

Physical basic of heat and cold temperature :

Heat and cold have been used for medical purposes for several thousand years . if we want to describe temperature as a physical phenomenon, however, we should try to understand it on a molecular scale .

- ✓ Matter is composed of molecules that are in motion .
- ✓ Molecules motion means that they have kinetic energy .
- ✓ Kinetic energy (K.E) is related with temperature (T) .
- ✓ $K.E \uparrow \Leftrightarrow T \uparrow$ i.e.: In order to increase the temperature of gas it is necessary to increase the average kinetic energy of its molecules. this can be done by putting the gas in contact with a flame .

○ *Heat :*

The energy transferred from the flame to the (gas) molecules causing the temp. rise is called heat .

- Solid +heat \Rightarrow liquid .
- Liquid +heat \Rightarrow gas .
- Gas + heat \Rightarrow ions .

Thermometry and temperature scales

Temperature is difficult to measure directly, so we usually measure it indirectly by measuring one of many physical properties that change with temperature by a suitable calibration .

- All scales are based on easily states, such as, the freezing and boiling points of water (ice point , steam point) .

Ice point : a mixture of ice and water which is in equilibrium with air , saturated with vapor at 1 atmospheric pressure .

Steam point : are based on liquid water vapor (with no air) in equilibrium at 1 atmospheric pressure .

The temperature scales used in **SI** and English system are : (where **SI** is international system)

1- Celsius scales (also called the centigrade scale), which is in common use throughout most of the world : the ice and steam points are values of $(0 - 100^{\circ}\text{C})$ respectively .

** Normal body temperature (37°C) .

2- Fahrenheit scale : the ice and steam points are the values of $(32 - 212^{\circ}\text{F})$ respectively .

** Normal body temperature (98.6°F) .

3- Absolute temperature scale: the ice and steam points are the values of $(273.15 - 373.15\text{ K})$ respectively .

A- normal body temperature (310 K) . we notice that in figure 1

B-The lowest temperature is the absolute zero (0 K) is $(- 273.15^{\circ}\text{C})$.

- The temperature unite on this scale is the **Kelvin** (K) without the degree symbol.
- In English system, the absolute temperature scale is called the **Rankin** scale .

NOTICE : *this scale used for scientific work but it is not used in medicine .*

- **The relationships between different temperature scales are :**

The **Kelvin** scale is relative to the **Celsius** scale by :

$$T_{(K)} = T_{(^{\circ}\text{C})} + 273.15$$

The **Fahrenheit** scale is relative to the **Celsius** scale by :

$$T_{(^{\circ}\text{C})} = \frac{5}{9} (T_{(^{\circ}\text{F})} - 32)$$

Rankin scale is relative to the **Fahrenheit** scale by :

$$T_{(R)} = T_{(^{\circ}F)} + 459.67$$

The temperature scales in two unite system are relatively :

$$T_{(R)} = 1.8T_{(K)}$$

And $T_{(^{\circ}F)} = 1.8T_{(^{\circ}C)} + 32$

Q1/ In a hot room, a person skin temperature is about $(35^{\circ}C)$, find his skin temperature on the kelvin and Fahrenheit scales ?

Sol/ from $T_{(K)} = T_{(^{\circ}C)} + 273.15$

$$T_{(K)} = 35 + 273.15 = 308.15^{\circ}K$$

$$T_{(^{\circ}F)} = 1.8T_{(^{\circ}C)} + 32 \Rightarrow T_{(^{\circ}F)} = 1.8 \times 35 + 32 = 95^{\circ}F$$

Q2/ A pan of water is heated from $(30^{\circ}C)$ to the boiling point. What is the change in its temperature on the Kelvin and Fahrenheit scales ?

SOL/ $T_{(K)} = T_{(^{\circ}C)} + 273.15 = 30 + 273.15 = 303.15$

$$T_{(^{\circ}F)} = 1.8T_{(^{\circ}C)} + 32 = 1.8 \times 30 + 32 = 86$$

$$\therefore T_{(K)} = T_{(^{\circ}C)} + 273.15 = 100 \text{ boiling} + 273.15 = 373.15$$

$$\therefore T_{(^{\circ}F)} = 1.8T_{(^{\circ}C)} + 32 = 1.8 \times 100 \text{ boiling} + 32 = 212$$

$$\therefore \Delta^{\circ}C = 100 - 30 = 70^{\circ}$$

$$\Delta^{\circ}K = 373.15 - 303.15 = 70^{\circ}$$

$$\Delta^{\circ}F = 212 - 86 = 126^{\circ}F$$

We can see this degree on thermometer in figure 1

Q/ Calculate the normal body temperature on Kelvin, Celsius, and Fahrenheit scales ?

Q/ It is difficult to measure body temperature with the house thermometer. why ?

Ans/

- a- It is difficult to place the house thermometer under the tongue .
- b- The house thermometer would give a low reading because the temperature will fall when the thermometer was removed from the mouth .

Q / What is expansion value (the volume) for liquid (mercury) in a thermometer ? explain.

Ans/ The expansion of the liquid in a thermometer is not (1cm^3) of mercury increases in volume by only (1.8%) in going from ($0-100^\circ\text{C}$).

in order to show this expansion, thermometers are designed so that the mercury is forced to rise from the bulb in a capillary tub with a very small diameter. the smaller the diameter of the capillary, the greater is the sensitivity of the thermometer, a fever thermometer, which needs to show fractions of degrees, requires a capillary so small-less than 0.1 mm in diameter- that it would be very difficult to read if it were not designed for visibility .

The ways to measure the body Temperature :

1- Glass fever thermometer :

- * Contain mercury or alcohol .

Principle :

The change in temperature ($\Delta T \propto \Delta V$) change in volume it uses mercury because :

- a. The volume expansion (ΔV) with (ΔT) is very small ($1\text{cm}^3\text{Hg}$) increase volume by (1.8%) when the temperature changes from ($0\text{ to }100^\circ\text{C}$) .
- b. It's clear color.

- c. It has low adhesion force with the wall of glass .

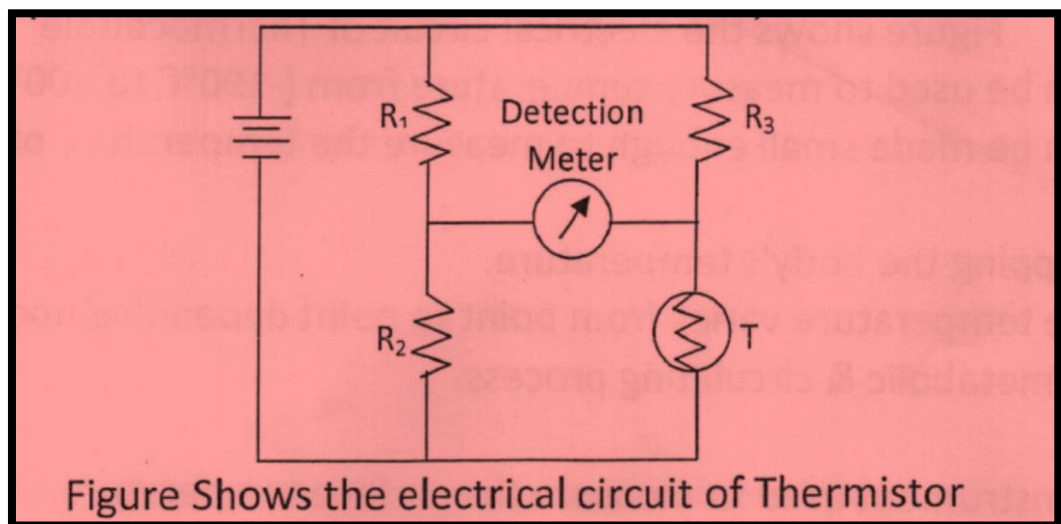
Q/ Two things increase the visibility of the thermometer .

- A. The glass acts as a magnifying glass .
- B. Use an opaque white backing .

2- **Thermistor:** is a special resistor that changes its resistance rapidly with temperature ($\approx 5\% / ^\circ C$) .

Principle :

- The change in temperature ($\Delta T \propto \Delta R$) change in the electrical resistance .



- The resistance of thermistor (T) can be measure with a simple bridge circuit to determine the temperature .
- The meter (M) can be calibrated directly in degrees Celsius or Fahrenheit .

Method :

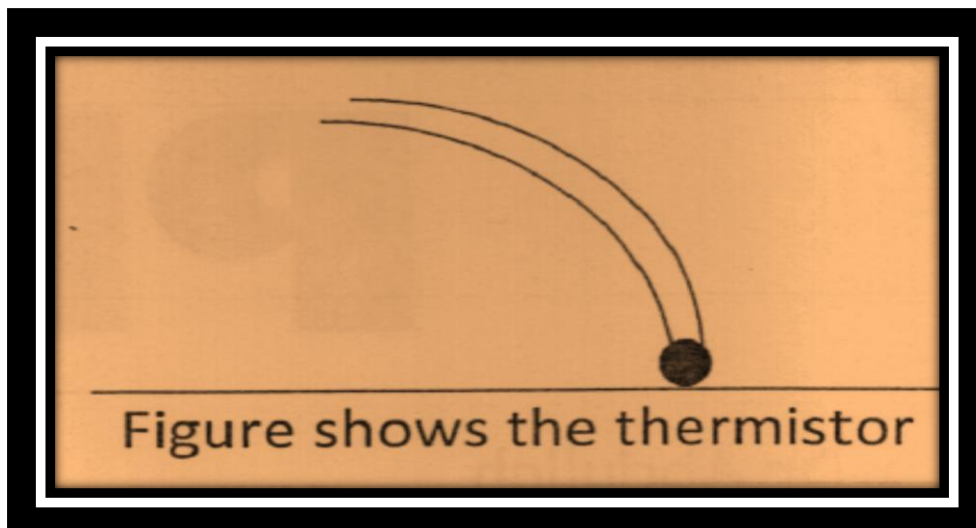
When the bridge is balanced (R_1, R_2, R_3, R_4 and M) are equal. the meter (M) reading zero .

When the temperature is changed, it results unbalanced bridge voltage the meter .

- The meter reading can be Fahrenheit or Celsius .

Q / Thermistor is used in medicine because (Advantages) :

- 1- Good sensitivity .
- 2- Can measure temperature changes of (0.01°C).
- 3- Small size .
- 4- Rapidly response to change in temperature .



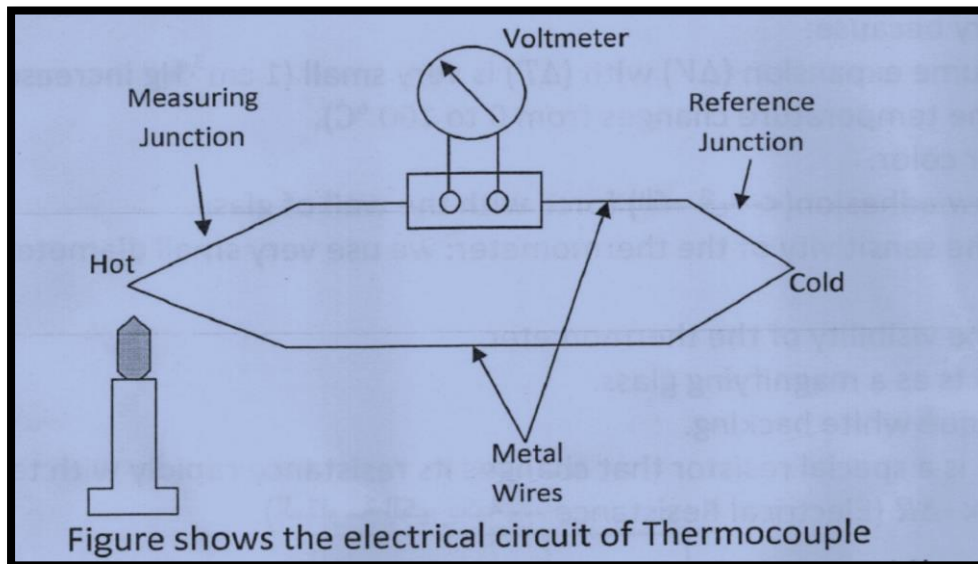
Medical application :

Thermistor (pneumograph): is placed in the nose to monitor the breathing rate of the patient by showing the temperature rate between the inspired cold air and the expired warm air .

3- Thermocouple :

Consist of two junctions of two different metals . if the two junctions are in different temperatures, a voltage is produced that depends on the temperature difference .

Principle : voltage (e.m.f) $\propto \Delta T$.



Thermocouple can be used to measure temperatures from $(-190^{\circ}\text{C to } 300^{\circ}\text{C})$.

Thermocouple can be made small enough to measure the temperature of individual cells (because it has very sharp end). The metals of thermocouple must be with quite difference of atomic numbers .

Thermograph : (راسم حراري)

- mapping the body's temperature .
- The body's surface temperature varies from point to point depending upon:
 - a. external physical factors .
 - b. internal metabolic .
 - c. circulatory process near the skin .
- Blood flow near the skin is the dominate factor .

Thermogram: (يأخذ صورة حرارية للجسم)

- ❖ an instrument the safest and simple routine method used to measure the surface temperature of the body .

Principle : the thermogram is used to measure radiation emitted from the body .

- ❖ At body temperature (37°C) the emitted radiation is in infrared (IR) region at wave length much longer than those observable by the human eye .
- ❖ The surface temperature above a tumor was typically about (1°C) higher than nearby normal tissue, therefore a very sensitive temperature measurement device had to be used (thermistor) .
- ❖ Most breasts cancers could have an elevated skin temperature in the region of the cancer .
- ❖ All object regardless of their temperature emit radiation .
- ❖ Thermogram can detect small tumor (less than 1 cm^2 in diameter) in breast cancer.

Stefan – Boltzmann law :

- The basic equation describing the radiation emitted by a body is :

$$W = e\sigma T^4$$

W :the total radiation power per surface area (A), watt/ cm^2

T : absolute temperature ($^{\circ}\text{C} + 273$)

e :emissivity=1 (for radiation emitted from the body) .

σ : Stephan Boltzmann constant $= 5.7 \times 10^{-12} \text{ W/cm}^2 \cdot \text{K}^4$

e.g : breast cancer

e.g/ A- what is the power radiated per cm^2 from skin at temperature of 33°C ?

$$W = e\sigma T^4$$

$$T = 33 + 273 = 306\text{ K}$$

$$W = 1 \times 5.7 \times 10^{-12} \times (306)^4 = 0.05\text{ W/cm}^2$$

B. what is the power radiated from a nude body ($1.75 \times 10^4\text{ cm}^2$) in area ?

$$W = \frac{P}{A}, \quad P = W \times A$$

$$P = 0.057\text{ W/cm}^2 \times 1.75 \times 10^4\text{ cm}^2 = 875\text{ W}$$

C. if the radioactive power received from the surrounding walls (background) = 735 watt, what is the net power ?

$$875 - 735 = 140\text{ watt}$$

Note: the commercial instrument used in clinical thermography can measure the temperature differences of $\Delta T = 0.2^\circ\text{C}$ and record a thermogram in 2 second.

To get a good thermogram :

- Before thermograph :
 - a. Clothes must be removed because clothing affects skin temperature .
 - b. It's necessary to keep the temperature of the thermograph room at 20°C and cool uniformity to enhance the temperature difference and contrast thermograph image .

Breast cancer detection :

for breast cancer detection the steps that must be followed are :

1. **Palpation** (smooth touching), but it is **difficult** to detect **a small tumor (less than 1cm diameter)**.
2. **Thermography** to detect the **elevated temperature area** but the results have been **disappointing** because of high **false positive** (an abnormal thermogram for a subject without cancer) and **false negative** (a normal thermogram for a cancer patient), due to **different blood flow** patterns in the two breasts (in fig) .
3. **Mammography** (low voltage X –ray),it is **successful** and much more reliable than thermography for detection of breast cancer **(80% and over)**, but it presents a **radiation hazard** to the body .
4. **Biopsy**, it gives information only about the material excised, but some cancer tissue near the excised region can be missed .
5. **Histo – pathology** .
 - This advantage the thermogram give false positive result due to different blood flow pattern in the two breast .

Mammography (X–ray) is more accurate than thermograph in detection of breast cancer .

Q:/ compare between mammography and thermograph

<i>Mammography</i>	<i>Thermogram</i>
It can detect 80% of breast cancer (more accurate)	Less accurate. It gives false positive result due to different blood flow pattern
Infusive less safety because it's ionizing radiation	non infusive (more safety) because of it's infrared (non ionizing).

medical application of thermograph :

1. Detect breast cancer .
2. Detect other type of cancer .
3. Study blood circulation in head .
4. Study blood supply in diabetic leg .

Heat therapy:

Q/ Heat has two therapeutic effects :

1. **Increase in metabolism resulting in a relaxation of the capillary system** (vasodilation) .
2. **Increase in blood flow as blood moves** into cool the heated area .

Q / physical Methods of producing heat in the body:

1. **Conductive heat**: is based on the physical fact that **if two objects at different temperature are placed in contact, heat will transfer by conduction from the warmer object to the cooler one**, i.e.(hot water or hot materials can be placed in contact with the treated area (superficial area). **The total heat transferred will depend upon :**
 - a. The area of contact .
 - b. The temperature difference .
 - c. The time of contact (duration) .
 - d. The conductivity of materials .

Heat conduction by: **hot bath, hot pack, electric heating pad, hot paraffin, etc.**

Q/Conductive heating is used in treating conditions such as :

1. arthritis 2. neuritis 3. Sprains 4. Strains 5. Contusions

2. **Infrared (IR) radiation heat** : is also for surface heating of body .

It is the same form of heat we **feel from the sun** or from an open flame.

- The IR wave lengths used are **between 800-40,000 nm**, ($1\text{nm}=10^{-9}$).
- The waves penetrate the skin about **3mm** and increase the surface temp.
- Excessive exposure causes **reddening**(erythema) and sometimes **swelling** (edema).
- This type of heating is used to treat the same condition of conductive heating, but it is considered to be more effective because the heat penetrates deeper .

3. **Radio wave heating (diathermy)** :

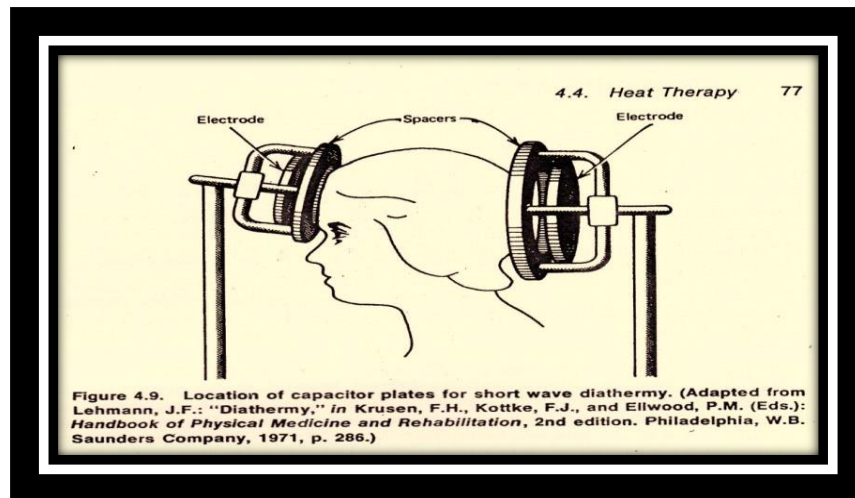
A- *Short wave diathermy* :

- ✓ Utilized electromagnetic waves in the radio rang (wave length~10m).
- ✓ It heats the deep tissues of the body .
- ✓ Heat from diathermy penetrates deeper in to the body than radiant and conductive heat .
- ✓ It has been used in **relieving muscle spasms, pain from protruded intervertebral discs, degenerative joint disease, and bursitis.**
- ✓ Two different methods are used for transferring the electromagnetic energy in to the body :

1. *The first method:*

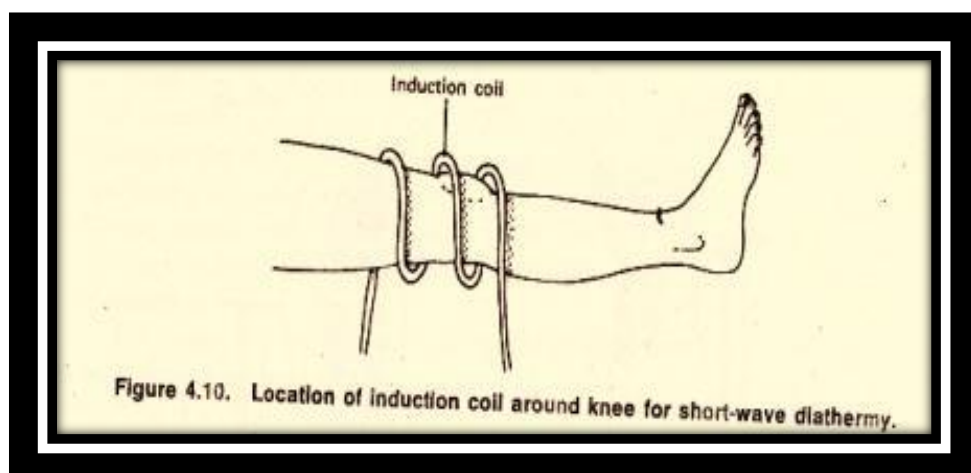
- ❖ The part of the body to be treated is placed between two metal plate-like electrodes energized by the high-frequency voltage (see the fig.) .
- ❖ The body tissue between the plates acts like an electrolytic solution.

- ❖ The charged particles are attracted to one plate and then the other depending upon the sign of the alternating voltage on the plates .



2. *The second method :*

- ❖ It is a magnetic induction (see the blow fig.) .
- ❖ In induction diathermy, either a coil is placed around the body region to treated or a (pancake) coil is placed near that part of the body.
- ❖ The alternating current in the coil results in an alternating magnetic field in the tissues .



B-Micro waves diathermy:

- ❖ It is another form of electromagnetic energy .
- ❖ It is easier to apply than short-wave diathermy .
- ❖ The frequency closer to 900 MHz is effective in therapy, causing uniform heating around body regions .

- ❖ It is used in the treatment of fractures, sprains and strains, bursitis, injuries to tendons .

4. Ultrasonic waves heating:

- US waves used for deep heating .
 - US waves are completely different from the electromagnetic waves (E.M.W) diathermy .
 - They produce mechanical motion like audible sound waves except the frequency is much higher (~1MHz) .
 - US waves vibrate tissues producing heating .
 - Ultrasonic heating has been useful in relieving the tightness and scarring that often occur in joint disease, aids joints that have limited motion .
-
- It is useful for deposition heat in bones because they absorb ultrasound energy more effectively than does soft tissue .

Pressure

Typical pressure in human body :

Typical pressure in human body	Typical pressure (mm Hg)
<ul style="list-style-type: none"> ▪ <u>Arterial blood pressure</u> Maximum (systole) Minimum(diastole) 	100 – 140 60 – 90
<ul style="list-style-type: none"> ▪ Venous blood pressure 	3 -7
<ul style="list-style-type: none"> ▪ Great veins 	< 1
<ul style="list-style-type: none"> ▪ Capillary blood pressure 	30
<ul style="list-style-type: none"> ▪ Middle ear pressure 	< 1
<ul style="list-style-type: none"> ▪ Eye pressure (aqueous humor) Gastrointestinal pressure 	20 10-20
<ul style="list-style-type: none"> ▪ Intrathoracic pressure (between lung and chest wall) 	-10

Biofluids mechanics :

In this chapter we will discuss the concept of pressure as it relates to fluids in the body .

Pressure: is defined as the force per the quantity force per unit area referred to as stress .

There are many units which the pressure measured with them .

✓ In SI units:

$$1\text{N/m}^2=1\text{Pascal (Pa)}$$

$$1\text{atm (atmosphere)}=1.03*10^5 \text{ Pa}=760\text{mmHg}=1033\text{cmH}_2\text{O}$$

$$1\text{Pas}=0.987*10^{-5}\text{atm}=0.0075\text{mmHg}=0.0102\text{cmH}_2\text{O}$$

The pressure "P" under a column of liquid can be calculated from :

$$P = \rho gh$$

Where ρ : is the density of liquid .

g : is the gravitational acceleration .

h : is the height of column .

- The density of mercury is about (13600kg/m^3) or (13.6gm/cm^3) .
- The density of water is (1000kg/m^3) or (1gm/cm^3) .
- A column of water has to be (13.6) times higher than column of mercury in order to produce the same pressure .
- The density of whole blood is a bit higher (1.06gm/cm^3) at (37°C).

There are two types of pressure :

1. **Absolute pressure** : is the pressure of the fluid inside the container plus (+) the atmospheric pressure for example, the pressure inside the tire of the bicycle is $(4.13 \times 10^{-5} \text{ N/m}^2)$, so the absolute pressure is $(4.13 \times 10^{-5} + 1.01 \times 10^{-5} \text{ N/m}^2) = 5.14 \times 10^{-5} \text{ N/m}^2$.
2. **Gauge pressure** : is the absolute pressure minus (-) atmospheric pressure .

Note/All the pressures used in this chapter are gauge pressures .

Negative pressure :

There are a number of places in the body where the pressures are lower than atmospheric or negative ,.. for example, when we breathe in (inspire) the pressure in lungs must be somewhat lower than atmospheric pressure or the air would not flow in .

The lung pressure during inspiration is typically a few centimeters of water negative .

When a person drinks through a straw the pressure in his mouth must be negative by amount equal to the height of his mouth above the level of the liquid he is drinking .

EX/Calculate the pressure in millimeters of mercury equal to a pressure of 20 cmH₂O ?

Sol/ $760 \text{ mmHg} \rightarrow 1033 \text{ cmH}_2\text{O}$

$X \rightarrow 20 \text{ cmH}_2\text{O}$

Then the pressure (X)=14.7 mmHg

Or $1.36 \text{ cmH}_2\text{O} \rightarrow 1 \text{ mmHg}$

$20 \text{ cmH}_2\text{O} \rightarrow X$

Then the pressure (X) = 14.7 mmHg

Q/ prove that :

$$P = \rho gh$$

$$\begin{aligned} P &= \frac{F}{A} \\ \text{Sol / } \rho &= \frac{M}{V} \end{aligned}$$

$$P = \frac{F}{A} = \frac{Mg}{A} = \frac{\rho Vg}{A}$$

$$\text{but } \Rightarrow V = Ah$$

$$\therefore P = \frac{\rho Ahg}{A} = \rho gh$$

Ex/ suppose you are a deep-sea preparing for a dive to (30m), what absolute pressure and gauge pressure will you experience ?

Solu/ all 1 atm = 10.33m(H₂O)

$$X = 30\text{m}$$

$$X = 3 \text{ atm (gauge pressure)}$$

$$\text{Absolute pressure} = 3 + 1 = 4 \text{ atm}$$

Ex/ calculate atmospheric pressure in day was the height of mercury is (76cm) ?

$$\text{Solu/ } \rho gh = 13.6 \text{ gm} \cdot \text{sec}^{-3} \cdot 980 \text{ cm} \cdot \text{sec}^{-2} \cdot 76 \text{ cm}$$

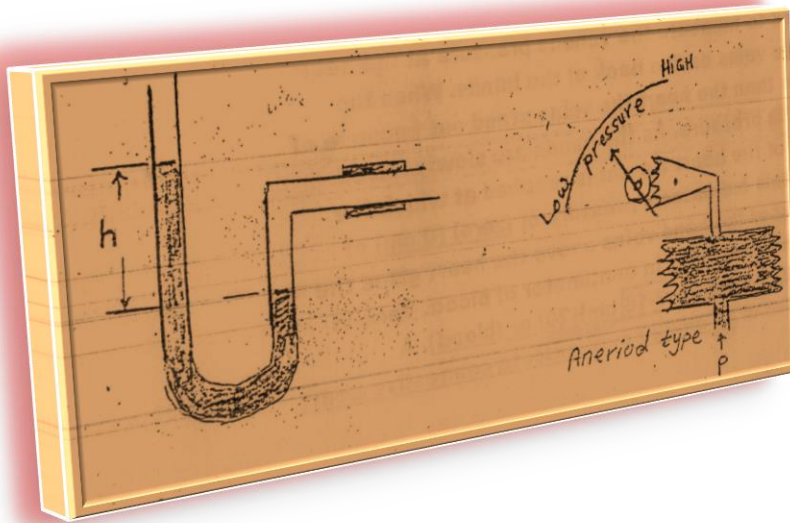
$$= 1.01 \cdot 10^6 \text{ dyne/cm}^2 = 1.013 \cdot 10^5 \text{ N/m}^2$$

Measurement of pressure in the body :

1. Manometer :

- It is a U –tube .
- Containing fluid (Hg, or H₂O) .

- Connected to the pressure to be measured .
- Can measure both positive and negative pressure .



2. **Sphygmomanometer**

- It's the most common clinical instrument used in measuring blood pressure .
- The types of sphygmomanometer are :
 - A. Mercury manometer : the pressure is indicated by the height of column of mercury inside glass tube .
 - B. Aneroid type : the pressure changes the shape of a sealed flexible container which causes a needle to move on a dial .
 - C. Electronic system: contains a digital screen .

Some parts of the body can be act like crude pressure indicators .

Example :

1. **Ear**: is very sensitive to pressure .

A person going up or down in an elevator or an airplane is often aware of the change in atmospheric pressure on the ears .

2. **Veins**: as a hand is raised slightly above the level of the heart these veins become smaller due to the lower venous blood pressure .

Method :

A simple method to measure the venous pressure at the heart is to observe the veins on the back of the hands . when the hands are lower than the heart the veins stand out because of increased venous pressure. As the hands are slowly raised above the level of the heart a point is reached at which the veins collapse :this indicates a pressure of (zero) (0 cm) of blood . the height of the hand veins above the heart gives the venous pressure at the heart in centimeter of blood . venous pressure normally averages (8-16cmH₂O) or(blood).a pressure in excess of 16cmH₂O may indicate congestive heart failure .

Pressure inside the skull:

The brain contains approximately 150 ml (cm³) of cerebrospinal fluid (CSF) a series of interconnected openings called ventricles. one of the ventricles,(the aqueduct), is especially narrow .

If at (birth) this opening (aqueduct) is blocked for any reason, the (CSF) trapped inside the skull and measure the internal pressure .

The increased pressure causes the skull to enlarge. this condition called hydrocephalus (water-head). Hydrocephalus occurs in infants .

To measure hydrocephalus .

1. Crude method

- Measure the circumference of the skull just above the ear .
- The normal values for newborn =32-37 cm .
- Larger value than (32-37cm) may indicate hydrocephalus.

2. Transillumination

- Use of the light scattering properties of the rather clear CSF inside the skull .

3. Ultrasound

Eye- pressure

The clear-fluids (water) in the eyeball that transmit the light to the retina in eyeball (called aqueous humor) maintains the internal pressure of eye .

The pressure in normal eyes range (12-23mmHg) .

The eye continuously produces aqueous humor and a drain system allows the surpluses to escape. If a partial blockage of this drain system occurs, the pressure increases and the increased pressure can restrict the blood supply to the retina and thus affect the vision, this condition, called glaucoma .

Eye –pressure measurements .

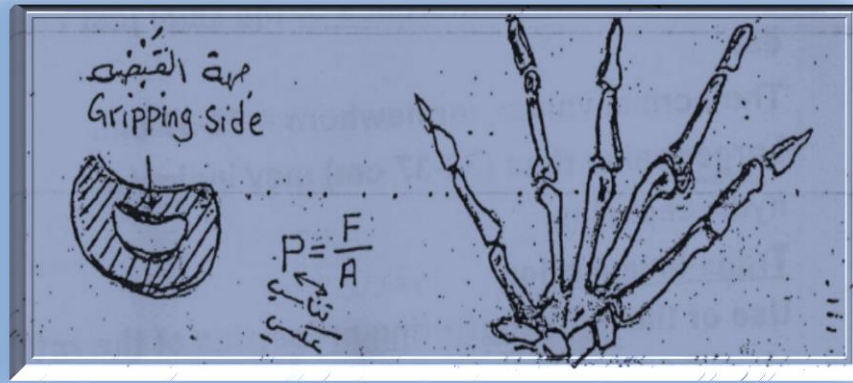
1. By feel

- ✓ Estimated the pressure inside the eye by (feel) as they passed on the eye with their fingertips .
- ✓ **Tonometer .**

Is An instrument used to measure the eye pressure in arbitrary units rather than in mmHg .

Pressure in the skeleton

- ✚ The highest pressure in the body is found in the weight-bearing bone joints .
- ✚ When walking, the pressure is reduced as the area increased to reduce pressure :
 - A. Bone joint lubrication (the higher the pressure, the better the lubrication).
 - B. The finger bones are flat rather than cylindrical on the gripping side ; the force is spread over a large surface : this reduces the pressure in the tissues over the bones .

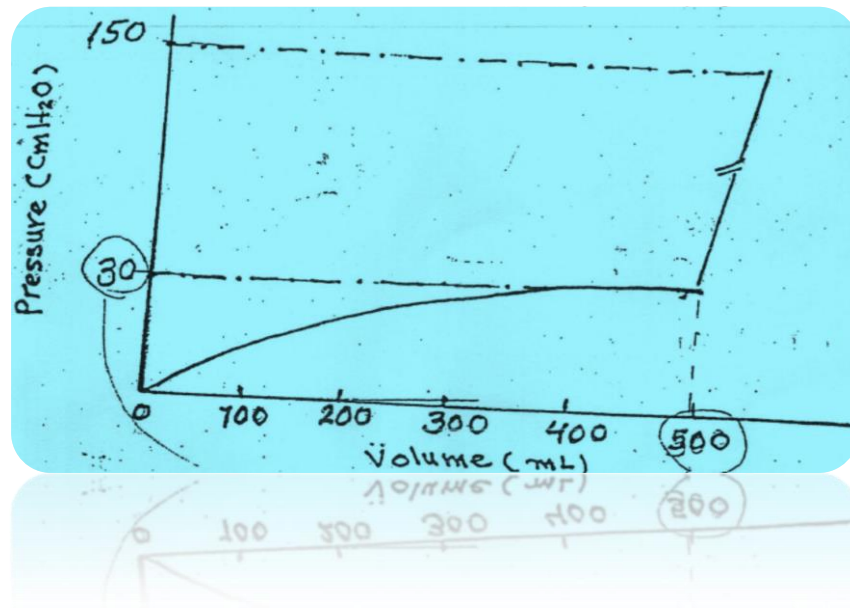


Pressure in the urinary bladder

1. Internal pressure in the bladder is due to accumulation of urine .
2. The typical (**P-V**)relationship in the urinary shows in fig .
3. When the bladder is filled with urine, the volume of the bladder $= \frac{3}{4}\pi R^3$ is increase . (this mean : for a given increase in (R) the volume increase as (R^3) while the pressure ($P = F/A = F/\pi R^2$) only increases as (R^2) .
4. For adult, the maximum volume in bladder before voiding=500ml, at pressure=30 cmH_2O .

When the micturation reflex occurs, the resulting sizable muscular contraction in the bladder wall produces a momentary pressure of up to 150 cmH_2O . see fig .

5. Normally voiding pressure =20-40 cmH_2O .
6. For men who suffer from prostates obstruction of the urinary passage it may be over 100 cmH_2O .
7. The bladder pressure increases during : (a). coughing, (b). straining, (c). sitting, (d). during pregnancy. (e). stress situation.



Bladder pressure measurement :

- a. indirect method (catheter)
- b . direct method (cystometer)

Direct Cystometry: The pressure is measured by a needle inserted through the wall of the abdomen into the bladder. this technique gives information of the function of the exit values that cannot be obtained with the catheter technique .

pressure effect while diving

Boyles law: for a fixed (mixture) quantity of gas at a fixed temperature the product of the absolute pressure and volume is constant .

$$\text{PRESSURE} * \text{VOLUME} = \text{Constant}$$

$$P \times V = C$$

Note :this means , if the absolute pressure is doubled, the volume is decreased to half . $\left(P \propto \frac{1}{V}\right)$

Eg/ What volume of air at an atmospheric pressure of $1 \times 10^5 \text{ N/M}^2$ needed to fill a 14.2 liter tank to pressure of $1.45 \times 10^7 \text{ N/M}^2$

Solution :

$$P_1 V_1 = P_2 V_2$$

$$(1 \times 10^5)(V_1) = (1.45 \times 10^7)(14.2)$$

$$V_1 = 2 \times 10^3 \text{ LITER}$$

E.g/ **middle ear is an air cavity** .

- (for comfort ,pressure in middle ear = pressure outside)
- When diving , it's very difficult to get equalization and feel pressure in ears .
- If the pressure across the eardrum =120 mmHg , that will cause the eardrum to rupture .

Henry`s law :

States : the amount of gas that will dissolve in a liquid is proportional to the partial pressure of the gas in contact with the liquid .

E.g/ - **At sea level** :

The air contain 20% O_2 and 80% N_2

The partial pressure of Oxygen is $(P_{O_2}) = \left(\frac{20}{100} \times 760\right) = 150 \text{ mmHg}$

The partial pressure of Nitrogen is $(P_{N_2}) = \left(\frac{80}{100} \times 760\right) = 610 \text{ mmHg}$

- **Under water (30M depth)**:

The pressure in the lung at any depth in water is too much greater that (which is denoted by) the pressure in the lungs **at sea level** .

This means: that the air in the lungs is dense under water and that the partial pressures of (O_2) and (N_2) are higher than 150 and 610 mmHg at sea level, this will result :

1. The higher pressure oxygen causes more (O_2) molecules to be transferred (dissolved) into the blood, and the (O_2) poisoning results if partial pressure of oxygen gets too high .
2. O_2 poisoning occurs when (P_{O_2})=0.8 atm, and this occurs at depth about 30M.
3. According to the Henry's law, excess in N_2 dissolved in blood and tissue, this can produce 2 problems :
 - A - Nitrogen necrosis (intoxication effect)
 - B - bends (decompression)

hyperbaric oxygen therapy (hot):

In some medical application, it's useful to increase the percentage of O_2 , in order to provide more O_2 to the tissue . it's used hyper-oxygen chamber .

- medical application :

1. Gas gangrene : is a disease due to bacteria (bacillus) it cannot be survived in presence of O_2 , patient treatment with hot and without the need for amputation .
2. Carbon monoxide poisoning :
 - the presence of a few (CO) on red blood cells (**RBCs**) greatly reduce the ability of **RBCs** to transport O_2 to the tissue .
 - **Normally**, the amount of O_2 dissolved in blood is 2% that carried by **RBC**.
 - **Treatment with hot**: the partial pressure O_2 can be increased by factor of 15 according to Henry's law allowing enough O_2 to be dissolved to fill the body's needs .

Hot in radio therapy :

Theory : the tumor consist of :

- a. **Normal tissue** : which is well oxygenated (Rich in O_2)
- b. Malignant (cancer cell) : which is poor in O_2
- c. The normal cells well oxygenated are more sensitive to the (ionizing radiation RAY) than the cancer cells . X - RAY and γ - Ray
- d. This is mean the radio therapy may cause damage to the normal tissue
- e. To improve the radiotherapy treatment we use (hot) .

Treatment

1. The patient is placed inside a transparent plastic tank .
2. The pressure inside the tank is about 3 atm. .
3. The ionizing radiation is beam through the wall of the tank .
4. The treatment takes about 10 minutes .

E.g / Assume you are a shallow – water diver preparing for 10M dive into salt water .

- a. What absolute pressure and gauge pressure will you experience ?
- b. Normally, your lungs have an available volume of (6L) what will happen to that volume ?
- c. Suppose you can't equalize the pressure in your middle ear . what will happen during the dive ?

Sol/

- a.** Gauge Pressure (ΔP) = Absolute pressure – atmospheric pressure

$$\Delta P = \rho gh = 1000 \times 10 \times 10 = 10^5 \text{ N/M}^2$$

$$10^5 \text{ KPa} = \text{absolute pressure} - 1 \text{ atm}$$

$$1 \text{ atm} = \text{absolute pressure} - 1 \text{ atm}$$

$$\text{Absolute pressure} = 2 \text{ atm}$$

- b.**

$$P_1 V_1 = P_2 V_2$$

$$1 \text{ atm} \times 6L = 2 \text{ atm} \times V_2$$

$$V_2 = 3L (\text{Decreased as the pressure increase})$$

- c.** If it is not equalized, that will cause eardrum rupture.

EX/ Negative pressure or suction is often used to drain body cavities. In the drainage arrangement for the gastrointestinal region show, the negative pressure supplied to the collection bottle is (100 mmHg) and the top end of the tub is (37cm) above the end of the tub in the body. Find the negative pressure at the lower end of the tub .

SOL:/

If negative pressure supplied to the collection bottle is =100 mmHg .

$$\text{The Pressure in the bottle } P = \rho h g = 1 \times 980 \times 37 = 36260 \text{ dyn/cm}^3$$

$$36260 = 13.6 \times 980 \times h$$

$$h = 27 \text{ mmHg (the negative pressure of the top end of the tub)}$$

$$\text{Net pressure} = 100 - 27 = 73 \text{ mmHg}$$

Equation of state :

Any equation that relates the pressure (P), temperature (T) and specific volume (V) of a substance is called an equation of state .

Ideal gas equation of state :

- ✓ It's the simplest and best known equations of state for substances in the gas phase .
- ✓ This equation predicts the (P, V, T) behavior of a gas .
- ✓ At low pressure, the volume of a gas is proportional to its temperature .

That is $P = R \left(\frac{T}{V} \right)$

$$PV = RT \quad \text{IDEAL GAS EQUATION OF STATE .}$$

Where R : gas constant

P : absolute pressure

T : Temperature

V : specific volume

$$R = \frac{R_u}{M} \quad KJ/(Kg.K)$$

R_u : universal gas constant and $R_u = 8.314 \quad KJ/(K mol.K)$

M : Molar mass "molecular weight"

- ✓ The mass of the system is equal to the product of its molar mass "M" and the moles number "N" .

$$m = MN \quad (Kg)$$

- ✓ The ideal gas equation can be written in different forms :

$$PV' = RT \quad \text{Where} \quad (V' = \frac{V}{m})$$

$$P \frac{V}{m} = RT$$

$$PV = mRT \quad \text{Where} \quad (m = MN)$$

$$PV = MNRT \quad \text{Where} \quad (RM = R_u)$$

- ✓ **When we fixed mass of system, the properties of an ideal gas at two different states are related to each other .**

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2} \quad \text{general lawes of gases}$$

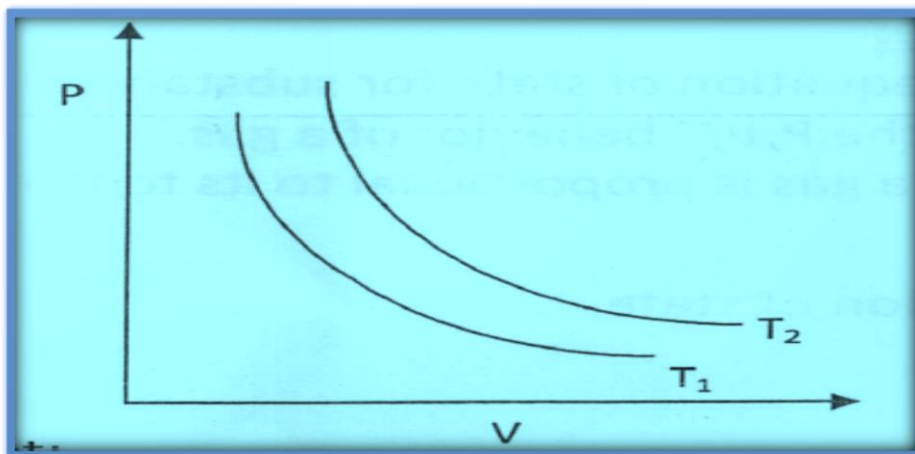
- ✓ **When T is constant, the cross product of pressure and specific volume is constant. that mean : as the mass is constant "as denoted before " the specific volume will equal the volume .**

$$\text{Because } v = \frac{V}{m}$$

Where T : constant

Then

$$P_1 V_1 = P_2 V_2 = P_3 V_3 \quad [\text{Boyels law}]$$



✓ **When the pressure is constant :**

P: constant

$$\text{Then : } \frac{V_1}{T_1} = \frac{V_2}{T_2} \quad \text{Charles's law}$$

Eg/ Determine the mass of the air in a room whose dimension are $(4 \times 5 \times 6)$ at (100 KPa) and (25°C) .

Sol / Absolute temperature $(T) = 25^\circ \text{C} + 273 = 298 \text{ K}$

The volume of the room $= (4 \times 5 \times 6) = 120 \text{ m}^3$

From the table, the gas constant for air is :

$$R = 0.287 \text{ KPa} \cdot \text{M}^3 / (\text{Kg} \cdot \text{K})$$

By substitute these values in the equation :

$$PV = mRT$$

$$m = \frac{PV}{RT} = \frac{100 \times 120}{0.287 \times 298} = 140.3 \text{ Kg}$$

$$PVN = mRT$$

- **The ideal gas law can be expressed in terms of the total number of molecules "N" where :**

$$N = n N_a$$

$N = \text{Total no. of moles}, \quad n = \text{no. of moles}$

$N_a = \text{Avogadro's no.} = 6.022 \times 10^{23} \text{ molecules /mole}$

$$= 6.022 \times 10^{26} \text{ molecules / K.mole}$$

$$PV = nRT \Rightarrow PV = \frac{N}{N_A} RT$$

Where $K = \frac{R}{N_A}$

$$\text{Boltzman const.} = 1.38 \times 10^{-23} \text{ J/molecules} \cdot K$$

$$= 8.63 \times 10^{-5} \text{ e.v/molecules} \cdot K$$

substitute in $PV = NKT$

One mole of a substance is that mass that contain Avogadro`s no. of molecules .

E.g/ An ideal gas occupies a volume of (100 cm^3) at (20°C) and pressure of (100 KPa) . determine the no. of moles a gas in the container .

Sol/ $PV = NKT$

Equation of state in real gas ;

Real gas : gas have a distance between his molecules .

In real gas we have two equation:

a. Clausius equation :

$$P(V - nb) = NRT$$

b. Vander Waals equation :

$$\left(P + \frac{a}{v^2} \right) (v - b) = RT$$

Where **a** and **b** : constant for any one gas but differs for different gasses .

NOTE /

$$P_{real} < P_{ideal}$$

Relative Density: Ratio of the density of substance of some standard substance at a specified temperature.

{ Note: Usually water at 4°C for which $\rho_{H_2O} = 1000 \text{ Kg/M}^3$ }

$$\rho_s = \frac{\rho}{\rho_{H_2O}}$$

Specific Volume: The volume per unit mass.

$$v = \frac{V}{m} = \frac{1}{\rho} (\text{M}^3/\text{Kg})$$

Intensive Properties(الخصائص الضمنية): Properties which are independent of the size of the system such as T, P and ρ .

Extensive Properties(الخصائص اللاضمنية): Properties of very directly with size of the system Such as (Mass "m", Volume "V", total energy "E").

Thermodynamic Coordinate(احداثيات تيرموديناميكية):

(P, V, T) or (P, ρ , T) are thermodynamic Coordinates. Any change of this three coordinates we have thermodynamic process.

If T: is constant -----> We have isotherm process.

If P: is constant -----> Isobaric process.

If V: is constant -----> Isochoric or Isometric process.

Adiabatic Process(العمليات الديناميكية الكظمة): In this process no change in energy. The quantity of thermal energy is constant.

$$Q_1 = Q_2$$

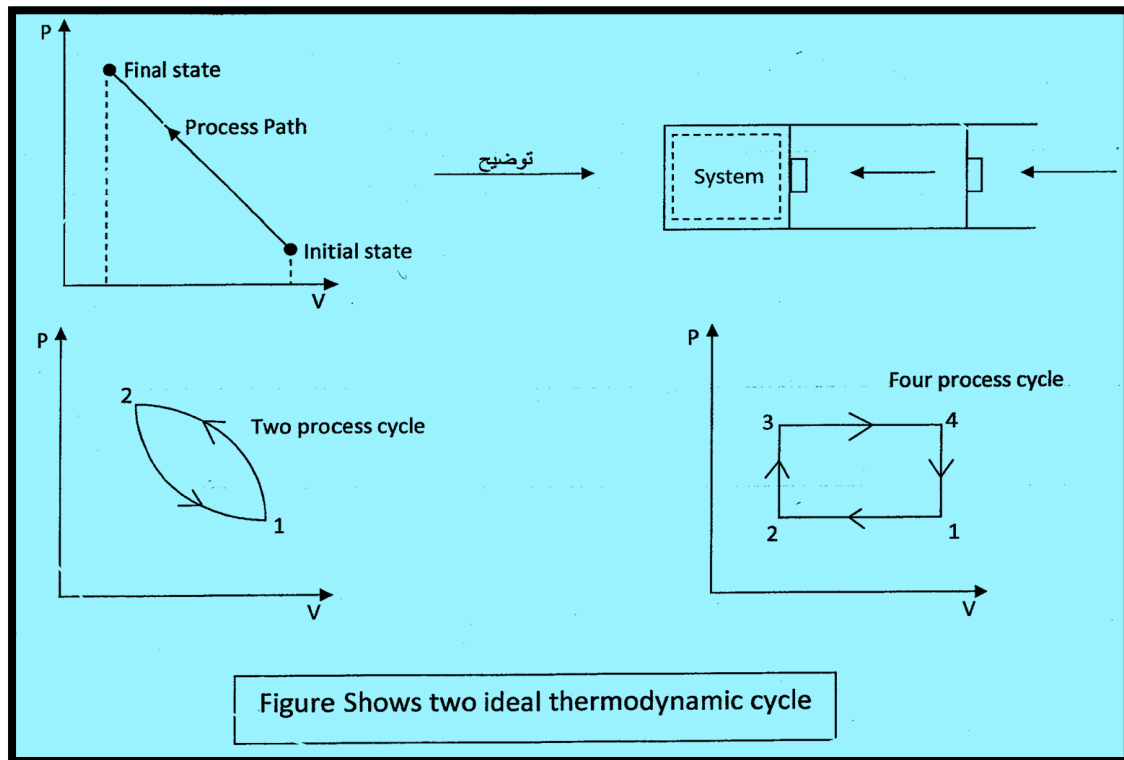
Q is constant (ثابت)

$$dQ = \text{zero (مشتقة الثابت صفر)}$$

Process: Any change that a system undergoes from one equilibrium state to another.

Path: Series of states through which a system passes during process.





Energy, Work and heat , power of the body:

Heat : The form of energy that transferred between two systems by a temperature differences .

- ❖ Heat transferred during the process between two states (state1 and state 2) is denoted by Q_{12} .
- ❖ Heat has energy unit (KJ) .(Kilojoules) .
- ❖ $q = \frac{Q}{M} (KJ/Kg)$ heat transferred per unit mass .

Note -1/ Heat and internal energy are two different things .

Energy is associated with **a state** .

Heat is associated with **a process** .

Note -2/Heat is a directional quantity .

Heat transferred to a system (+) .

Heat transferred from a system (-) .

The direction of energy → from higher temperature body to lower .

Work : is an energy interactions between a system and its surrounding.

- Work is form of energy like heat .
- Work has energy unit such as (KJ) .

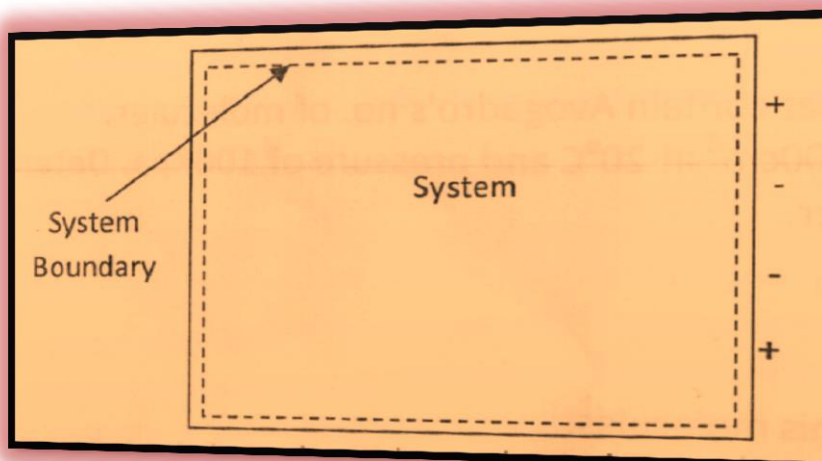
The work done during the process between state 1 and state 2 (or initial and final state) is denoted by W_{12} or W

- $W = \frac{w}{m}$ (KJ/Kg) : **work done per unit mass** .

Power: workdone per unit time .

- **The Power law**: $p = \frac{w}{t} \left(\frac{KJ}{s} \text{ or } Kw \right)$.
- The work done by a system is (+) .
- The work done on a system is (-) .

The figure below show the sign convention for heat and work



1. Both heat and work are boundary phenomena .
2. Both heat and work are transient phenomena .
3. Both are path functions .

Mechanical forms of work:

The work done by constant force (**F**) on a body is displaced a distance (**S**) in the direction of force is :

$$W = F \cdot S \quad \text{.....(1)}$$

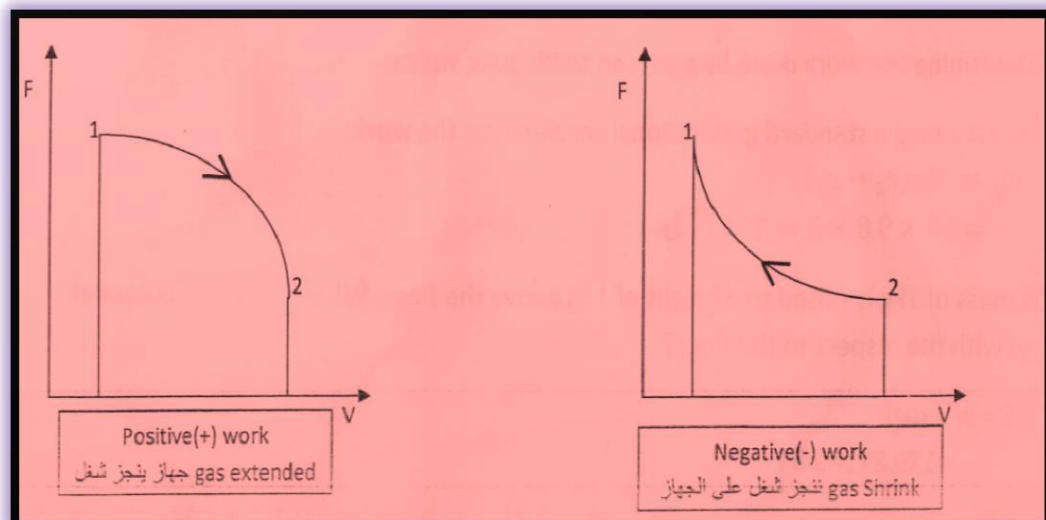
If the force is not constant, the work done is obtained by the differential amount of work :

$$W = \int_1^2 F \cdot dS \quad \text{.....(2)}$$

Equation no.1 and equation no.2 give only the magnitude of the work .

- Work done by a system against external force acting in the direction of the motion(-) .
- Work done by a system against external force acting in the opposite direction of the motion(+)

The figures below show the positive and negative work :



Gravitational work :

The work done by or against a gravitation force .

The force acting on body is :

$$F = m g$$

Where m =mass of the body, g =acceleration of gravity .

When the work required to raise the body from level Z_1 to Z_2 is :

$$W_g = \int_1^2 F \cdot dz = \int_1^2 mg \cdot dz = mg \int_{z_1}^{z_2} dz = mg(z_2 - z_1)$$

Figure

Note / The gravitational work depend on the end state and is independent of the path .

- The work done is equal "in magnitude " to the change in the potential energy of the system .

The sign of the gravitational work :

(+) if done by the system. (the system falls) .

(-) if done on the system. (the system raised) .

Note : potential energy (P.E) = work done to put body in position .

$$P.E = work = Fh = mgh$$

Ex.1 / Determine the work done by a person to lift 10 kg suitcase 2m .

Sol./ by assuming a standard gravitational acceleration the work :

$$W_g = Mg(z_2 - z_1)$$

$$= 10 \times 9.8 \times 2 = 196 J$$

EX/ A mass of 1kg is raised to a height of 1m above the floor . what is the P.E (potential energy) with the respect to the floor ?

Sol./

$$P.E = W = mgh$$

$$= 1 \times 9.8 \times 1 = 9.8 J$$

Acceleration work :

The work associated with the change in velocity of a system .

$$F = m \times a \quad \text{Newten } 2^{nd} \text{ law}$$

$$a = \frac{dv}{dt} \Rightarrow F = m \times \frac{dv}{dt}$$

The differential displacement (ds) is reacted to velocity V by :

$$v = \frac{ds}{dt} \Rightarrow ds = Vdt$$

Substituting the **F** and **ds** relation in the equation :

$$W = \int_1^2 F \cdot ds \Rightarrow W_a = \int_1^2 F \cdot ds = \left(\frac{mdv}{dt} \right) (Vdt)$$

$$W_a = m \int_1^2 V dv = m \left(\frac{V_2^2 - V_1^2}{2} \right) \Rightarrow W_a = \frac{1}{2} m (V_2^2 - V_1^2)$$

Where $\frac{1}{2} m V^2 = W_a = \text{kinetic energy of a body}$

The work done to accelerate body is independent of path, the work equivalent to the change in the kinetic energy of the body .

The sign of work acceleration is :

(+) if done by the system .

(-) if done on the system .

Ex/ Determine the power required to accelerate 900kg car from rest to velocity 80km/h in 20 seconds, on a level road .

$$\begin{aligned}\text{Sol/} \quad W_a &= \frac{1}{2} m (V_2^2 - V_1^2) \\ &= \frac{1}{2} \times 900 [(80)^2 - 0] = 222.2 \text{ KJ} \\ W = \text{power} &= \frac{W_a}{\Delta t} = \frac{222.2}{20} = 11.1 \text{ KW}\end{aligned}$$

Shift work:

A force acting (**F**) through a moment arm (**r**) generates a torque (**T**) which is determined from :

$$T = Fr$$

This force is act through distance (**S**) which is related to the radius (**r**) by :

$$S = (2\pi r) \times n$$

r=revolution

the shift work :

$$\begin{aligned}W_{sh} &= FS \\ W_{sh} &= \frac{T}{r} \times 2\pi n r = 2\pi n T\end{aligned}$$

The power : the shift work done per unit time .

$$W_{sh}^{\circ} = \frac{W_{sh}}{t} = 2\pi n^{\circ} T$$

Where $n^{\circ} = \frac{n}{t} = \text{No. of revolution per unit temp.}$

Rpm=revolution per minute .

Ex/Determine the power transmitted through the shaft of a car when the torque applied is 200(N.M) and the shaft rotates at a rate of 4000 Rpm .

SOL/

$$W = 2\pi n^{\circ} T$$

$$= 2\pi \times 4000 \frac{1}{\text{min.}} \times 200 \text{ N.M} = ????$$

Spring work :

When a force is applied to a spring the length of the spring changes when the length of the spring changes by differential amount (dx) under influence of a force (F), the work done is:

$$W_{Spring} = F \cdot dx \quad \dots\dots(1)$$

For linear elastic spring, the displacement (x) is proportional to the force applied, that is :

$$F \propto x$$

$$F = Kx \quad \dots\dots(2)$$

Where K=Spring constant , x=displacement

x=measured from the undisturbed position of the spring .(x=0 when F=0)

substitute equation (2) in equation(1) and integrating, yield :

$$W_{spring} = \frac{1}{2} K (x_2^2 - x_1^2)$$

$$\Delta W = \int_1^2 K x dx$$

$$= K \int_1^2 x dx$$

$$= \frac{1}{2} K (x_2^2 - x_1^2)$$

Where x_1, x_2 are the initial and final displacement.

Both x_1, x_2 are measured from the undisturbed position of spring .

Q/ PROVE THAT

$$1. W = RT \ln \frac{V_f}{V_i}$$

Prove that :

$$2. W = RT \ln \frac{P_1}{P_2}$$

SOL/ for ideal gas $PV = RT$

$T = \text{const.}$

$$1. dW = PdV \Rightarrow W = \int_{V_i}^{V_f} P dv$$

For ideal gas :

$$PV = RT \Rightarrow P = \frac{RT}{V}$$

$$W = \int_{V_i}^{V_f} \frac{RT}{V} dV = RT \int_{V_i}^{V_f} \frac{dV}{V}$$

$$W = RT [\ln V_f - \ln V_i]$$

$$W = RT \ln \frac{V_f}{V_i}$$

$$2. \quad P_1 V_1 = RT \text{ and } P_2 V_2 = RT$$

$$\therefore \quad P_1 V_1 = P_2 V_2$$

$$\frac{P_1}{P_2} = \frac{V_1}{V_2}$$

$$W = RT \ln \frac{P_1}{P_2}$$