how many joules of energy you get when you buy 1 kilowatt-hour of electricity.

Answer:

Using conversion factors, it can be shown that 1 kilo-watt*hour is equivalent to **3.6 x 10^6 Joules**. First, convert 1 kW-hr to 1000 Watt-hours. Then convert 1000 Watt-hours to 3.6 x 10^6 Watt-seconds. Since a Watt-second is equivalent to a Joule, you have found your answer.

6. An escalator is used to move 20 passengers every minute from the first floor of a department store to the second. The second floor is located 5.20 meters above the first floor. The average passenger's mass is 54.9 kg. Determine the power requirement of the escalator in order to move this number of passengers in this amount of time.

Answer:

A good strategy would involve determining the work required to elevate one average passenger. Then multiply this value by 20 to determine the total work for

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elevating 20 passengers. Finally, the power can be determined by dividing this total work value by the time required to do the work. The solution goes as follows:

$W_{1\ passenger} = F \cdot d \cdot \cos(0\ deg)$

$W_{1\ passenger} = (54.9\ kg \cdot 9.8\ m/s^2) \cdot 5.20\ m = 2798\ J$ (rounded)

$W_{20\ passengers} = 55954\ J$ (rounded)

$P = W_{20\ passengers} / time = (55954\ J) / (60\ s)$

$P = 933\ W$

Read &Solve Examples

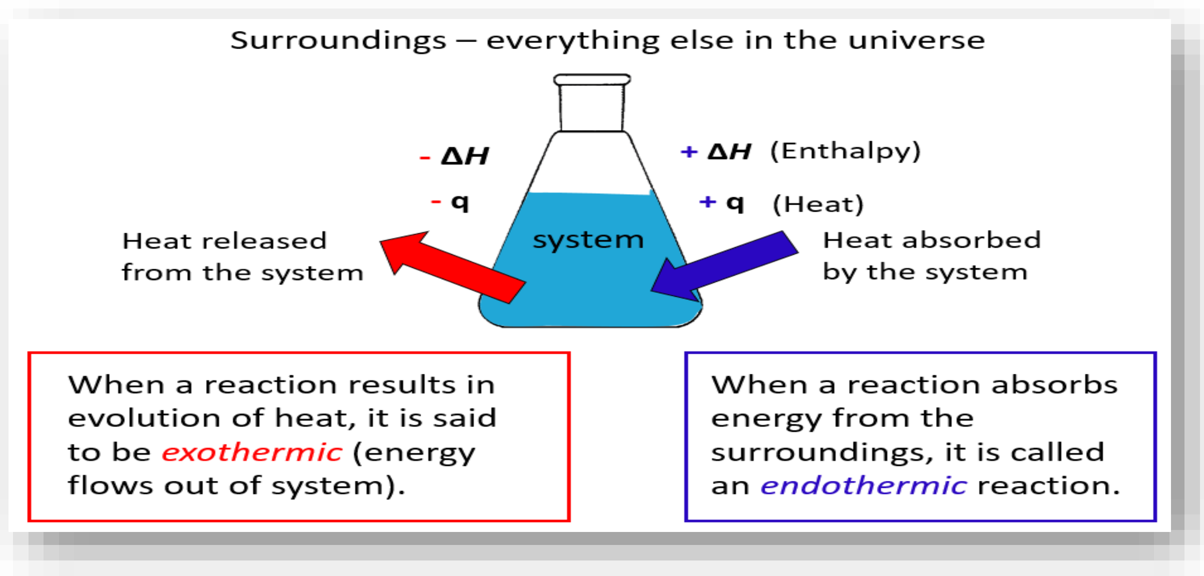

Fig 14: The effects of Exo & endo thermic.

Note:

We see so many changes happening around us every day, such as boiling water, rusting of iron, melting ice, burning of paper, etc. In all these processes, we observe that the system in consideration goes from an initial state to a final state

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where some amount of heat is absorbed from the surroundings and some amount of work W is done by the system on the surrounding.

In thermodynamics, a reversible process is a process, involving a system and its surroundings, whose direction can be reversed by infinitesimal changes in some properties of the surroundings, such as pressure or temperature.

An irreversible process is one in which the system and its environment cannot return together to exactly the states that they were in.

The irreversibility of any natural process results from the second law of thermodynamics.

The reversible process is the ideal process which never occurs, while the irreversible process is the natural process that is commonly found in nature.

A process can be reversible only when its satisfying two conditions

- Dissipative force must be absent.
- The process should occur in infinite small time.

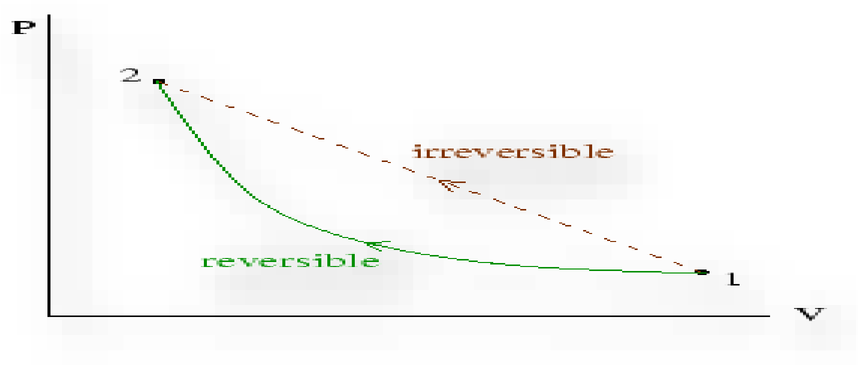

Fig 15 : reversible & irreversible process.

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