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 $\uparrow \Leftrightarrow \uparrow$ T 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 liquid .
- Liquid +heat gas .
- Gas + heat 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°C)respectively .

** Normal body temperature $(37°C)$.

2- Fahrenheit scale : the ice and steam points are the values of $(32-212\ °F)$ respectively .

** Normal body temperature $(98.6\ °F)$.

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

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

B-The lowest temperature is the absolute zero$(0K)$ is $(-273.15°C)$.

- 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 :

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

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

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

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 :

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

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

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

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

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

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

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

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

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

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

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

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

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 $\left(1cm^3\right)$ of mercury increases in volume by only (1.8%) in going from $\left(0-100\,^{\circ}C\right)$.

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 $(\Delta T \alpha \Delta V)$ change in volume it uses mercury because :

a. The volume expansion (ΔV) with (ΔT) is very small $(1 cm^3 Hg)$ increase volume by (1.8%) when the temperature changes from $(0\ to\ 100\ ^\circ C)$.
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 .

1- ***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 .

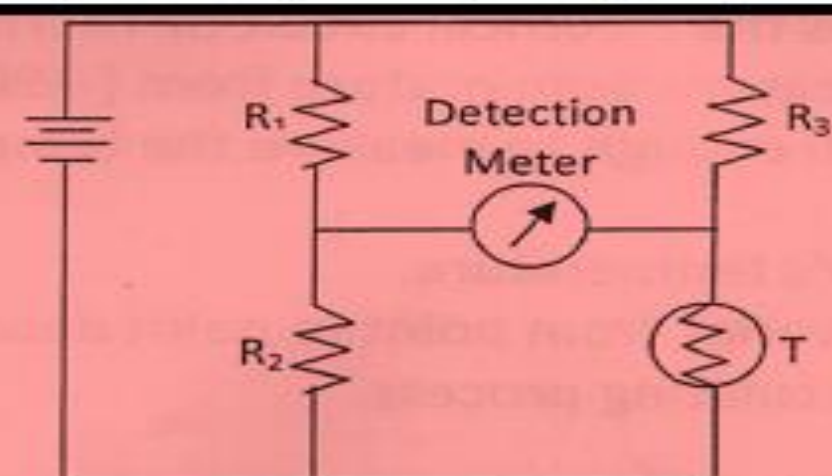

Figure Shows the electrical circuit of Thermistor

- 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 $(0.01\ ^\circ C)$.
3- Small size .
4- Rapidly response to change in temperature .

Figure shows the thermistor

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 .

1- ***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) $\propto \Delta T$.

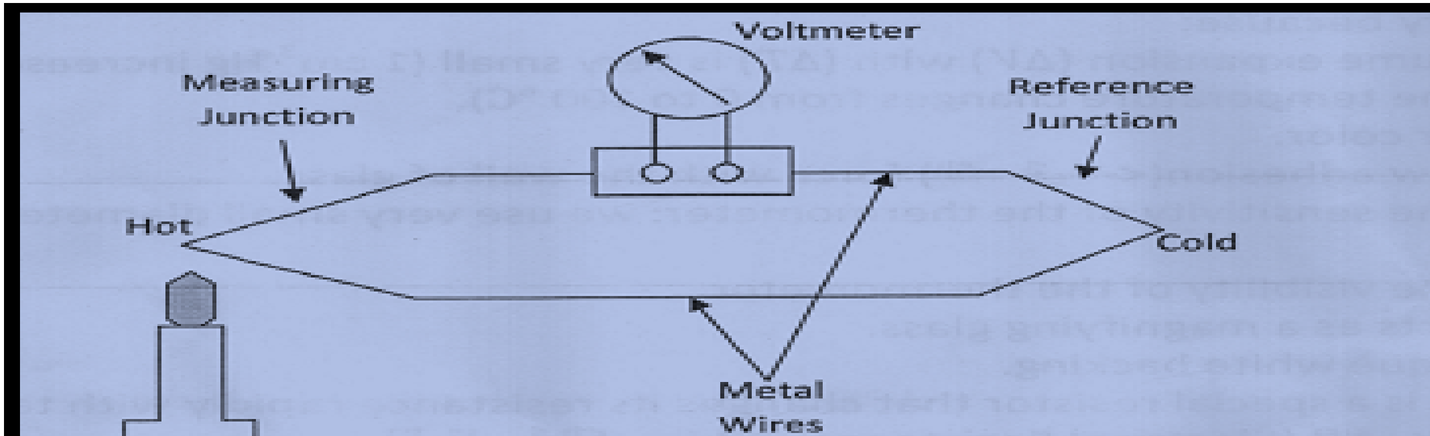

Figure shows the electrical circuit of Thermocouple

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

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 $(37^{\circ}C)$ 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 ($1^{\circ}C$) 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 cm2 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 ($^\circ$ C +273)

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

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

e.g : breast cancer

E.g/ A- what is the power radiated per cm ^{2} from skin at temperature of 33 $^\circ$C ?

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

$$T = 33 + 273 = 306\ K$$

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

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

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

$$P = 0.057\ w/cm^2 \times 1.75 \times 10^4\ cm^2 = 875W$$

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

875-735=140 watt

Note: the commercial instrument used in clinical thermography can measure the temperature differences of $\Delta T = 0.2\ ^\circ C$ 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

Mammography	Thermogram
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 :

- **The area of contact .**
- **The temperature difference .**
- **The time of contact (duration) .**
- **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

6. sinusitis 7. back pain .

2. <u>Infrared (IR) radiation heat</u> : 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, ($1nm=10^{-9}$).
- 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. <u>Radio wave heating (diathermy)</u> :

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 .

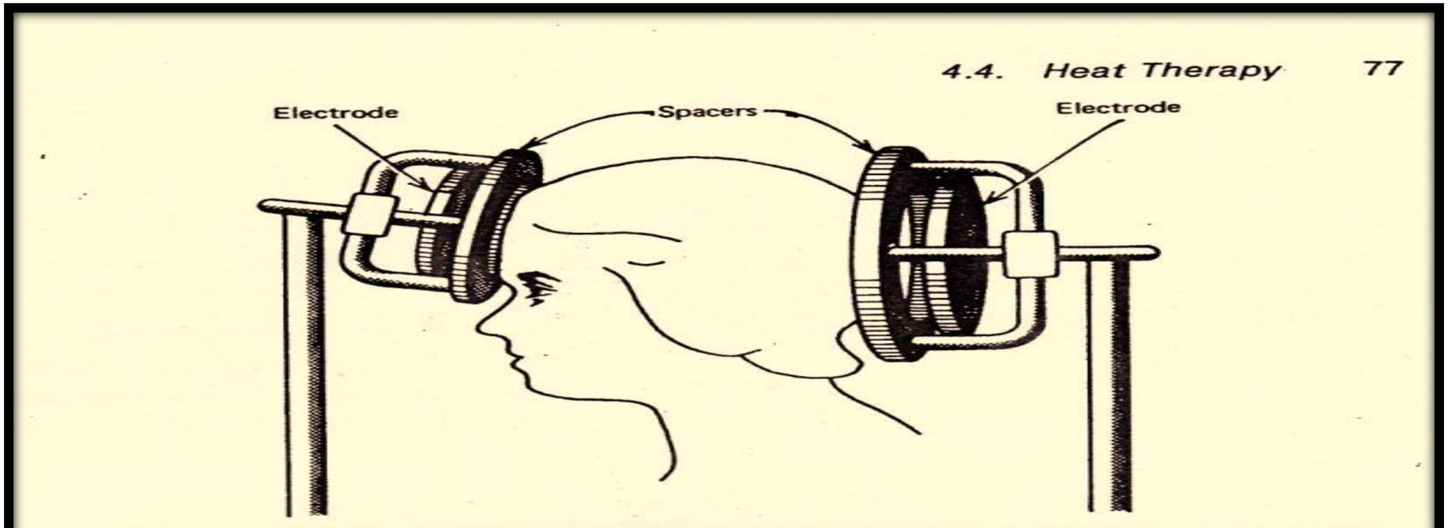

Figure 4.9. Location of capacitor plates for short wave diathermy. (Adapted from Lehmann, J.F.: "Diathermy," *in* Krusen, F.H., Kottke, F.J., and Ellwood, P.M. (Eds.): *Handbook of Physical Medicine and Rehabilitation*, 2nd edition. Philadelphia, W.B. Saunders Company, 1971, p. 286.)

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 .

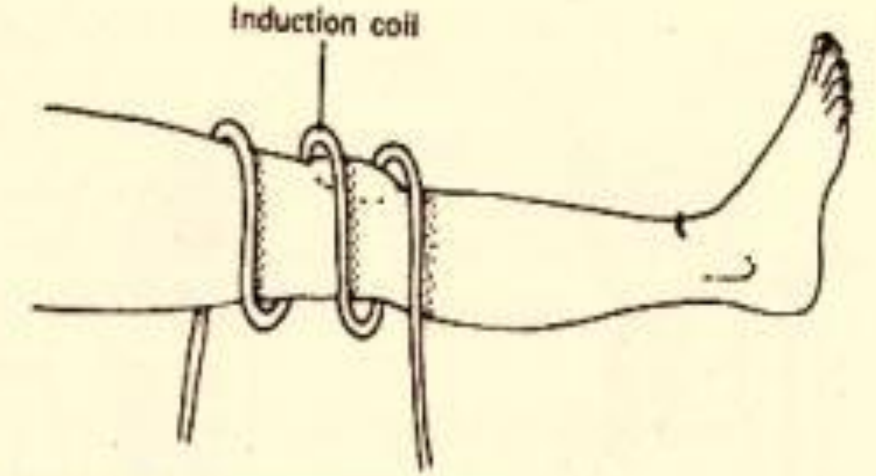

Figure 4.10. Location of induction coil around knee for short-wave diathermy.

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 .