كلية الحضارة الاهلية الجامعة

Learning package in field of

Medical Physics

Prepared by:

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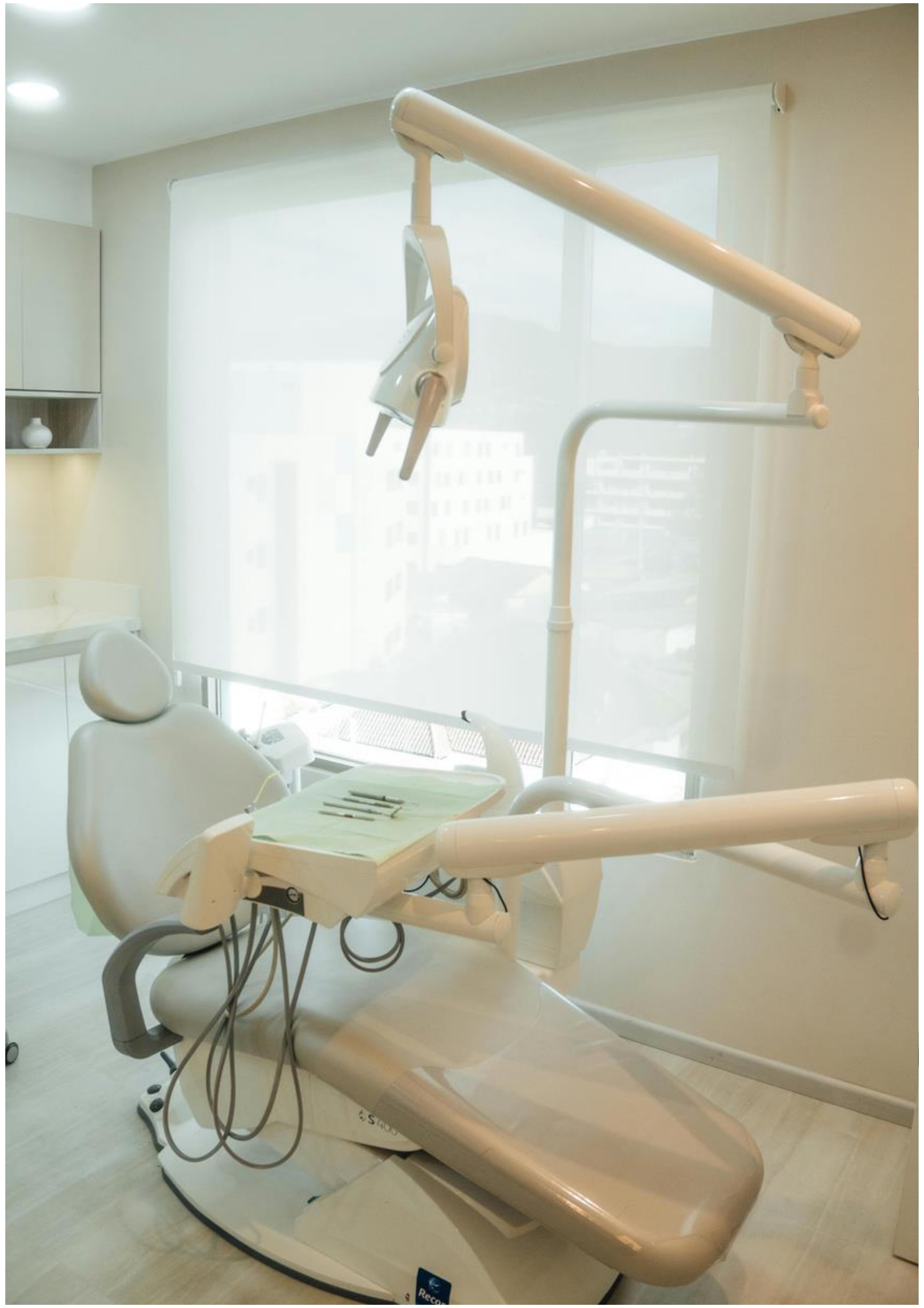
the 1st:

Cosmetic and Laser Techniques Department



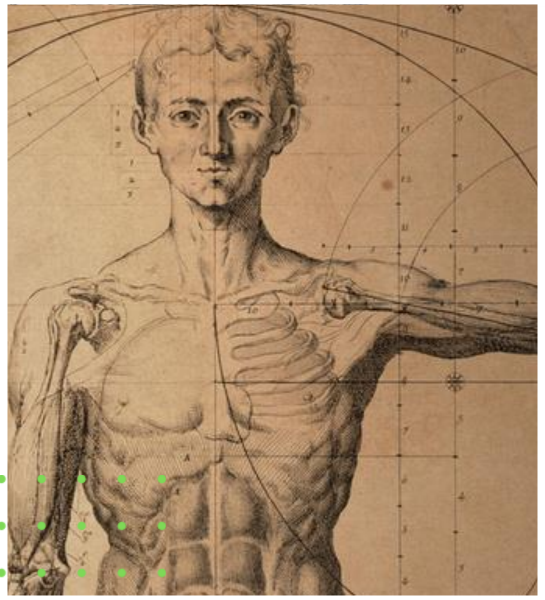
Contents

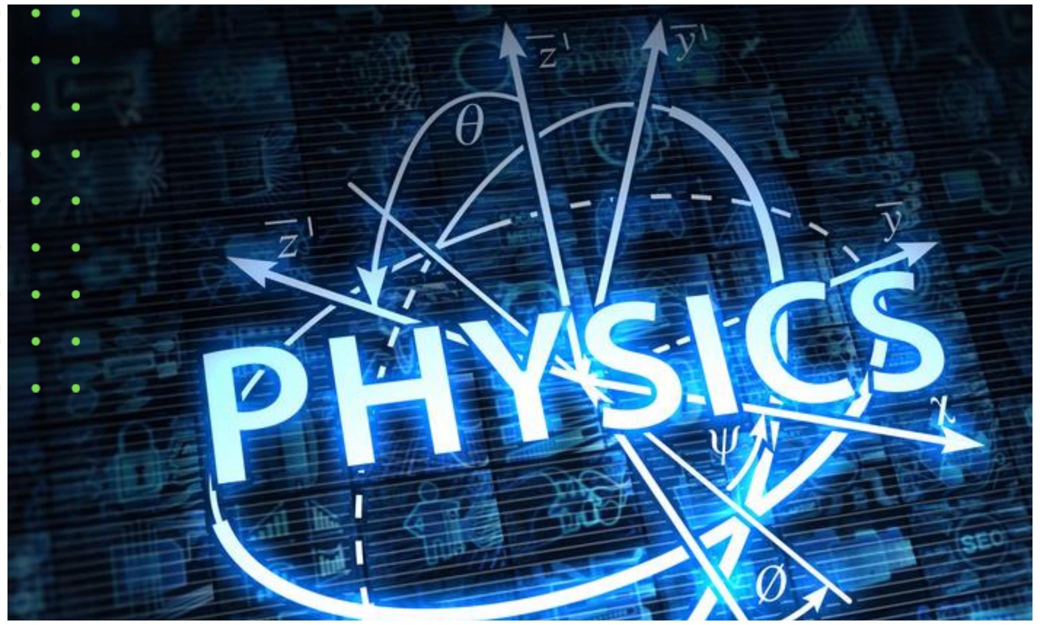
General objective

The overarching objective of this "Medical Physics" file is to provide a comprehensive and integrated educational package aimed at:

General objective

1. Establishing a strong understanding of the physical principles governing the structure and function of the human skeletal system, starting from the basic components of bones and their mechanical properties.
2. Linking fundamental physics principles (such as energy, work, and power) to biological processes in the body, and how food energy is converted into work and heat.
3. Exploring the medical applications of heat and cold (thermotherapy, cryotherapy, cryosurgery) and the mechanisms of energy transfer in these treatments.
4. Explaining the physical foundations of techniques for diagnosing bone diseases, such as measuring bone mineral density using photon absorptiometry and neutron activation.





General objective

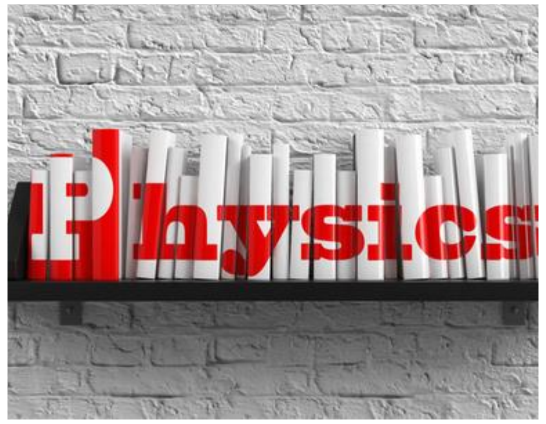
٥. Equipping first-year students in medical technology departments (such as anesthesia and laser techniques) with the necessary physical tools to understand the operation of devices and techniques used in their future specialization.

٦. Applying physical laws and models (such as Young's Modulus, the Stefan-Boltzmann Law, and heat capacity) to body tissues to calculate quantities like stress, compression, and radiated energy.

٧. Introducing students to the importance of precise physical measurements in medicine, by explaining the principles of instruments like thermometers and thermographs.

٨. Demonstrating how medicine utilizes the physical properties of materials (such as the superconductivity of materials for deep cooling) in fields like tissue and cell preservation.

٩. Enhancing analytical thinking through solving applied problems that connect physical equations with physiological conditions in the body.



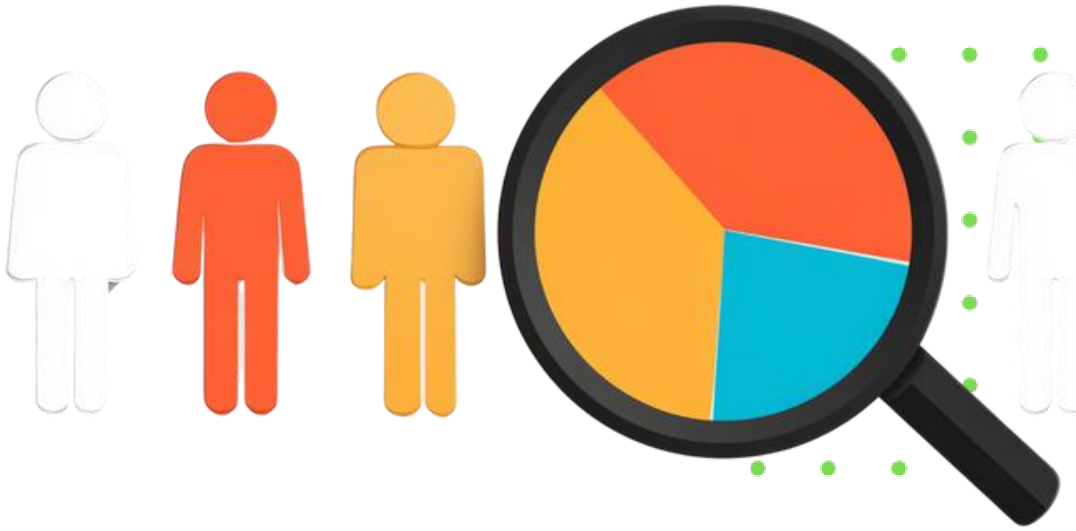
Objectives of the package

1. Define the mechanical properties of bone and link them to its microscopic structure (compact vs. spongy).
2. Apply Young's Modulus to calculate bone deformation (e.g., compression) under specific forces.
3. Explain the mechanism of joint lubrication and the role of synovial fluid and cartilage in reducing friction.
4. Use the thermal radiation law (Stefan-Boltzmann) to understand and apply medical thermal imaging.
5. Compare therapeutic heating mechanisms (such as conduction, radiation, diathermy, and ultrasound) in terms of depth and application.

Behavioral goals

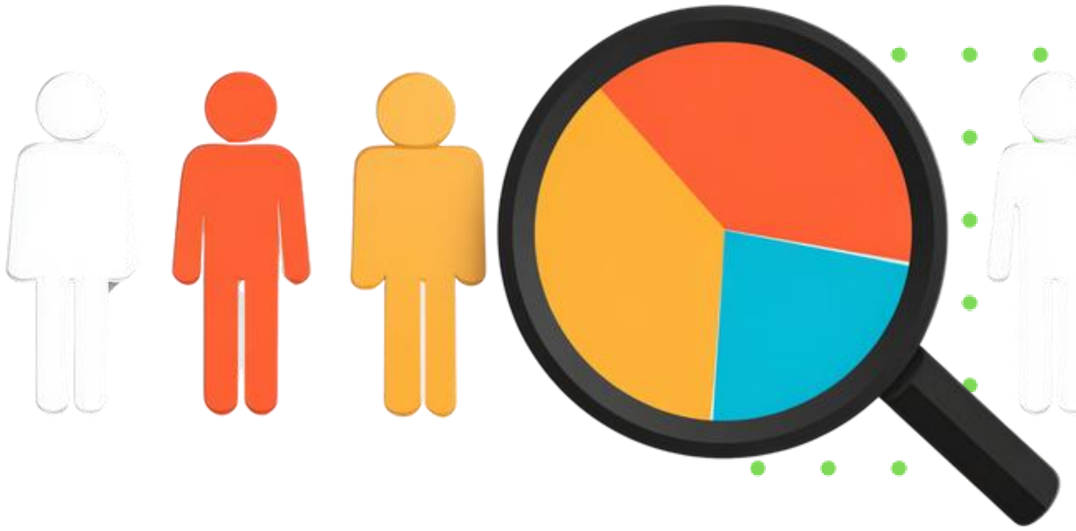
Here is a summary of behavioral objectives based on the file content, one point per paragraph:

1. Explain Basic Principles: The student explains fundamental concepts such as bone structure, physical laws (e.g., Young's Modulus, Stefan-Boltzmann Law), and energy transfer in the body using correct scientific terminology.
2. Apply Physical Laws: The student solves quantitative problems related to bone deformation under force, heat transfer, and heat capacity by applying the appropriate physical formulas and laws.
3. Analyze Material Properties: The student compares the properties of compact and spongy bone and analyzes the relationship between microscopic structure and the mechanical strength/behavior of body tissues.
4. Evaluate Therapeutic Techniques: The student compares different therapeutic heating (conduction, radiation, diathermy) and cooling techniques, evaluating them based on their physical principles, depth of penetration, and appropriate medical applications.



Behavioral goals

5. Connect Principles to Effects: The student connects physical principles (e.g., energy transfer, radiation) to their physiological effects (e.g., increased blood flow, reduced inflammation) in a medical context.



6. Discuss Safety Protocols: The student discusses potential risks (e.g., burns, overexposure) and necessary safety precautions when using physical techniques (like radiation or heat therapy) for medical diagnosis and treatment.

Package Description

- **Package Title:** Medical Physics
- **Target Audience**: Students of the College of Health and Medical Technology, Department of Cosmetic and Laser Techniques
- **Training Location**: Al-Hadhara Civilian College
- **Allocated Time**: 8 sessions, with each session lasting 2 hours
- **Training Methods and Approaches**: Blended Learning - Collaborative Learning - Discussion - Role-playing
- **Assessment Methods**: Tests - Activities - Workshops - Oral Exams
- **Theories Used**: Behavioral Theory "Reward - Punishment"

Units Included in the Package

1. Learning and Teaching: Through delivering educational content to students.
2. Instructional Design: By utilizing Learning Design methodologies.
3. Assessment and Feedback: Through posing questions to students and correcting information.
4. Digital Content Development: Using software such as (Canva - Kama).
5. Facilitation Strategies: Through (Collaborative Learning - Brainstorming - Project-Based Learning).
6. Professional Ethics: By adhering to lecture timings, awarding grades to committed students, prohibiting talking without permission, and maintaining discipline.
7. Quality of Education: Through quality inputs, educational processes, and outcomes.
8. Research Methodology: The analytical descriptive approach will be adopted.

Professional Ethics in Teaching

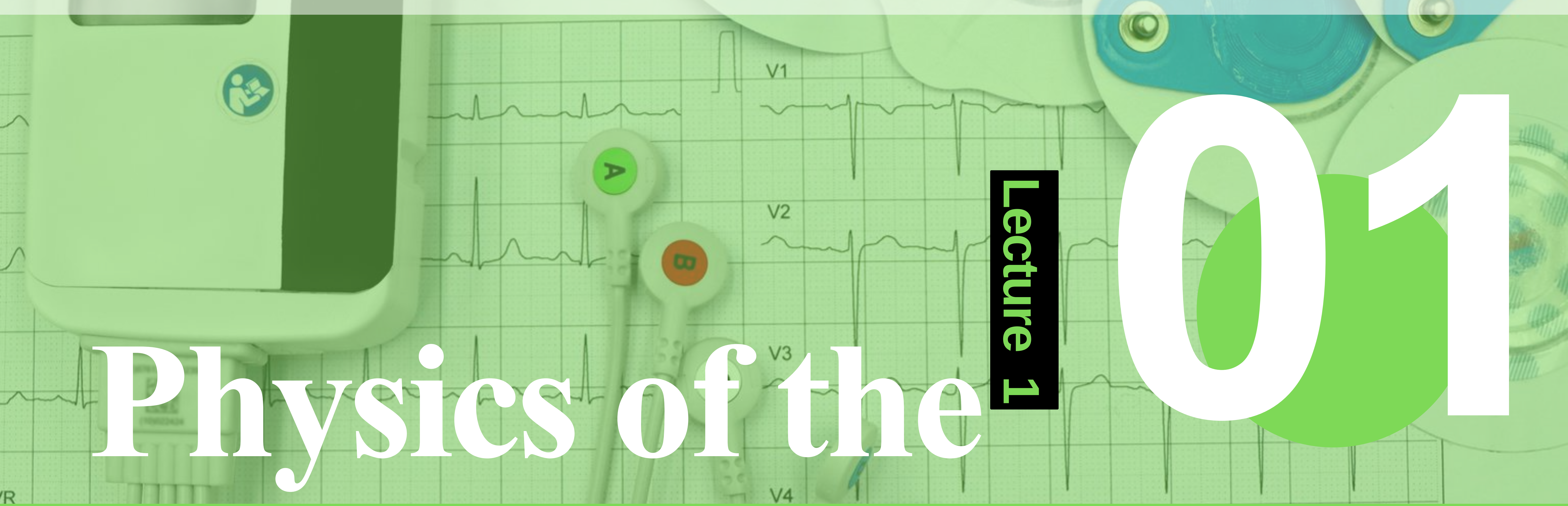
A teacher must consistently consider the academic and psychological state of students, adapting teaching methods to meet their needs without compromising the academic requirements and objectives of the lecture.

Justice and Equality: Treat all students fairly, without bias or discrimination.

Student Safety and Protection: Ensure a safe and supportive educational environment that fosters psychological and social growth.

Competence and Development: Commit to continuously updating professional knowledge and skills.

Role Model and Integrity: Embody the highest standards of behavior, honesty, and sincerity in all interactions.



Lecture 1

01

Physics of the Skeleton

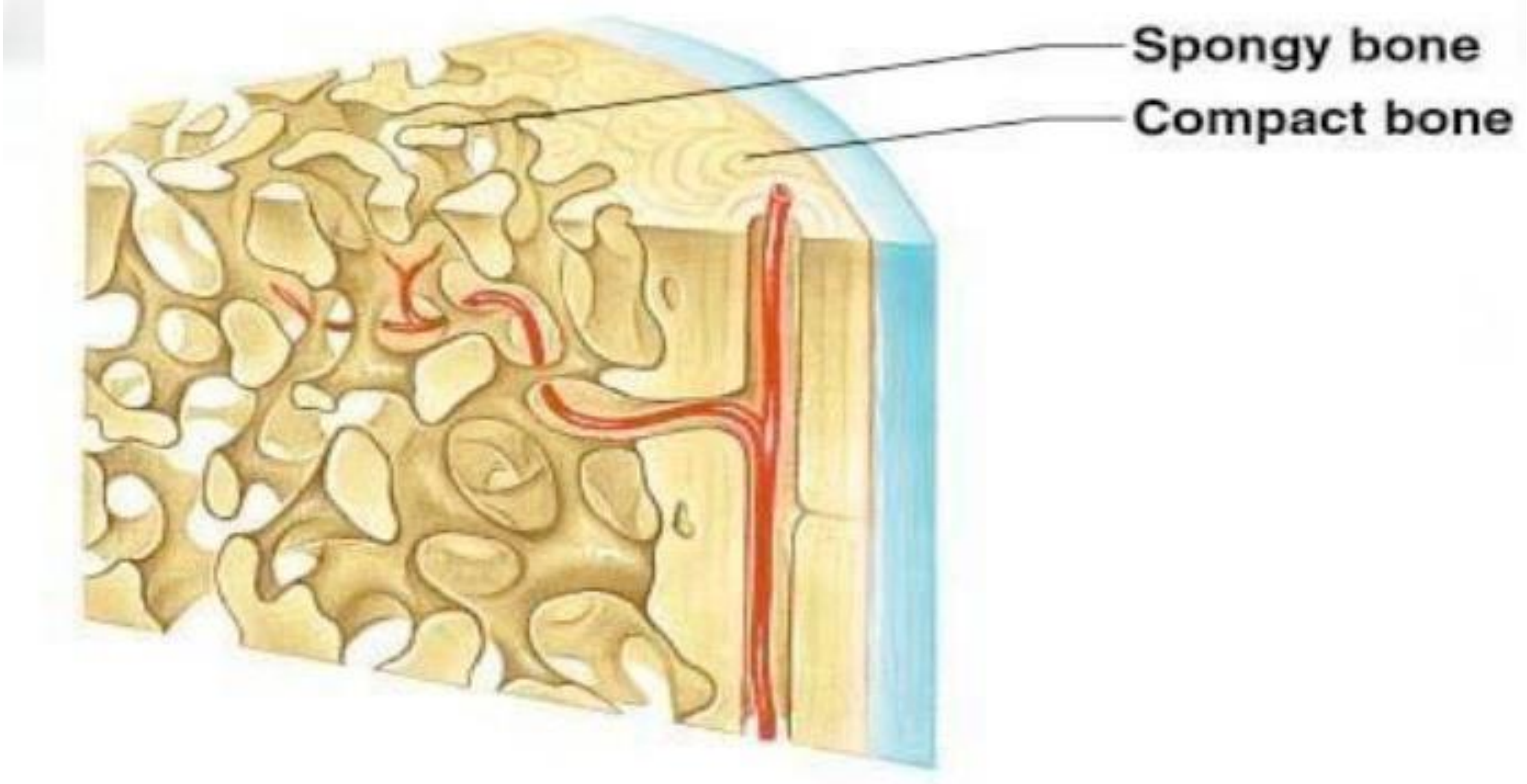
Physics of the Skeleton

Skeleton comes from a Greek word meaning dried up body. Bone appears dead and dried up, but it is not! Bone is living tissue.

Parts of the skeletal system

- Bones (skeleton)
- Joints
- Cartilages
- Ligaments (bone to bone) (tendon=bone to muscle)

Functions of Bones



1.Support of the body (framework)

2.Protection of soft organs

3.Serve as levers (with help from muscles)

4.Storage of minerals and fats (calcium)

5.Blood cell formation

There are two basic types of bone tissue in the human body.

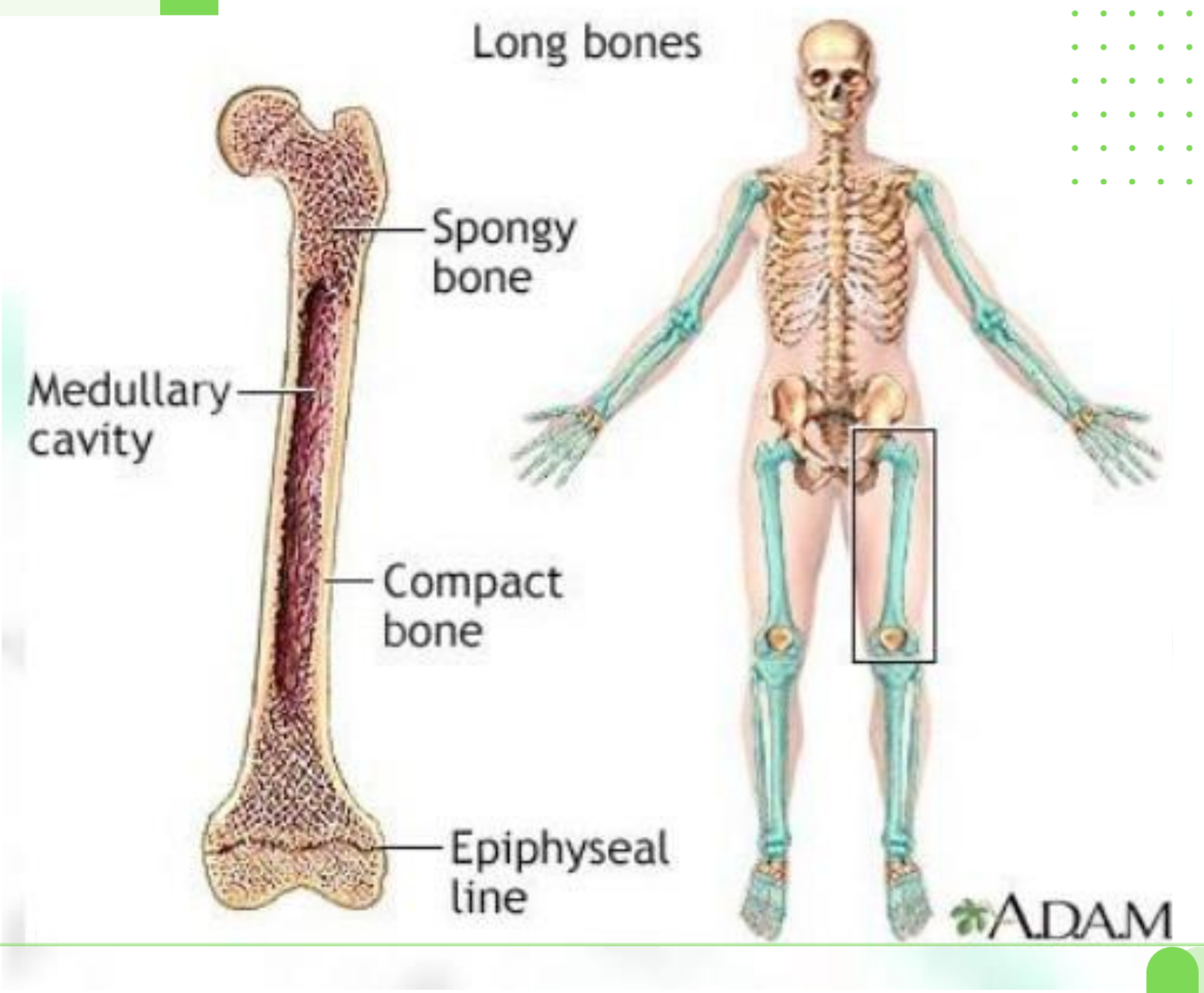
1.Compact bone {dense and hard)

2.Spongy bone {Cancellous and Many open spaces}

Classification of Bones

1.Long bones

- Typically, longer than wide.
- Have a shaft with heads at both ends.
- Contain mostly compact bone.
- Found in legs and arms.
- Examples: Femur, humerus.



Classification of Bones

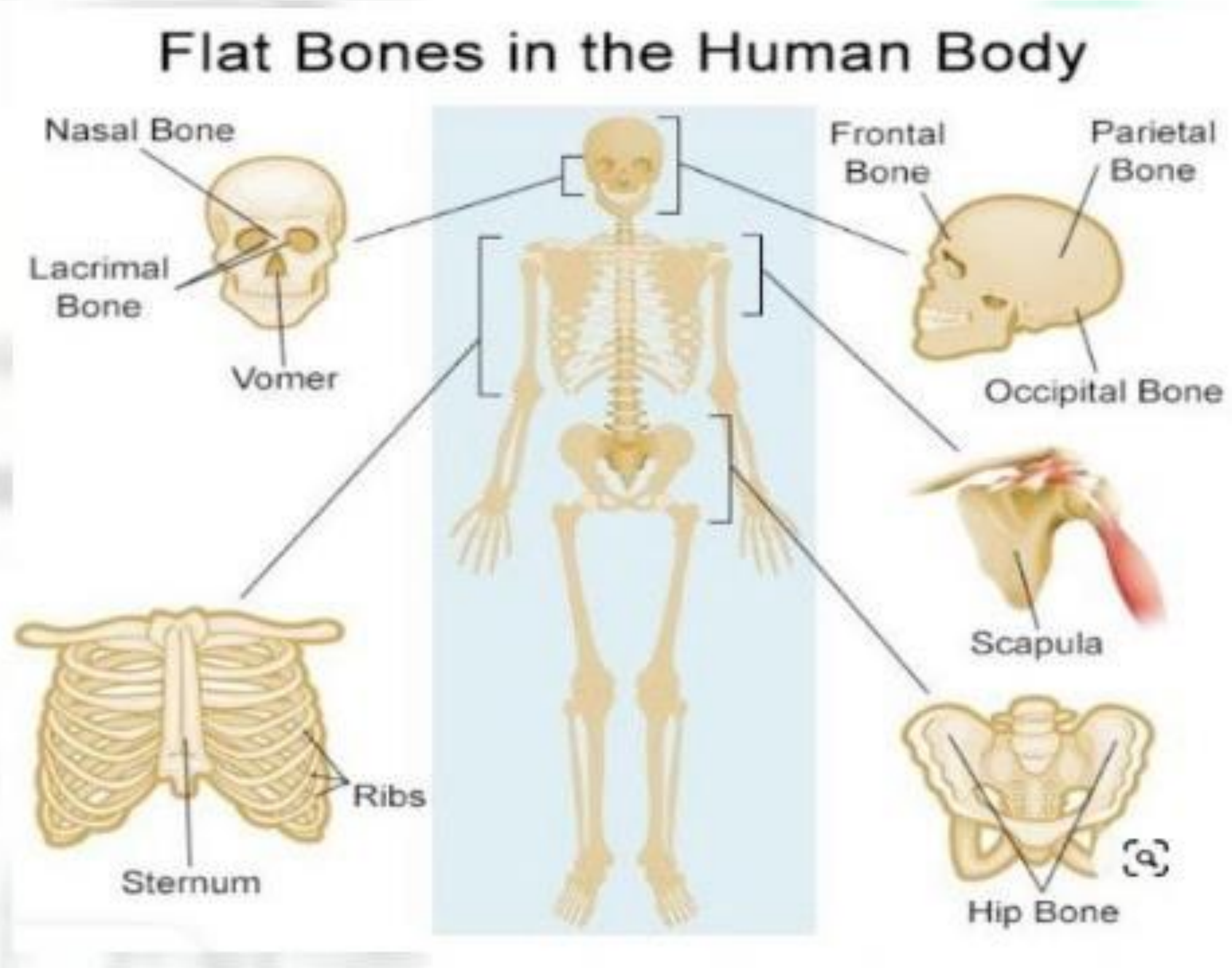
1.Short bones

- Generally, cube-shape and small.
- Contain mostly spongy bone.
- Found in wrist, ankles, and toes.
- Examples: Carpals, tarsals

Classification of Bones

1.Flat bones

- Thin and flattened Usually curved
- Cover organs and provide surface for leg muscle
- Thin layers of compact bone around a layer of spongy bo
- Examples: Skull, ribs, sternum



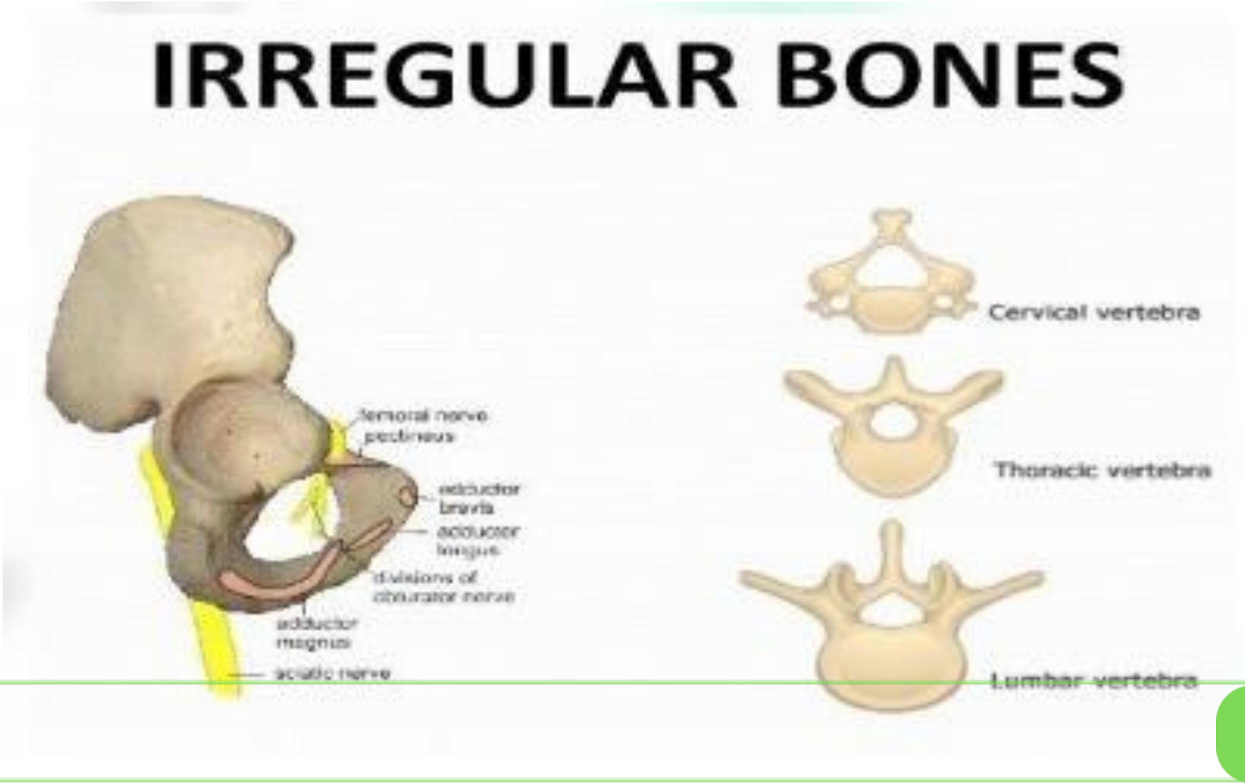
Classification of Bones

1.Sesamoid Bones

□The sesamoid bones get their name for resembling a sesame seed.

1.Irregular bones

□The irregular bones get their name for their odd shapes that do not fit the other categories of long, short, flat, or sesamoid.



What Are Bones Made of?

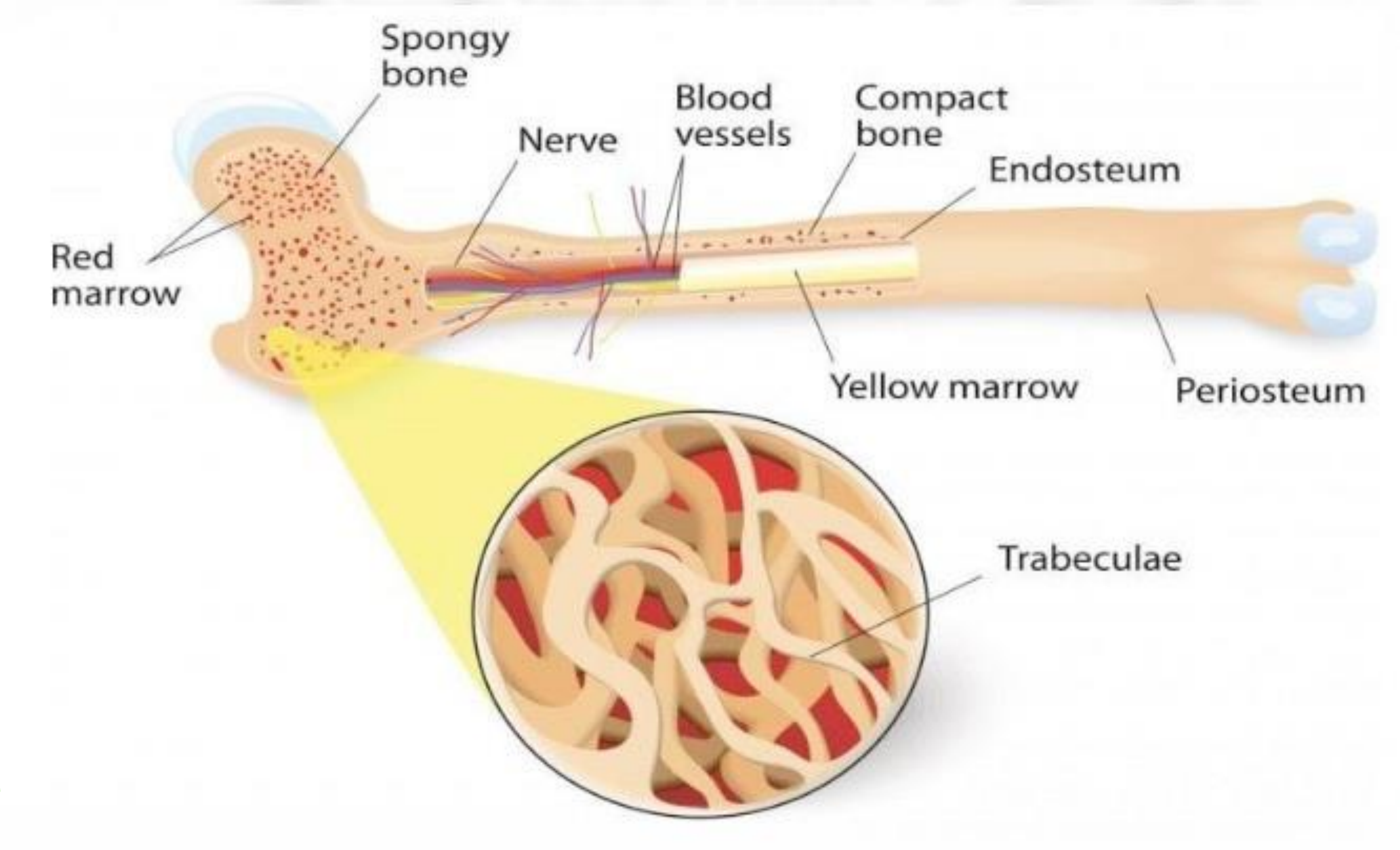
Periosteum: The outer surface of the bone; a thin, dense membrane that contains nerves and blood vessels that nourish the bone!

Compact: This is the next layer; it is very smooth and very hard. It is the part you see when you look at a skeleton!

Cancellous: Many layers within the compact bone; these look like sponges! Not as hard as compact bone, but it is still very hard. In many bones, the cancellous bone protects the innermost part of the bone.

The bone marrow: It is sort of like a thick jelly, and its job is to make blood cells.

What Are Bones Made of?



Composition of compact bone: Table 1 where Large percentage of calcium with heavier nucleus (high x-ray absorption).

Table 1 .Composition of Compact Bone

Element	Compact Bone, Femur (%)
H –	3.4
	15.5
N –	4.0
O –	44.0
Mg –	0.2
P –	10.2
S –	0.3
Ca –	22.2
Miscellaneous –	0.2

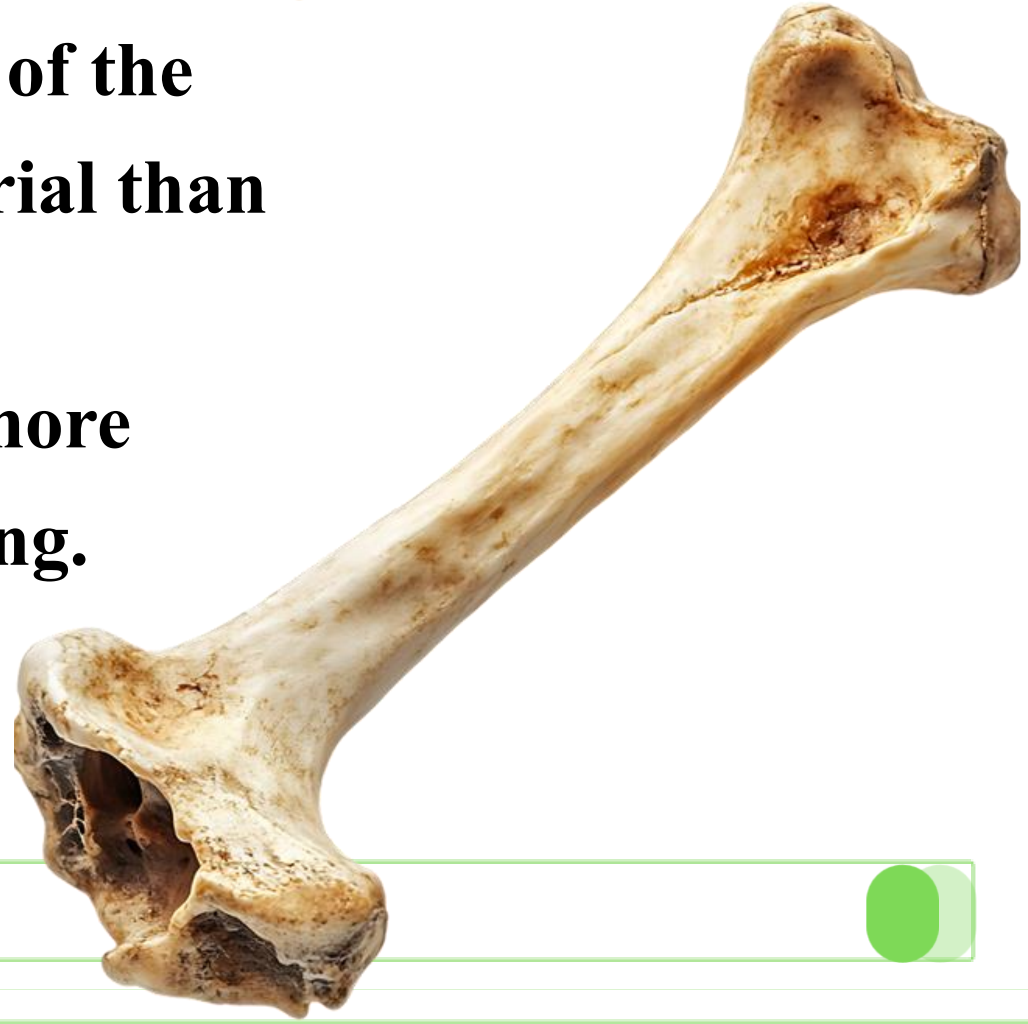
Generally, Bone = collagen + bone mineral + water

- Collagen
- Collagen which is the major organic fraction, 40% of the weight of solid bone and 60% of its volume. Flexible and bends easily, large tensile strength. Produced by osteoblastic cells.
- Bone mineral
- Bone mineral: inorganic component 60% of weight 40% of its volume. Formed on the collagen. Made up of calcium hydroxyapatite Ca10(PO4)6(OH)2. Very large surface area of $4\times10^5\ m^2$ ⇒ rapid interaction with chemicals in the blood and other body fluids.

How Strong Are Your Bones?

We mentioned in the previous lecture that there are two types of bones. So, what are the advantages of sponge (trabecular) bone over compact bone?

1. **Where a bone is subjected primarily to compressive force, such as at the ends of the long bones and the trabecular bone give the strength necessary with less material than compact bone.**
2. **Also because the trabecular is relatively flexible trabecular bone can absorb more energy when large forces are involved such as in walking, running, and jumping.**



Mechanical properties of bones

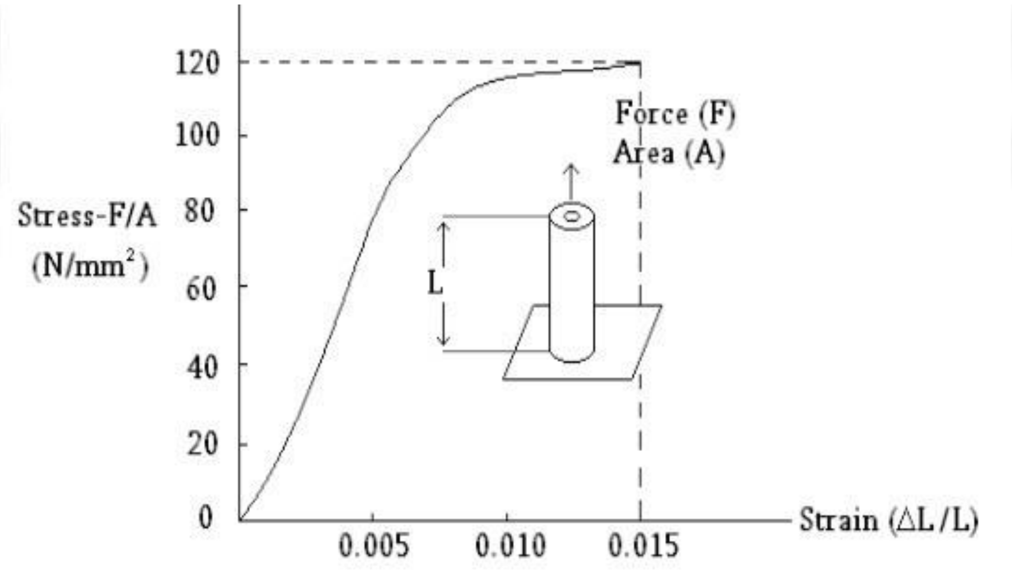
1.Density

The density of compact bones is constant = 1.9 gm/cm³ (or 1.9 times as dense as water). It is independent of age.

In old age, the bone becomes more porous and thinner due to reduced strength.

1.Bone elongation under tension and shortening under compression:

According to Hooke's law below a sample (e.g. bone) under a tensional force (F) will increase in length (ΔL) as the force increases, and the bone breaks at a stress of about 120 N/m². Healthy compact bone is able to withstand a compressive stress of about 170 N/m².



Young's Modulus of Elasticity of compact bone = 1.8×10^{10} N/m²

Hooke's law:

$$\sigma = Y\,\xi \text{, (stress-strain)}$$

How can derive Young's Modulus?

According to the definitions for:

Stress: the force (F) per unit area (A) of the sample

$$\sigma = F / A$$

- Tension: pulling it apart
- Compression: pushing it together

Strain: fractional change in length due to stress

(the ratio of the change in the length (ΔL) of the sample (e.g. bone) to the original length (L0))

$$\xi = \Delta L / L$$

Young's modulus: is the relationship between stress and strain

$$Y = \sigma / \xi = LF / A\Delta L$$

How can derive Young's Modulus?

Example:

Assume leg has a 1.2 m shaft of bone with an average cross-sectional area of 3 cm² what is the amount of shortening when body weight of 700 N is supported on the leg? (Y.M=1.8×10^{10} N/m²).

Solution:

$L0 = 1.2$ m, $A = 3$ cm² → 3×10^{-4} cm^2 $F = 700$ N

$\Delta L = LF / (A Y)$

$= (1.2 \times 700) / (3\times10^{-4} * 1.8\times10^{10})$

$\Delta L = 0.000155$ m

H.W: Calculate the change in length of a bone the original length is 40 cm exposed to a limited stress 2.33×10^{3} N/m², knowing that Y.M.= 1.8×10^{10} N/m².

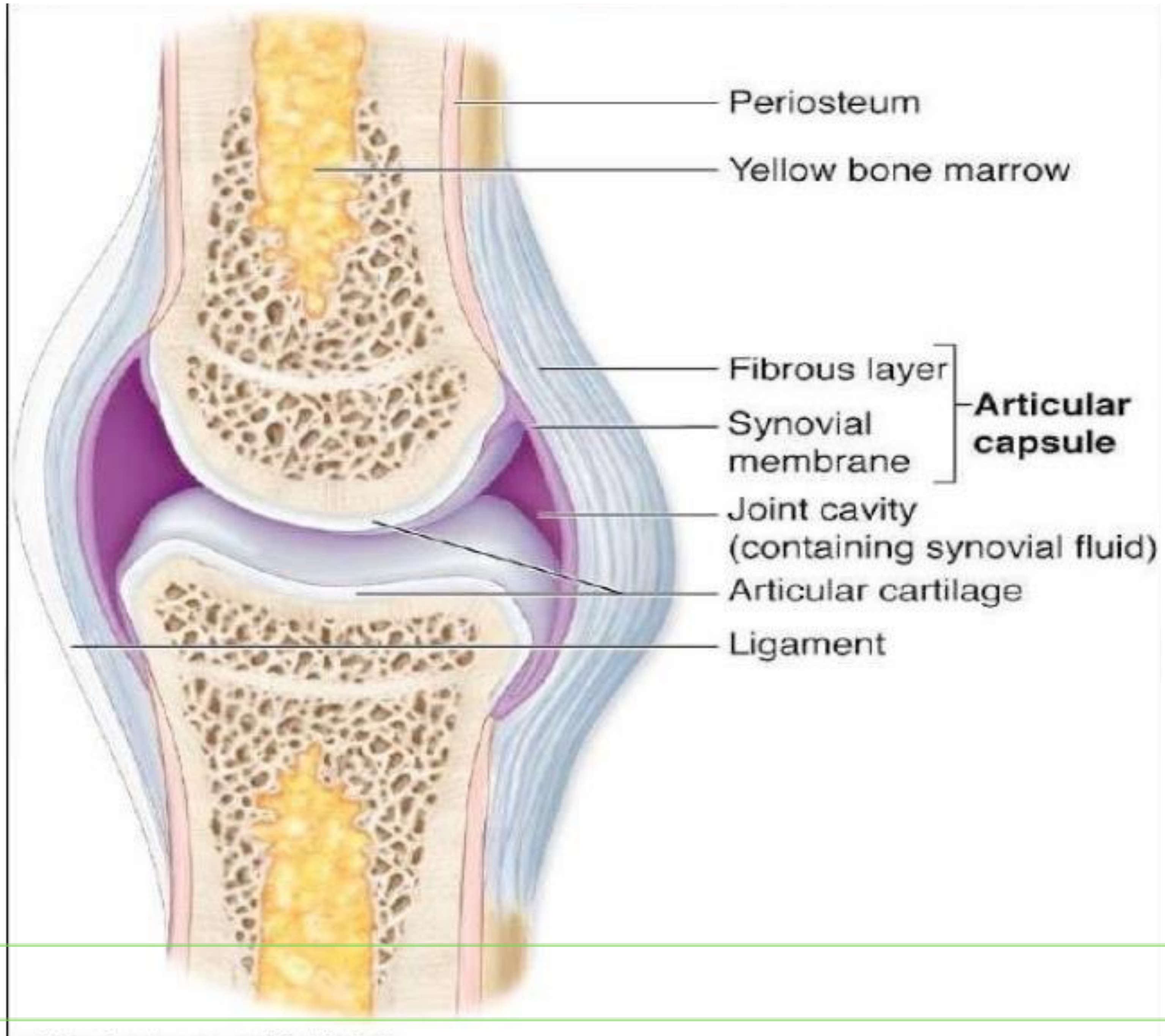
Lubrication of Bone Joints

Joints are places in the body where two bones come together. Each bone ended with synovial fluid, and the joints made most of the body movement. The surface of the articulate cartilage does not smooth the roughens of the cartilage but plays a useful role in joint lubrication by trapping some of the synovial fluid and because of its porous nature, another lubricating material is squeezed into the joint when it is under great test stress when it needs the most lubrication.

When the pressure increases on the joint, the lubrication threads squeeze out of the cartilage into the joint in one end each lubricating thread remains in the cartilage, and as the pressure is reduced the threads pull back into their holes. The viscosity of the synovial fluid decreases under the large shear stresses found in the joint.
The coefficient of friction of a healthy joint was found to be 0.01.

Lubrication of Bone Joints

Viscosity ∝ 1 / Lubrication



a Typical synovial joint

Measurement of bone mineral

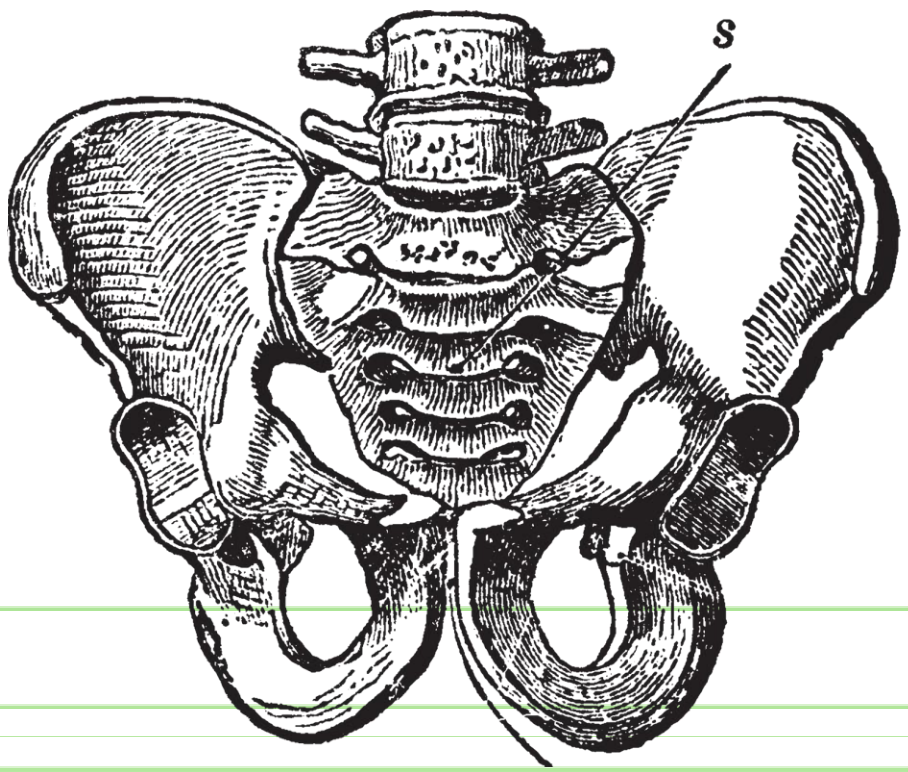
A few years ago, osteoporosis was difficult to detect until a patient appeared with broken hip or crushed vertebra. At that time it was too late to use preventive therapy. The strength of bone depends on the mass of bone mineral present. The physical techniques for studying bones are:

1. X-ray image: to measure the bone mineral, it is an old one. There are some problems of using x-ray, these are:

- X-ray beam has different energies and the absorption of x-ray by Ca varies rapidly with energy.
- Scattered radiation when it reaches the film.
- The film is a poor detector for making quantitative measurements.

The three problems are eliminated by using:

1. Mono energetic x-ray or gamma ray source.
2. A narrow beam to minimize scatter.
3. A scintillation detector that detects all photons.



Measurement of bone mineral

2. Photon absorptiometry technique: the determination of bone mineral mass by using:

$MB = K \, Log \, (I^o/I)$

MB: bone mineral, I^o: initial intensity, I: final intensity, k: constant.

3.Activation technique: take the fact that nearly all of calcium in the body is in the bones. The whole body is irradiated with energetic neutrons that convert a small amount of calcium and some other elements into radioactive forms that given off gamma rays, and the emitted gamma rays then detected and counted, the gamma rays from radioactive calcium can be identified by their unique energy.

First semester exam

Question 1:

A femur bone has an original length of 0.9 m and a cross-sectional area of 4 cm^2. If it is subjected to a force of 800 N, what is the amount of shortening? (Young's Modulus of bone = (1.8×10^{10} N/m^2)

Question 2:

If an arm bone is subjected to a stress of 3×10^6 N/m^2 and its Young's Modulus is 1.8×10^{10} N/m^2, calculate the resulting strain.

What type of bone tissue is primarily found in short bones?

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Lecture 2

02

Energy, Work and Power of the body

Energy, Work and Power of the body

Energy (E): Is the quantitative property that must be transferred to an object in order to perform work on, or to heat, the object. The SI unit of energy is the Joule(J). Common forms of energy include the kinetic energy, potential energy, the chemical energy, the radiant energy carried by light, and the thermal energy due to an object's temperature.

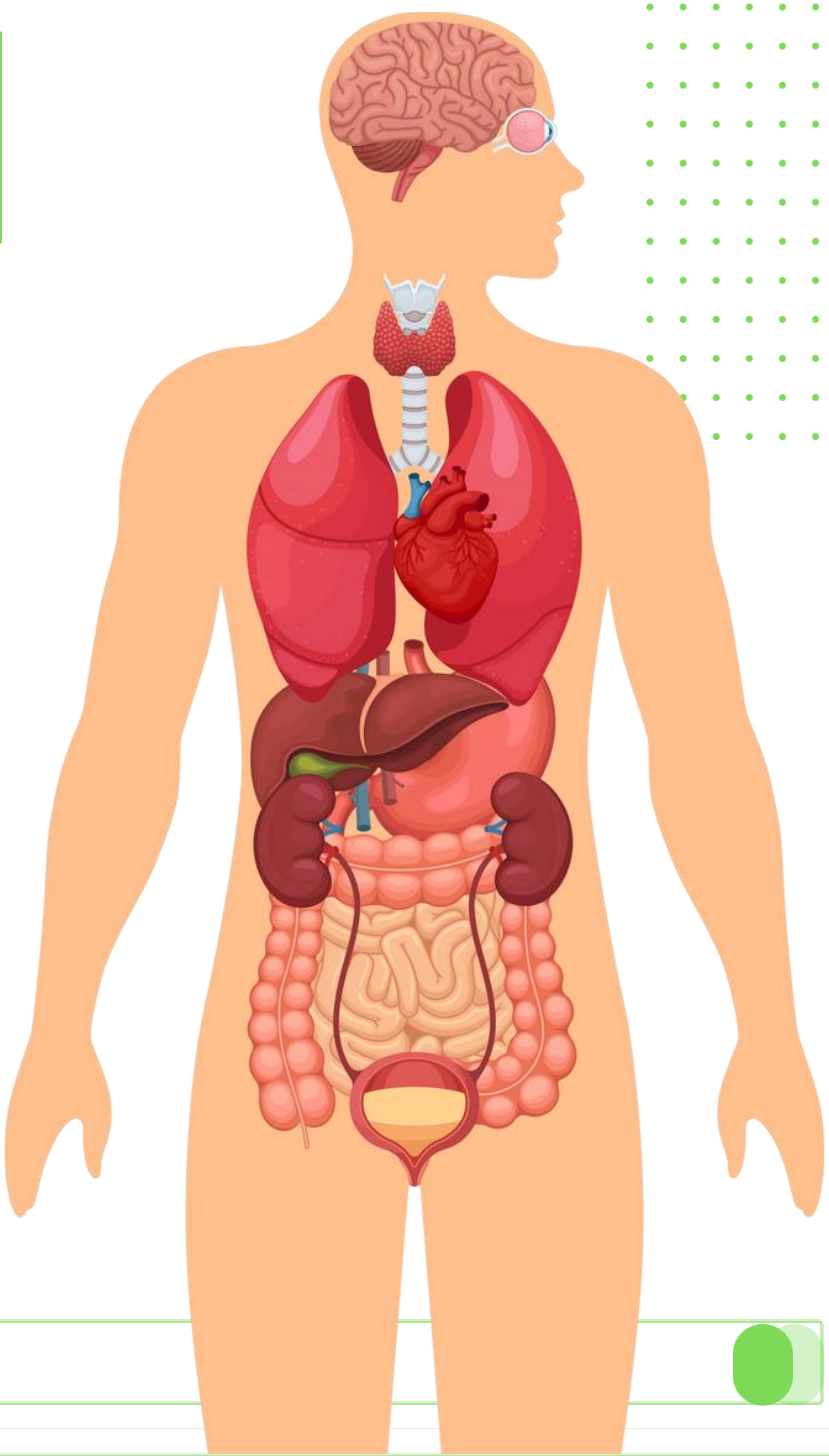
Work (W): Is defined as product of the force (F) and the distance (x) over which the force is applied. Work is done when a force is applied to an object and the object is moved through a distance, the unit is 1 N·m = J.

$$W = \text{Force} \times \text{Distance}$$

Power (P): Is the rate of doing work (W) or transferring heat, the amount of energy transferred or converted (E) per unit time (t). The SI unit of power is the joule per second (J/s), known as the Watt.

$$P = W/t$$

The Energy in Human Body



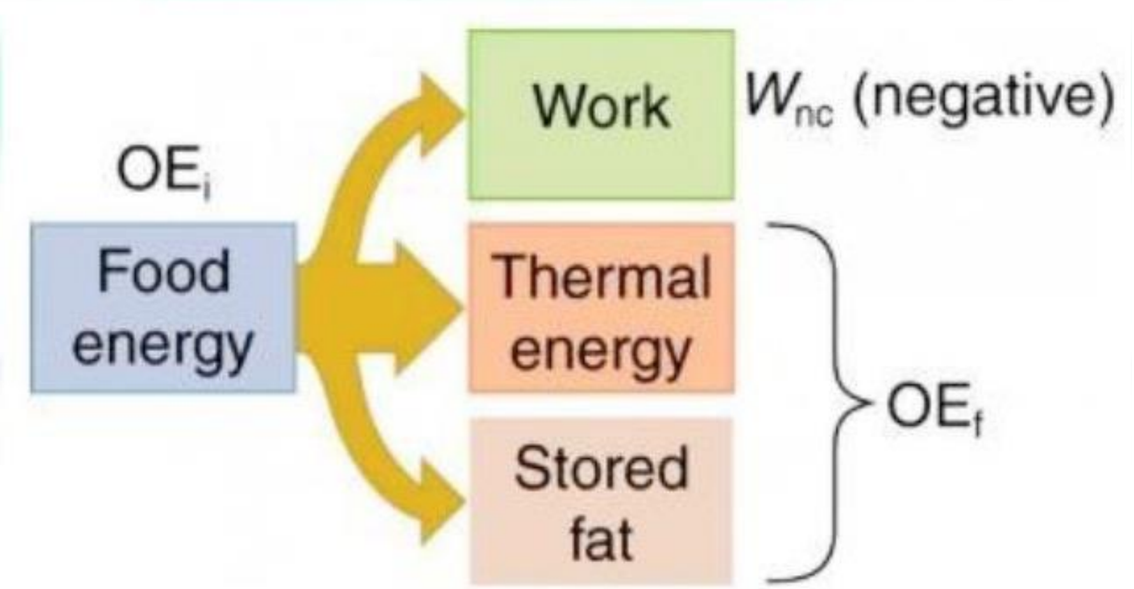
All body activities including thinking, doing work, or keeping the body temperature constant involve energy changes. For example under resting conditions the skeletal muscles and the heart using 25% of the body's energy, another 19% is being used by the brain, 10% is being used by the kidneys, and 27% is being used by the liver and the spleen. A small percent of about 5% of food energy being excreted in feces and urine. Extra food energy will be stored mainly as fat. External heat energy from environment can help maintain the body temp., but it has no use in body function.

The body uses the food energy to:

1.Operate body various organs.

2.Maintain a constant body temperature.

3.Do external work for example lifting.



Energy consumed by humans is converted to work, thermal energy, and stored fat. By far the largest fraction goes to thermal energy, although the fraction varies depending on the type of physical activity.

Conservation of energy in the body

The conservation of energy in the body is expressed by the first law of thermodynamics:

The change in stored energy in the body (food energy, body fat, and body heat) = The heat lost or gained from the body + Work done

$\Delta U = \Delta Q \pm \Delta W$ ………… ……………. (1)

Where:

ΔU: is the change in stored energy.

ΔW: is the work done by the body.

ΔQ: is the heat lost or gained.

The rate of change of energy is given by:

$$\frac{\Delta U}{\Delta t} = \frac{\Delta Q}{\Delta t} \pm \frac{\Delta W}{\Delta t} \quad \text{………… ……….. (2)}$$

Conservation of energy in the body

Where:

ΔU/Δt: Rate of change of stored energy.

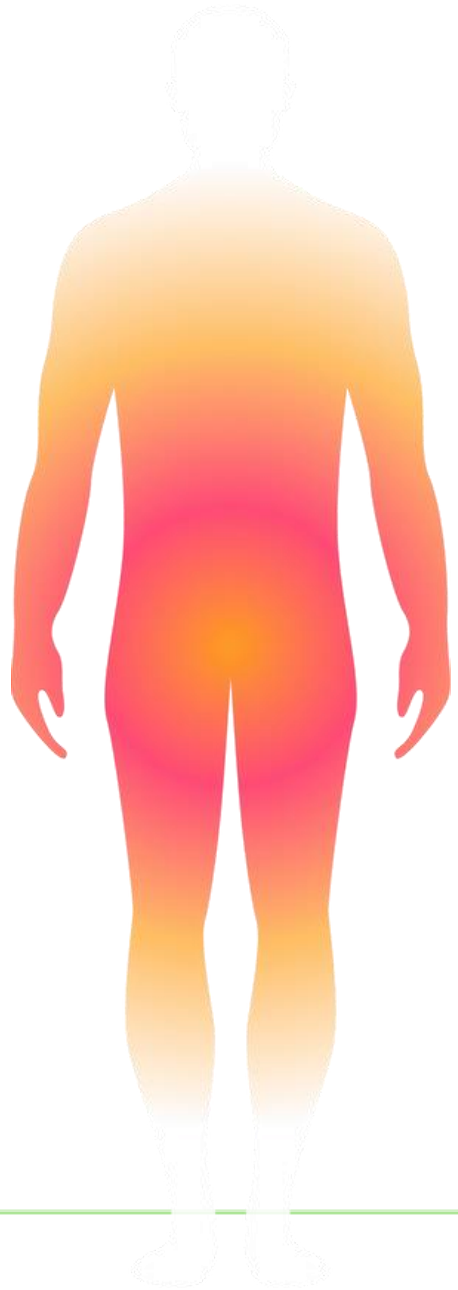
ΔW/Δt: Rate of doing work.

ΔQ/Δt: Rate of heat loss or gain.

Equation tells us that energy is conserved in all processes, but it does not tell us whether or not a process can occur.

The body's basic source of energy is the food energy; it must be chemically changed by the body to make molecules that can combine with oxygen in the body's cells.

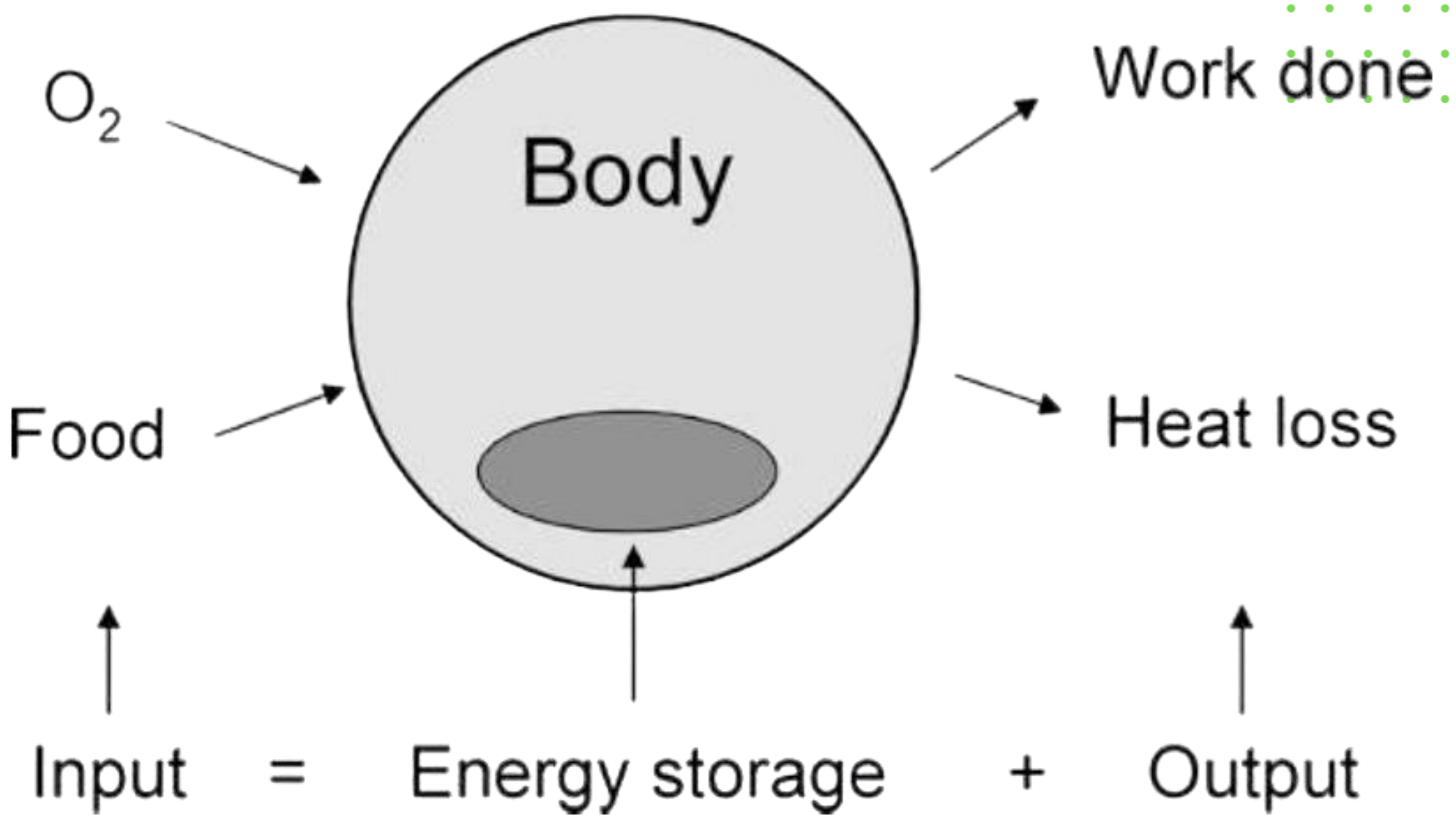
Figure below



Conservation of energy in the body

All types of energy have the same units, including heat (often expressed in terms of calories) and work (often expressed in terms of joules). One important conversion between units is:

1 calorie (cal) = 4.184 joule (J).



Energy flow into and from the body

Energy Content of Body Fuel

There is some similarity between metabolic oxidation and combustion, even though the body does not "burn" its fuels in oxygen. It is useful to learn about the combustion of these fuels because combustion tells you the maximum amount of energy that is available from breaking and rearranging bonds.

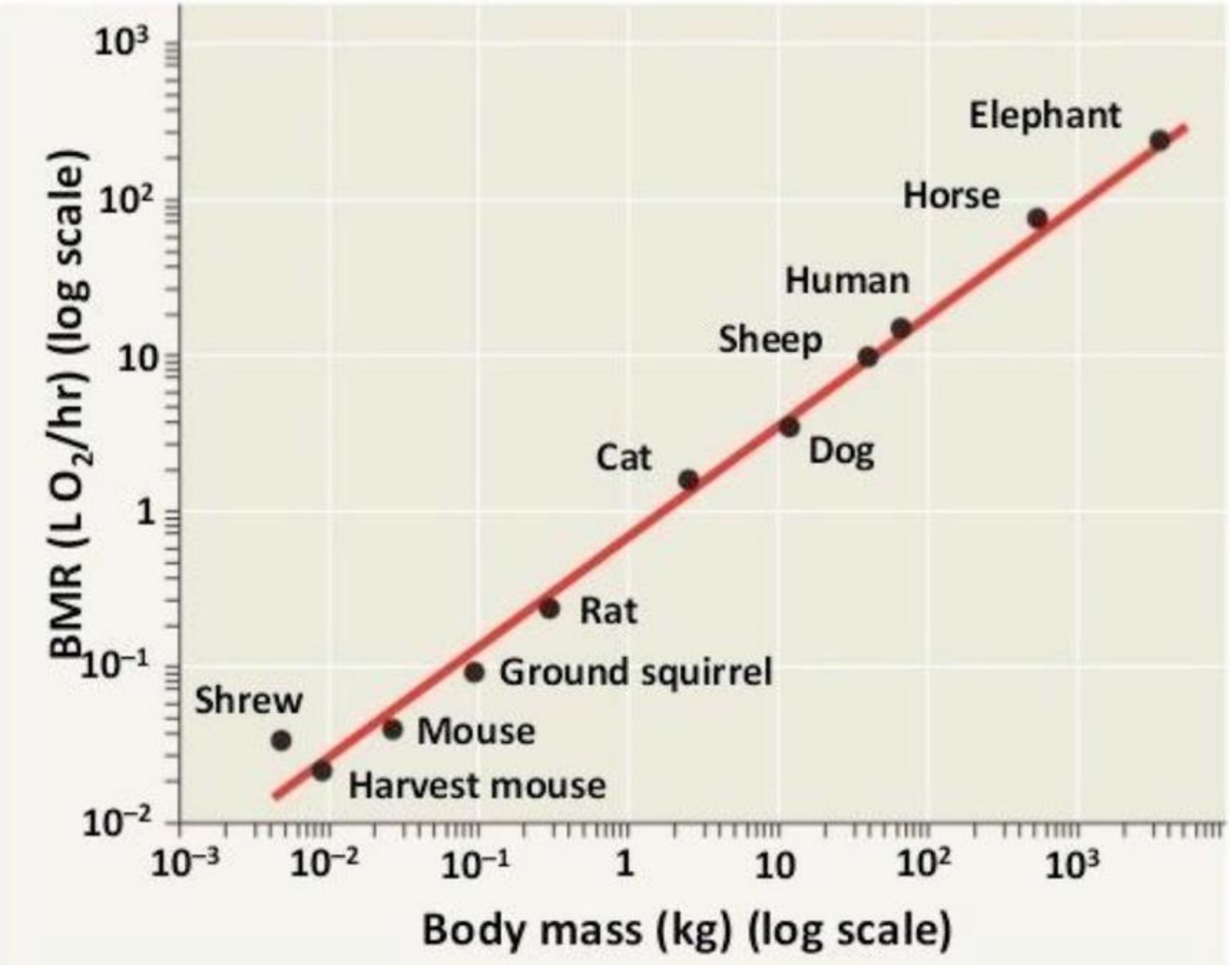
What do you mean oxidation?

Oxidation: A chemical process in which oxygen is used to make energy from carbohydrates (sugars). Also called metabolism. The oxidation process within the body, heat is produced as energy of metabolism.

The Basal Metabolic Rate (BMR)

BMR: It is the amount of energy needed to perform minimal body functions (such as breathing and pumping the blood through the arteries). BMR depends primarily upon thyroid function. A person of an over active thyroid has a higher BMR than a person with normal thyroid function. Since the energy used for basal metabolism becomes heat and dissipated from the skin, so BMR is related to the surface area, or the mass of the body. The metabolic rate depends on temperature of the body, and on sex, age, height, and weight. The BMR is proportional to mass.

The Basal Metabolic Rate (BMR)



Relationship between BMR and body mass for different beings

Mechanical Work and Power

The first law of thermodynamics equation (1) shows that stored energy can be used to supply heat or work. For people, this is mechanical work.

Mechanical work is the force you apply to an object (F) × the distance you push or pull it (x) and it can be also written as:

$\Delta w = F.\ \Delta x$ ………… ………… (3)

Or with accurate meaning:

$\Delta w = F\ \Delta x \cos(\theta)$ ………… …… (4)

where θ is the angle between F and the direction of movement.

The power is work per unit time.

$$P = \frac{\Delta w}{\Delta t} = F\frac{\Delta x}{\Delta t}\ ; \qquad \frac{\Delta x}{\Delta t} = v$$

$P = F\,v$ …………… ……………… (5)

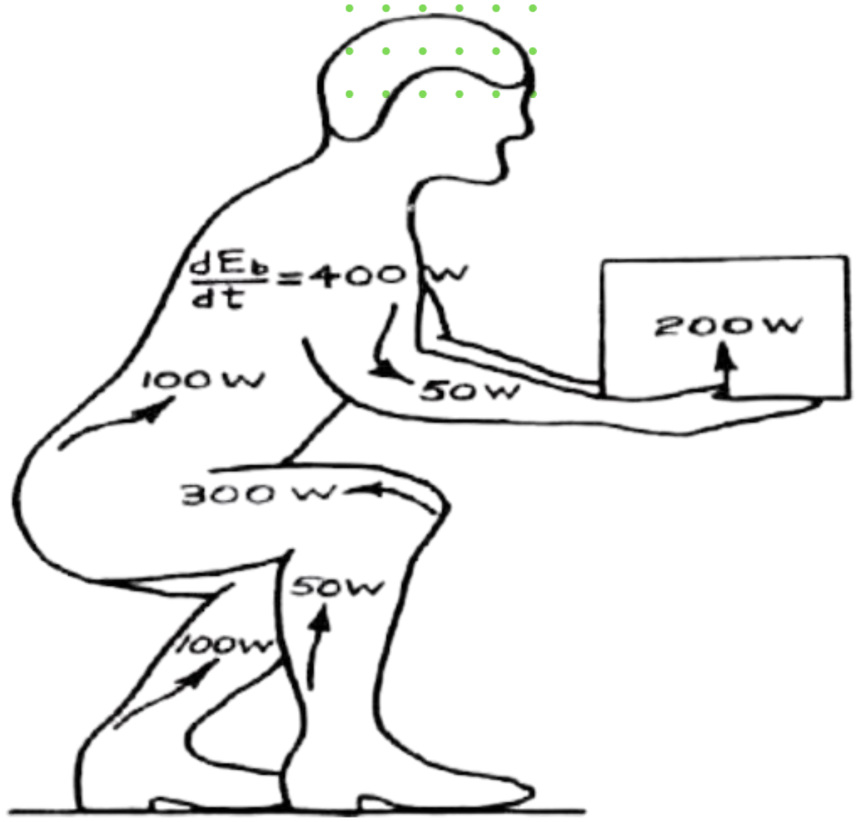
Mechanical Work and Power

where v is the velocity. When the force is perpendicular to the displacement (θ=90) work will be zero, such as walking body, his weight is perpendicular to distance of movement but practically it will not be zero because the uses energy against friction and other movement of his body, but in the case of climbing person for distance (h) the weight is on the same line of displacement then the work given

in the equation below

w = mgh where: g=9.8 m/sec2

we can call external work, work is also done about the joints of the body to lift the center of mass of the body itself, which is internal work. Also, concentric muscle contractions are said to do positive (mechanical) work, while eccentric contractions do negative work. Walking on level ground requires equal amounts of positive and negative work. Walking uphill requires relatively more positive work, while walking downhill requires relatively more negative work Figure below.The work efficiencies of positive and negative work are different.



"Internal" vs. "external" work in lifting an object.

Mechanical Work and Power

The efficiency of human body can be obtained from the law:

$$Efficiency\ (\mathcal{E}) = \frac{\text{The work done (output)}}{\text{The energy consumed (input)}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

$$\mathcal{E} = \frac{w=mgh}{E} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

Energy consumed = Metabolic Rate

Example

Person raising a box of mass (15 kg) to a table is (2 m) from the ground,Calculate the necessary energy in the units of calories, assuming that the efficiency of this person is (25%) and acceleration of the gravitational is (g=9.8 m/sec2).

Solution

$$\mathcal{E} = \frac{mgh}{E} \rightarrow E = \frac{mgh}{\mathcal{E}}$$

$$E = \frac{15 * 9.8 * 2}{0.25} \rightarrow E = 1176\,J$$

1 cal = 4.184 J

$$E = \frac{1176\,J}{4.184\,J/cal} \rightarrow E = 281.07\,cal$$

Modes of Heat Loss

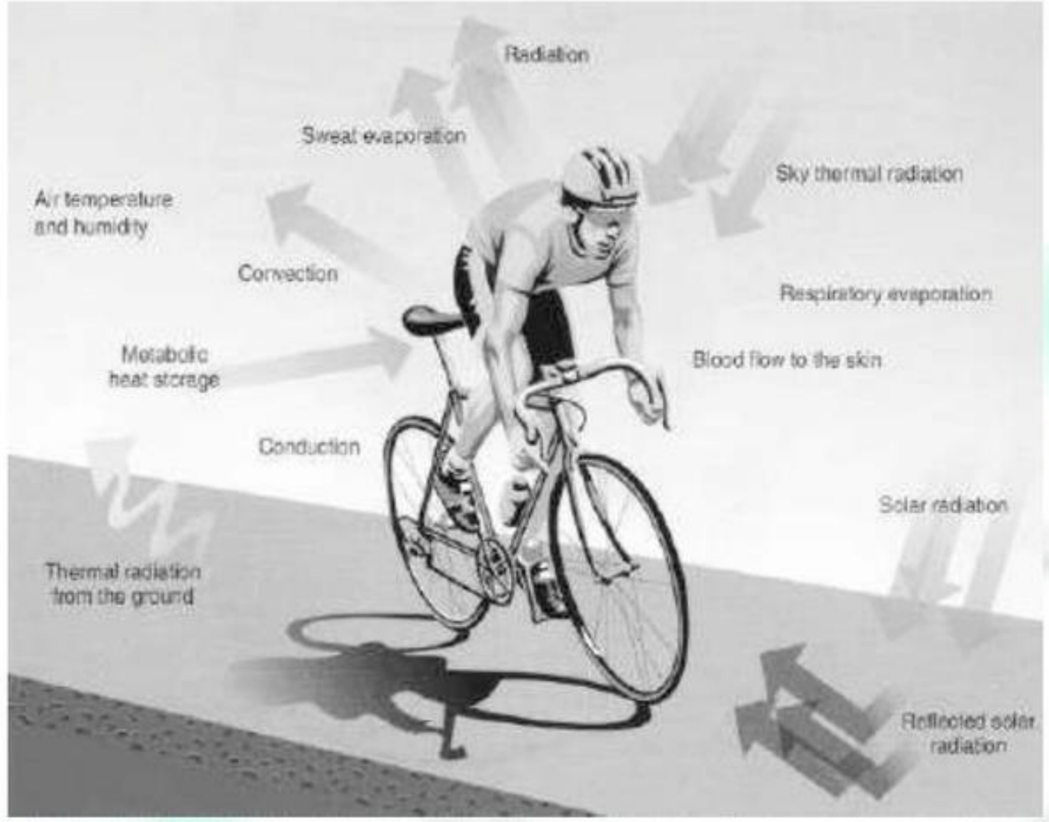
There are four modes of heat loss. -Figures (below).

1. Radiation loss.

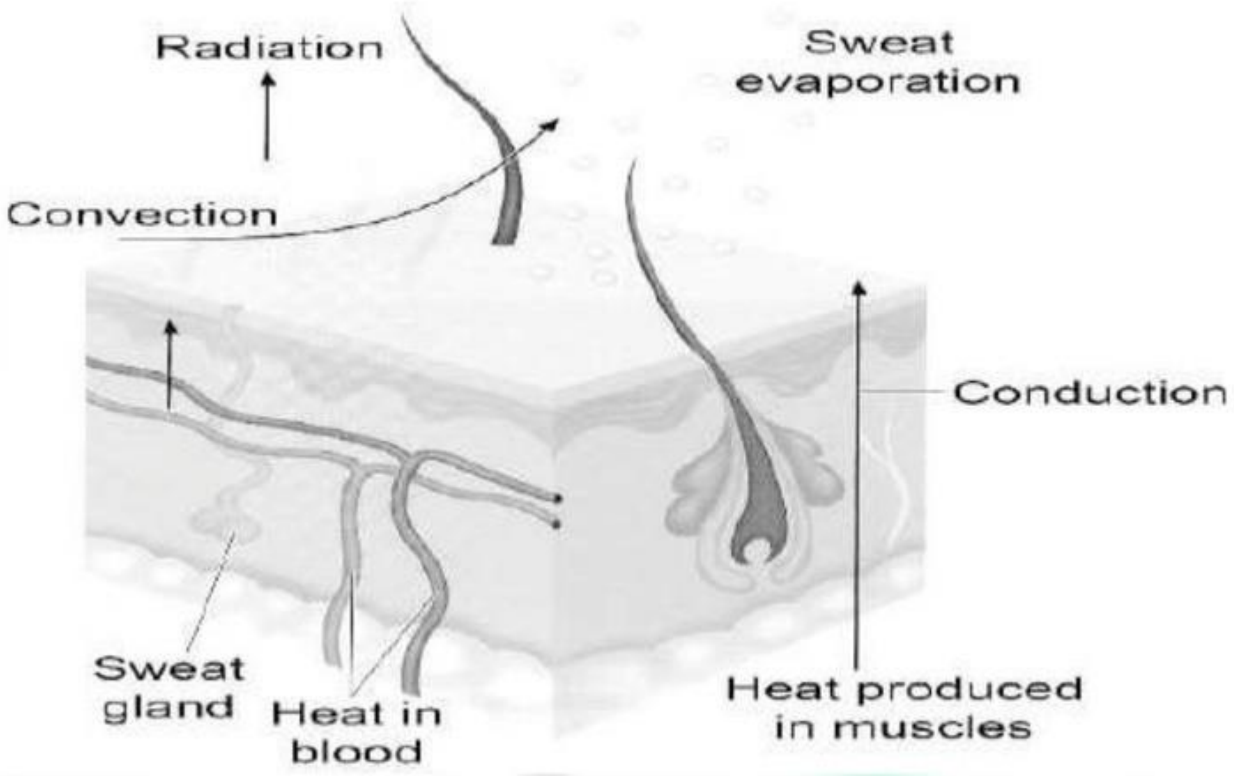
2. Convection and Conduction of air from the body .

3. The Evaporation of sweat .

4. The Evaporation of water through breathing



Overall body modes of loss of heat



More microscopic view of modes of heat loss by removal from the skin.

H.W: Calculate the power of a man who has completed a work of 7.2×10^3 Joule within a period of time estimated at 20 minutes.

Solution

second semester exam

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second semester exam

Lecture 3

03

Heat and Cold in Medicine

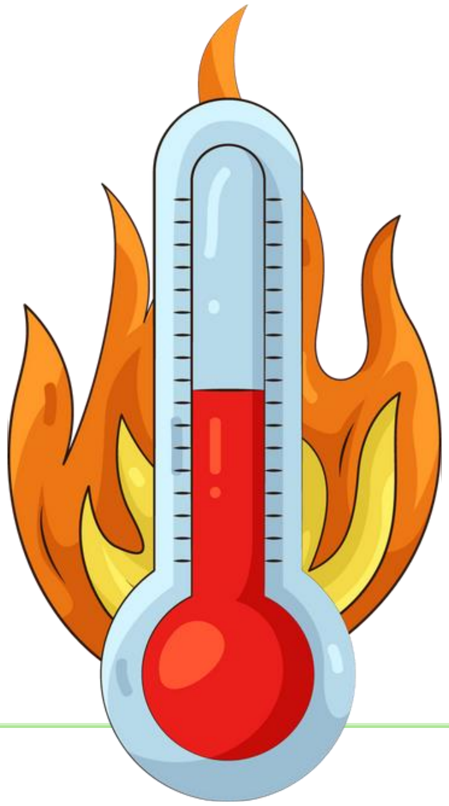
Definition of Heat

Heat is a form of energy associated with the movement of atoms and molecules in a substance. It is the energy that is transferred between systems or objects with different temperatures. The transfer of heat always occurs from a region of higher temperature to a region of lower temperature until thermal equilibrium is achieved.

Energy Transfer: **Heat is not a substance but a mode of energy transfer due to temperature difference.**

Units of Measurement:

- **SI Unit: Joule (J)**
- **Common Units: Calorie (cal)**



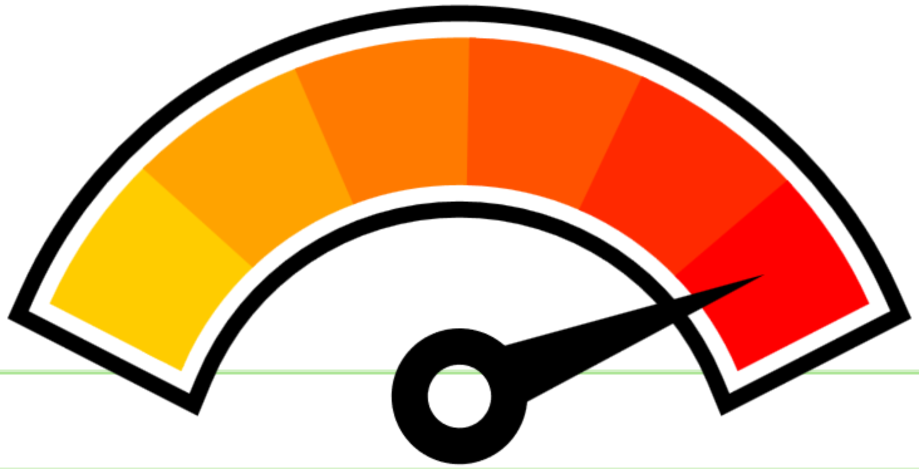
The effect of heat on the material

As molecules of all materials are moving, so they have kinetic energy (K.E). The average kinetic energy of an ideal gas can be shown to be directly proportional with temperature. The same thing is for liquids and solids. The movement of gas molecules are more free than liquid and liquid molecules are more free than solid, an increase of temp. of any material means an increase in the energy of molecules of that material. If enough heat added to a solid, it melts, forming a liquid. The liquid may be changed to a gas by adding more heat. Adding still more heat converts gas to ions.

Solid + heat ⇒ liquid

Liquid + heat ⇒ gas

Gas + heat ⇒ ions



Definition of Temperature (Temp.)

Is a physical quantity expressing hot and cold. It is measured with a thermometer calibrated in one or more temperature scales.

Thermograph - mapping the body's temperature

The surface of the body temp. is slightly different in different parts. Depending on external physical factors and internal metabolic and blood supply to the skin. All objects regardless on the temp. emit heat radiation. The body heat can give infrared radiation (IR) of long waves, which are not visible. By using this principle the thermograph instrument was designed to measure the radiation emitted from a part of the body, The total radiation power per surface area (P) is is given by Stefan – Bultzman Law : The power radiated (P) from a black body is directly proportional to the fourth power of the black body's thermodynamic temperature T (P αT^4):

P= e σ T^4 .... (1)

Where T: is the absolute temp. of the body ،e: is the emissivity depends upon the emitter material and its temp. for radiation from body e is almost 1 ,

σ: is the Stefan –Boltzmann constant=5.7×10^{-12} Watt/cm^2 °K^4.

Example

What is the power radiated per square centimeter from skin at a temperature of 306°K (33°C)? 2.What is the power radiated from area 1.75m 2 ($1.75\times 10^4 cm^2$) of a body?

P= e σ T^4 = (5.7×10^{-12}) $(306)^4$=0.05 W/cm^2

P= (0.05) ($1.75\times 10^4 cm^2$) =875 W.

Heat production for therapy

Heat production for therapy

Heating of tissue may be beneficial to damaged tissues. So that heat has two therapeutic effects:

1. Increase in metabolism resulting relaxation in capillary system(vasodilatation)

2. Increase in blood flow when blood moves to cool the heated area

1- Conductive heating:

Which transferred by conduction from the warmer object to the cooler one. (Hot bath, hot pack,electric heating pad, etc.)

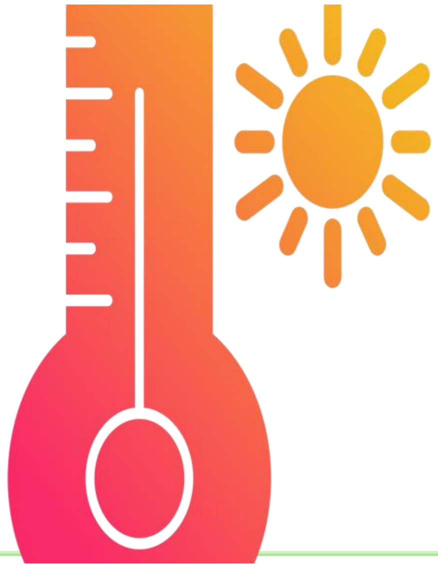
The total heat transferred will depends upon:

a) Contact area

b) Time of contact

c) Temperature different

d) The thermal conductivity of materials



Heat production for therapy

2- Radiant (IR) heating:

Heat radiation can be achieved by using infrared radiation (IR), it penetrates about (3mm) in the skin. It is considered to be more effective than conductive heating because it can penetrate deeper.

3- Electromagnetic (E.M) wave (Diathermy)

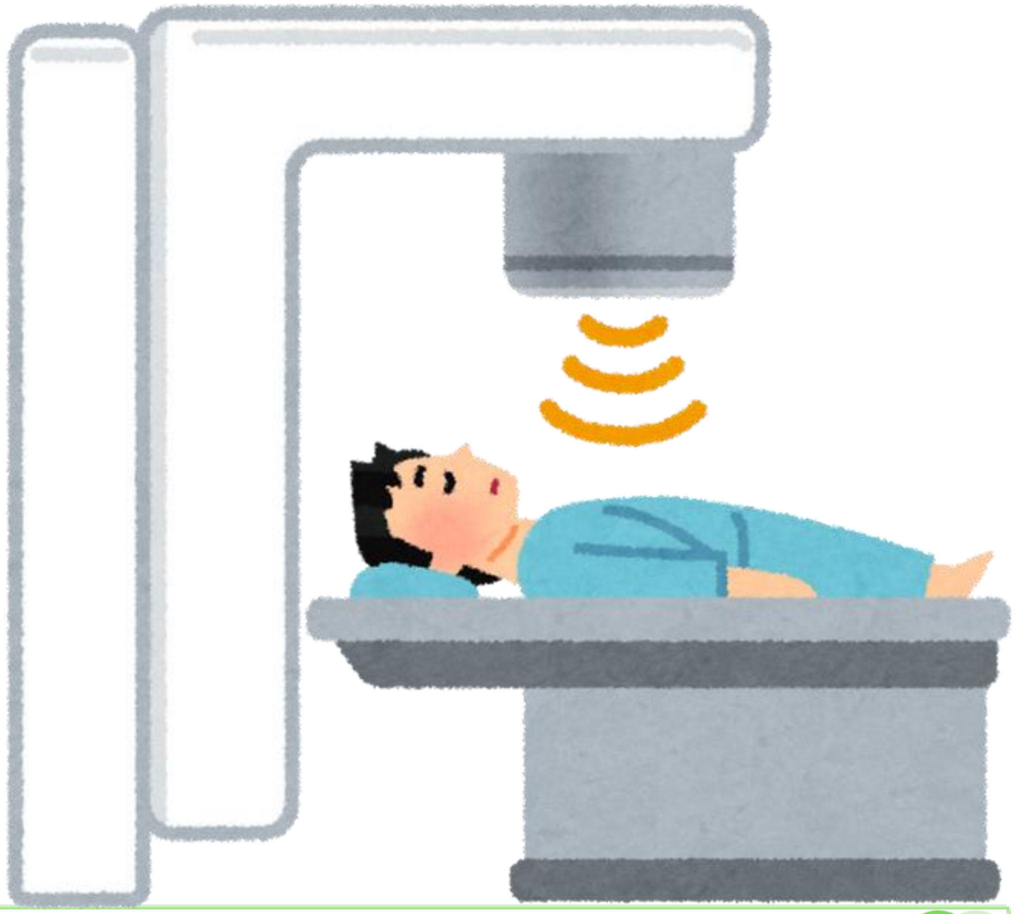
The energy (E) of electromagnetic waves is expressed in the following relationship:

E=hυ ……….. .... (2)

Where h is Blank's constant (h= 6.626×10^{-34}J/s , υ the frequency (υ=1/ λ)

So the classified according to energy E→υ→ λ:

A- Short-wave Diathermy with (λ = 10nm and υ =30 MHz) - (MHz =10^6 Hz)



Heat production for therapy

B- Long Wave Diathermy with $\upsilon = 10$ kHz

Heat from diathermy penetrates deeper into the body than radiant and conductive heat, thus it is useful for internal heating. It used in treatment of inflammation of the skeleton , bursitis , neuralgia ,Muscle spasm, pain from protruded intervertebral discs , degenerative joint disease.

- **Body absorption of radiation**

In physics, absorption of electromagnetic radiation is the way in which the energy of a photon is taken up by matter, typically the electrons of an atom. Thus, the electromagnetic energy is transformed into internal energy of the absorber, for example thermal energy.

In the body if the radiation intensity at the surface is (Io) penetrates the tissue with thickness (D), then the radiation intensity (I) at depth (x) is:

$I = Io \;\; exp^{(-x \setminus \; D)}$.................................... (3)

Heat production for therapy

4- Microwave diathermy:

Microwave diathermy utilizes electromagnetic radio waves used in treatment of fractures, sprains and strains, bursitis, injuries to tendons. we use microwaves diathermy for deep area covered with fatty layers.

Absorption of Microwave beam depend on :

1. The amount of water in the tissue. Because the energy is deposited more effectively in tissue with high water content, microwave energy is absorbed better in muscle tissue rather than in fatty tissue which have less water.

2. The frequency of microwaves: The energy is absorbed is very high at frequency ~ 20 GHz (GHz = 10^9Hz). It's poorly absorbed at lower frequency nearly 100 MHz and at very high frequency >1000 GHz.

Heat production for therapy

5- Ultrasonic diathermy:

These waves are different from electromagnetic waves. It produces mechanical vibration inside tissue. It is the same as the sound waves but it has much higher frequencies about 1 MHz with power of several watts per centimeter. It can move the tissue particles backward and forward with high frequency, in doing so it can increase the kinetic energy consequently it heats the tissue. Ultrasound can be produced by special transducers placed in direct contact with the skin. It is used for relieving tightness and scarring occurring in joint disease. It can dispose more heat in bones, as bones are better absorber for ultrasonic energy than soft tissue. It is also used in deep therapy. Heat therapy has also been used in cancer treatment in combination with radiotherapy. The tumor is heated about 42°C for approximately 30 minutes, and the radiation treatment is given after heat treatment.

Heat in medicine

Heat in medicine exemplifies the integration of physics and biology to promote healing and relieve discomfort. It is used both for its therapeutic properties and as a diagnostic tool.

1.Therapeutic Applications of Heat

a. Pain Relief and Muscle Relaxation: heat increases blood flow, reduces muscle stiffness, and enhances tissue elasticity.

b. Improving Circulation: heat dilates blood vessels, improving oxygen and nutrient delivery to tissues.

c. Hyperthermia Therapy for Cancer: tumors are more heat-sensitive than normal tissues to make them more susceptible to treatments.

d. Wound Healing: heat promotes the repair of damaged tissue by improving circulation and stimulating cellular processes.

e. Fever Therapy (Pyrotherapy): Historically, fever was induced to combat infections before antibiotics.

Heat in medicine

2.Diagnostic Applications

a. Thermography is a non-invasive imaging technique that measures the heat emitted by the body for detecting inflammation or abnormal blood flow.

b. Heat-Responsive Imaging in Research: Thermal probes are used in medical research to study metabolic activity and tissue responses to temperature changes.

3.Risks and Contraindications of Heat Therapy

- Burns: Excessive heat or prolonged exposure may damage skin or tissues.
- Worsened Inflammation: Heat can exacerbate swelling in acute injuries.

Conditions to Avoid Heat:

- Open wounds or infections.
- Areas with poor circulation or numbness.
- Active bleeding or hemorrhage.

third semester exam

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third semester exam

Lecture 4

04

Heat and Cold in Medicine

Cold in Medicine

Cold plays a significant role in medicine, both as a therapeutic tool and in preserving biological materials.

Therapeutic Applications of Cold

Cold therapy, also known as cryotherapy, is widely used in medical and therapeutic settings to treat injuries, reduce pain, and manage inflammation. Mechanism: Cold reduces blood flow (vasoconstriction) to the affected area, which helps minimize swelling and numbs nerve endings, reducing pain.

Local Anesthesia

Cooling sprays or ice packs are sometimes used as a temporary numbing agent before minor procedures, such as injections or superficial surgeries.

Cold in Medicine

Cryogenics

Is the science of very low temp., it is used in biology and called cryobiology. Low temp. can be produced by liquefying gases. The storages of liquefied gases is rather difficult because it can take heat rapidly from the environment by conduction, convection, and radiation.

Moderately low temp. was successful in some types of tissue blood and semen, low temp. have been used for long term preservation of blood, sperm, bone marrow, and tissue. Liquid nitrogen (-196°C) proved to be much better for preservation than solid carbon dioxide (-79°C).For conventional blood storage with anticoagulant at 4°C about 1% of the red blood cells hemolyze each day so the blood will not be suitable after 21 day. For rare blood types should be stored longer. Blood can be preserved for very long periods if frozen rapidly in liquid nitrogen (-196°C).

Cold in Medicine

There are two ways to freeze the blood to (-196°C):

1- Blood sprayed on the surface of liquid nitrogen and then frozen in small droplets in very short time forming sand-like particles stored at liquid nitrogen temperature.

2- The blood is kept in a thin wall highly heat conductive with large surface area metal container with small spacing. The container is immersed into liquid nitrogen bath making very rapid cooling.
The preservation of large tissue like bone, muscles is still under research. Problems:

A- Large dimensions make it difficult to cool all the cells at the same rate.
B- Adding and removing protective agents is difficult.

Cryosurgery

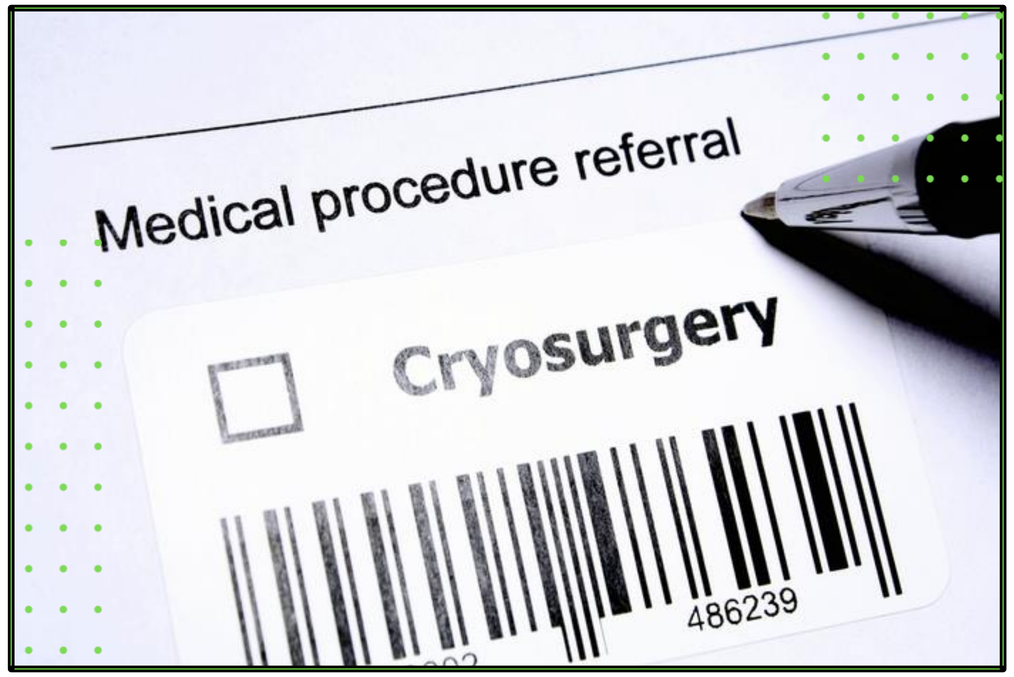
The cryogenic methods are used to destroy cells called cryosurgery. Advantages:

1- Cause a little bleeding.

2- The volume of the tissue destroyed can be controlled.

3- Little pain because low temp. desensitize the nerves.

4- Very short recovery.



Uses of Cryosurgery

Treatment of:

1. Parkinson's disease (Shaking Palsy) associated with basal ganglion of the brain. Treatment is done by destroying the part of the thalamus that controls transmission of nerve impulses.
2. Tumors and warts.
3. Eye surgery: repair of detached retina, cataract surgery.

Physiological Effects of Cold on the Body

a. Vasoconstriction

- Cold causes blood vessels to constrict, reducing blood flow.
- Benefits: Minimizes swelling and bruising.
- Risks: Prolonged exposure can lead to tissue damage.

b. Nerve Response

- Cold slows nerve conduction velocity, reducing pain perception and muscle spasms.

c. Metabolic Rate Reduction

- Cold lowers the metabolic activity of cells, beneficial in reducing inflammation and preserving tissues.

d. Hypothermia

- Medical Hypothermia: Deliberate cooling of the body to reduce metabolic demand and protect organs during surgeries or after cardiac arrest.

Fourth semester exam

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Questions:

- Briefly explain the two methods used to freeze blood for long-term preservation using liquid nitrogen, mentioning the advantage of each method.
- What are the main advantages of using cryosurgery compared to traditional surgery, according to the text?

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Fourth semester exam

Lecture 5

05

Thermometer and its kinds, Heat Transfer

Specific heat, heat capacity, latent heat

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 temp.

There are three temperature scales:

1. **Fahrenheit scale (°F): freezing 32°F, boiling 212°F.**
2. **Celsius (°C): freezing 0°C, boiling 100°C.**
3. **Kelvin (K): same divisions as Celsius but 0 K at absolute zero = -273.15°C.**

To convert from...	Use this equation...
Celsius to Fahrenheit	$T_F = \frac{9}{5}T_C + 32$
Fahrenheit to Celsius	$T_C = \frac{5}{9}(T_F - 32)$
Celsius to Kelvin	$T_K = T_C + 273.15$
Kelvin to Celsius	$T_C = T_K - 273.15$
Fahrenheit to Kelvin	$T_K = \frac{5}{9}(T_F - 32) + 273.15$
Kelvin to Fahrenheit	$T_F = \frac{9}{5}(T_K - 273.15) + 32$

Table 1.1 Temperature Conversions

Thermometry and Temperature Scales

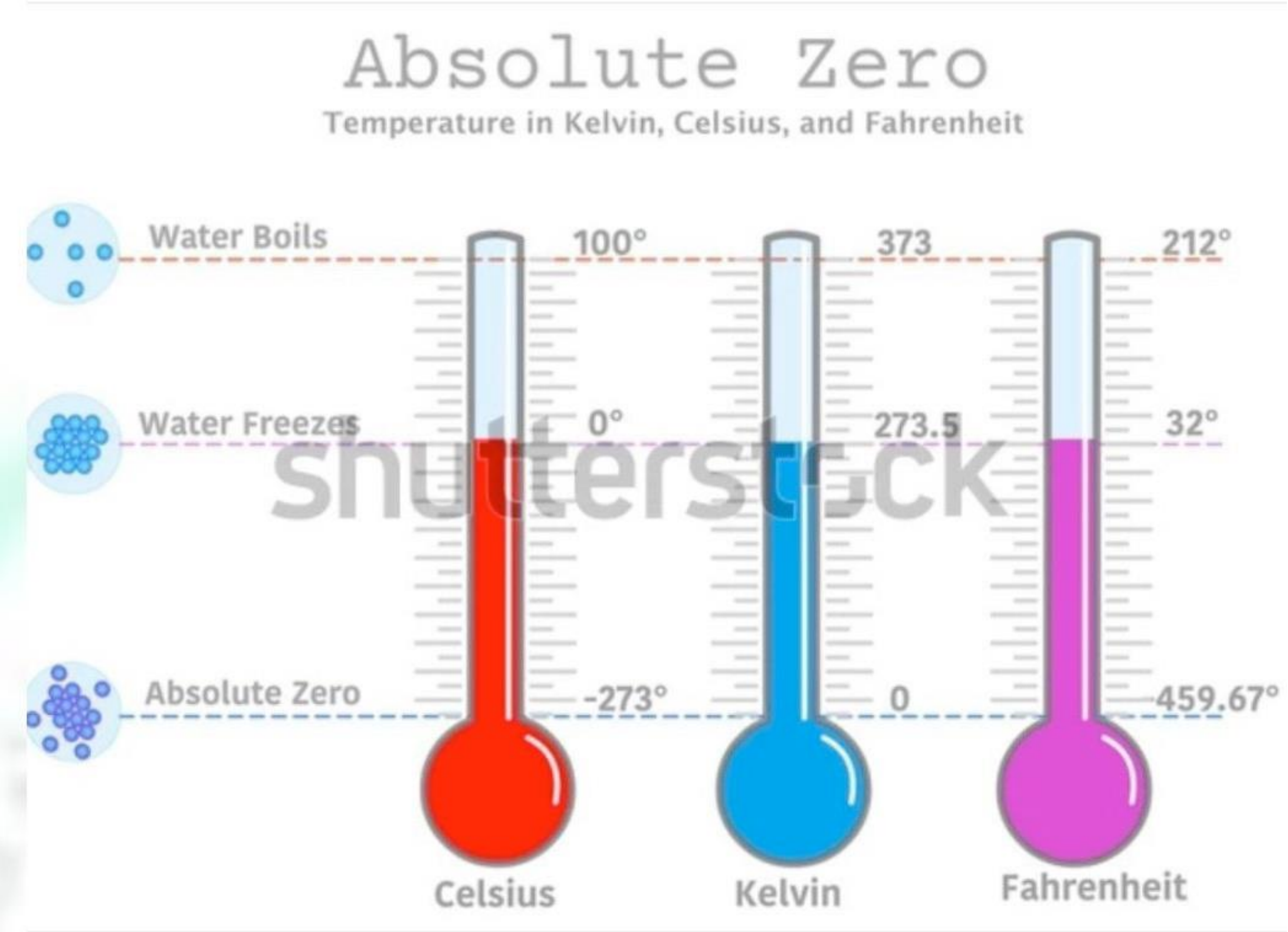


Fig. (1): Temperature Scales

Types of Thermometers

Thermometer, instrument for measuring the temperature of a system. Temperature measurement is important to many fields including manufacturing, meteorology, scientific research, and medicine, etc. A thermometer contains two essential elements: a sensor that detects a change in temperature and a device that communicates that temperature to the person reading it. Thermometers work by utilizing the physical properties of various substances. For example, liquids and solids expand as they heat up and contract when they cool down. Similarly, gases increase in pressure as they heat up and decrease as they cool down. Using known temperatures of a substance (such as the freezing and boiling points of a liquid), you can make a thermometer that translates these physical

Types of Thermometers

changes into a number that we understand as temperature. On this basis, thermometers are classified to:

The liquid thermometer: The thermometric property is the volume.

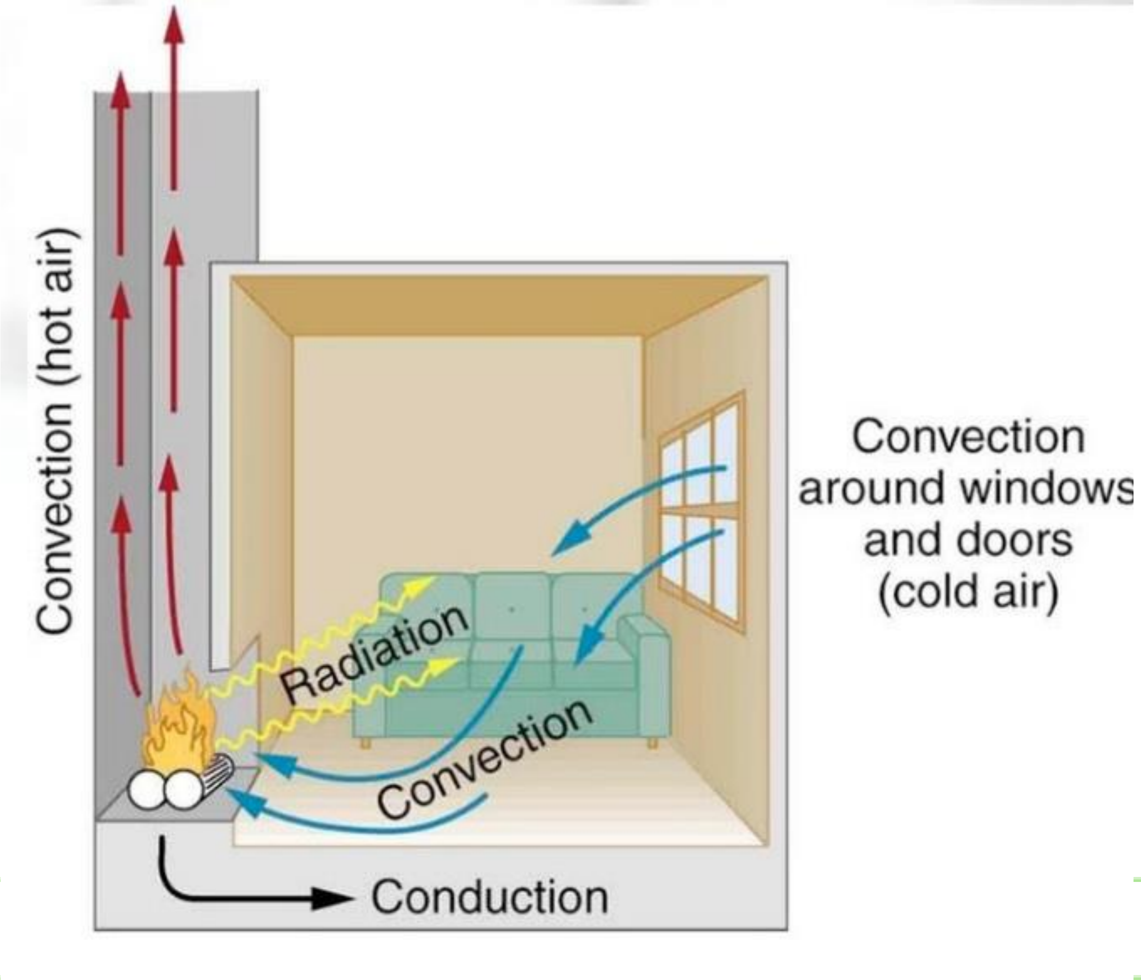
The gas thermometer: The thermometric property is the pressure at a constant volume.

Electric resistance thermometer: The thermometric property is the electric resistance for small coil of wire

Thermocouple: The thermometric property is the electromotive force.

Heat Transfer

Whenever there is a temperature difference, heat transfer occurs. Heat transfer may happen rapidly, such as through a cooking pan, or slowly, such as through the walls of an insulated cooler. There are three different heat transfer methods: conduction, convection, and radiation. At times, all three may happen simultaneously. See Figure below



Heat Transfer

Conduction is heat transfer through stationary matter by physical contact. (The matter is stationary on a macroscopic scale—we know there is thermal motion of the atoms and molecules at any temperature above absolute zero.) Heat transferred between the electric burner of a stove and the bottom of a pan is transferred by conduction.

Convection is the heat transfer by the macroscopic movement of a fluid. This type of transfer takes place in a forced-air furnace and in weather systems, for example.

Heat transfer by radiation occurs when microwaves, infrared radiation, visible light, or another form of electromagnetic radiation is emitted or absorbed. An obvious example is the warming of the Earth by the Sun. A less obvious example is thermal radiation from the human body.

Definition Heat Capacity

The amount of energy (or more specifically, the heat (Q)) that must be added to an object to raise its temperature by one degree is known as the heat capacity (Hcap) of that object), then it is given in calories/0 C or in Joules/0 C.

Mathematical expression of Heat Capacity (Hcap):

Change in thermal energy = (Heat capacity) x (Change in Temperature)

$$Q = H\ cap \times \Delta T$$

$$Hcap = Q/\Delta T$$

where Q = heat added or subtracted (calories or joules) , H cap = heat capacity (calories/ oC or joules/ oC) ,ΔT = change in temperature = T final – T initial (Celsius degrees).

Example 1

What is the heat capacity of (100 g) of iron if (9000 J) of thermal energy are required to increase the temperature of the iron by (20 oC)?

Solution:

$$H_{cap} = ?\ ,\ Q = 9000\ J,\ \Delta T = 20\ {}^{o}C$$

$$Hcap = \frac{Q}{\Delta T}$$

$$Hcap = \frac{9000}{20}$$

$$\therefore H_{cap} = 450\ J/{}^{0}C$$

Solution:

The heat capacity of an object depends both on its mass and its chemical composition, suppose m is mass of a system, then the heat capacity per unit mass is called the specific heat capacity we shall denote it by the letter C:

$$C = \frac{\text{Heat capacity (H)}}{m} = \frac{Q}{m\Delta T}$$

$$Q = mC\Delta T$$

We can also express the heat capacity by the number of moles which called molar heat capacity (Cm):

$$C_m = \frac{Q}{n\Delta T}$$

$$Q = nC_m\Delta T$$

Solution:

The specific heat can be measured under conditions either constant pressure Cp or constant volume CV.

The unit of specific heat is (Jgm-1 deg-1) and the unit of molar heat capacity is (Jmol-1 deg-1). The unit of heat is joule and we have another unit that is called Calorie (Cal). 1 Cal =4.186 J It has been found that specific heat capacity for solid material decreases when the temperature decreases and reached to zero

when temperature approaches the zero Kelvin. Then the specific heat does not depend on the size or shape of an object, but only on the material from which it is made. Table (1) Water has a large specific heat of (1 calorie per gram per degree Celsius) or (4.186 Joules per Kilogram degree Celsius). Ice floats because the volume of water increases when it freezes. This is connected to the change in the specific heat of water near 0 oC.

Object (Substance)	Specific Heat (cal/g°C)
Water	1
Ice	0.480
Soil	0.2 to 0.8, depending on water content
Average for human body	0.83
Aluminum	0.214
Protein	0.4

TABLE(1) Specific Heat for Some objects

Example 2

A. How much thermal energy is needed to raise (200 g) of iron by (10 oC)? The specific heat of iron is (0.450 J/g oC).

Solution:

$$Q = C \times m \times \Delta T$$

$$= 0.450 \times 200 \times 10$$

$$Q = 900\ J$$

B. What is the heat capacity of this object? (H.W)

❖ Note: The heat capacity is an extensive property of a given object, while the specific heat is an intensive property of an object.

Example 3

How much energy (in calories) is needed to warm up (300 kg) of water from (10 C) to a comfortable (37 C)? (Use the specific heat of the water is 1(cal/g C).

Solution:

$1Kg=1000g=10^3g$, $m=300\times10^3=$

3×10^5 g T1=10 0C, T2=37 0C ,

ΔT = T2-T1= 37-10=27 0C

$Q = C \times m \times \Delta T$

$=3\times 10^5 \times1\times27$

$Q =81\times 10^5$ cal

EXAMPLE

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Lecture 6

06

Pressure

Pressure

Pressure:
It is the force per unit area in a gas or liquid. (For solid the term pressure is replaced by "stress").
Units:
In metric system pressure is measured in units
a. Dynes per square centimeters
b. Newton per square meter (Pascal) or (Pa)
Note:
none of the above units is in common in medicine.
The used unit is the height of a column of mercury (Hg)
The peak systolic pressure = 120mm Hg = a pressure of a liquid mercury of this height on its base. While the atmospheric pressure = 760mm Hg

By the end of this section, you will be able to:

1- Explain the concept of pressure the in human body.

2- Explain systolic and diastolic blood pressures.

3- Describe pressures in the eye, skull, Digestive System , bladder, and skeletal system.

4-What Is the principle of Hyperbaric Oxygen Therapy? How Is the Treatment Performed?

Pressure is defined as the force per unit area. The pressure P under a column of liquid can be calculated from the following low:

$$P = \rho\ g\ h$$

Where the: ρ is the density of the liquid g is the acceleration due to the gravity h is height of the column

Ex:- what height of water will be produced the same pressure as 120mmHg.

Solution

$$: P = \rho\ g\ h = 13.6 \times 980 \times 12$$

$$= 1.6 \times 10^{5}\ dy/cm^{2} \quad \text{For water } P = \rho\ g\ h$$

$$1.6 \times 10^{5} = 1 \times 980 \times h$$

$$\text{So} \qquad h = 163\ cm$$

Or $(\rho\, g\, h)_{Hg} = (\rho\, g\, h)_{H2o}$

- $\rho_{Hg}\, h_{Hg} = \rho_{H2o}\, h_{H2o}$
- $h_{H2o} = (13.6x12)/1 = 163\ cmH_2o$

Ex:- Calculate the atmospheric pressure in N/m2

Solution:-

1 atm =760 mmHg =76 cmHg

The atmospheric pressure in N/m2 is equal

$$P = \rho\, g\, h =$$

$$13600 kg/m^3 \text{ x } 9.8 m/s^2 \text{ x } 0.76 m$$

$$= 1.01 \text{x} 10^5\ N/m^2$$

Gauge Pressure

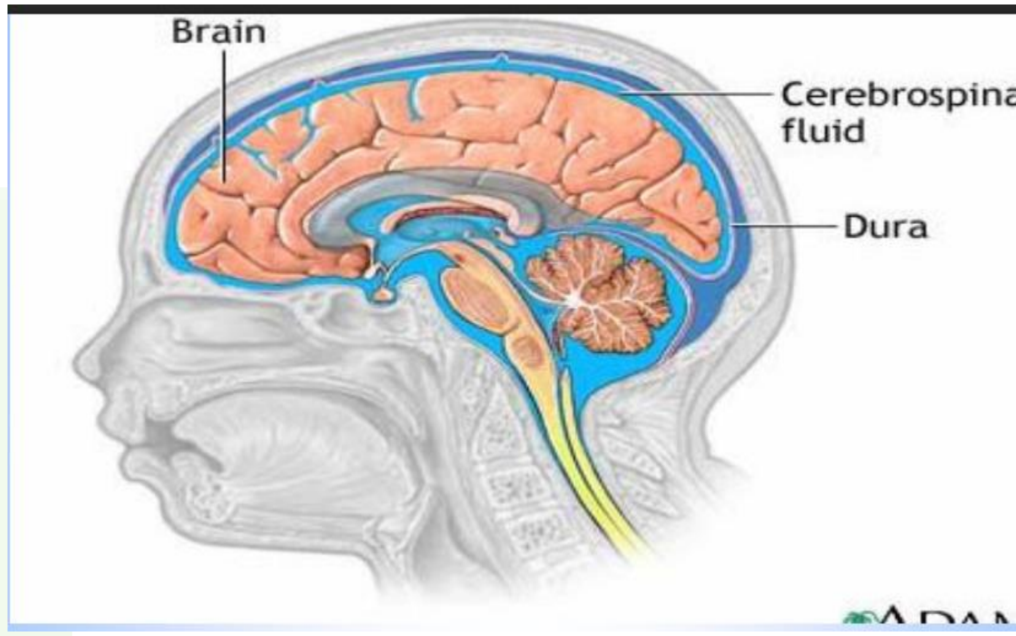
The excess pressure over atmospheric pressure

Negative Pressure

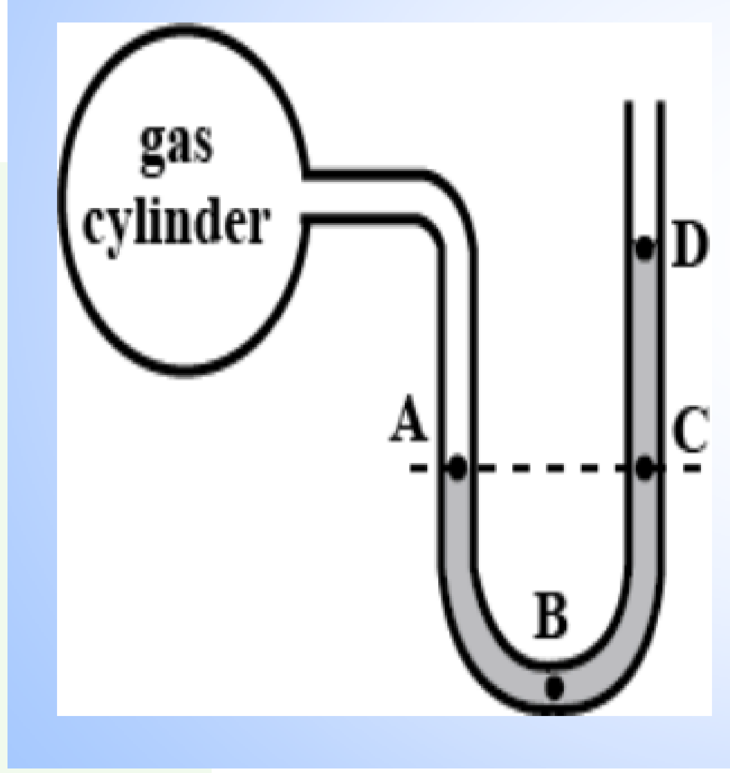
Any pressure lower than atmospheric pressure. For example: The lung pressure during inspiration is a few centimeter of water negative

There are numbers of places in the body where the pressure is lower than atmospheric pressure or negative .For example when we breath inspire the pressure in the lungs must be lower than the atmospheric pressure.
The most common clinical instrument used in the measuring pressure is the sphygmomanometer, which measure s blood pressure.

Measurement of pressure in the body An instrument that measures pressure is called a manometer.
A common type of manometer is a U-shaped tube containing a fluid that is connected to the pressure to be measured. The common clinical instrument used in measuring pressure is the sphygmomanometer



ressure inside the skull
The brain contains approximately 150cm3of cerebral spinal fluid (CSF) in a series of inter connected openings called ventricles



Thermodynamic Properties

- Any characteristic of a system is called a property and, in general, thermodynamic properties can be divided into:

1. **Extensive properties**: property that *dependent* upon the amount of mass present or upon the size or extent of a system. For example: **mass**, volume.
2. **Intensive property**: property that *independent* of the amount of mass and may vary from place to place within the system at any moment. For example: temperature, **pressure**.
3. **Specific properties** of material *are derived* from other intensive and extensive properties of that material. For example, the **density** of water: $\rho = \frac{m}{V}$

Pressure

- Pressure on the boundaries of a substance is caused by the collisions of the molecules of the substance with the boundaries of the system.
- As molecules hit the walls, they exert forces that try to push the walls outward.
- The forces resulting from all of these collisions cause the pressure exerted by a system on its surroundings.
- Pressure is a measure of the force (F) exerted per unit area (A) on the boundaries of a substance.

$$P = F/A$$

- The SI unit of pressure is the pascal.

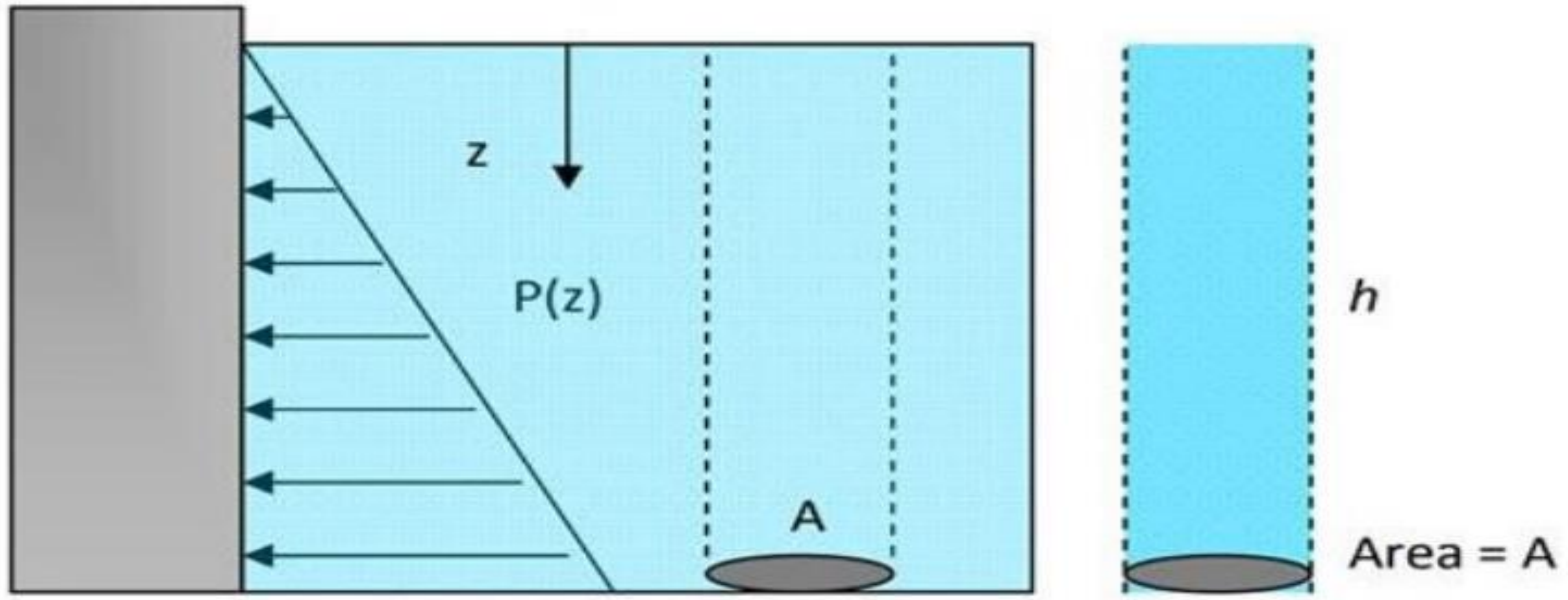
$$1\,\text{pascal} = 1\,N/m^2$$

- In fluids, gases and liquids, we speak of **pressure**;
- In solids this is **stress**.
- For a fluid at rest, the pressure at a given point is the same in all directions.

$$P = \frac{\text{Weight of liquid}}{\text{Area}}$$

$$P = \frac{mg}{A} = \frac{\rho A h g}{A}$$

$$P = \rho g h$$



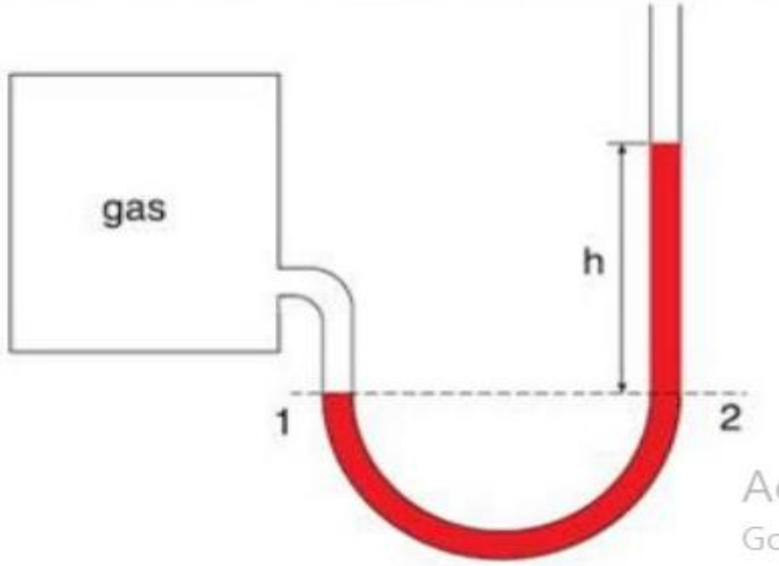
- Pressure of a fluid at rest increases with depth (due to added weight), but constant in horizontal planes.

- In thermodynamics calculations, always use **absolute pressure**, which is the actual pressure at a given position.
- An instrument that measures pressure by this method is called **Manometer**: A common type is a U-shape tube containing a fluid that is connected to the pressure to be measured.
- The levels in the arms change until the difference in the levels is equal to the pressure.

$$P = P_o + \rho g h$$

where P_o: is the atmospheric pressure.

- If the ($P < P_o$) called negative pressure,
- If the ($P > P_o$) called positive pressure.



Ideal Gas Law

- The relationship between the **pressure**, **volume**, and **temperature** for an ideal gas is given by the **ideal gas law**.

- The product of pressure and volume (**PV**) is a *constant* if the gas is kept at isothermal conditions.
- The value of the *constant* is **nRT**, so the ideal gas law

$$PV = nRT$$

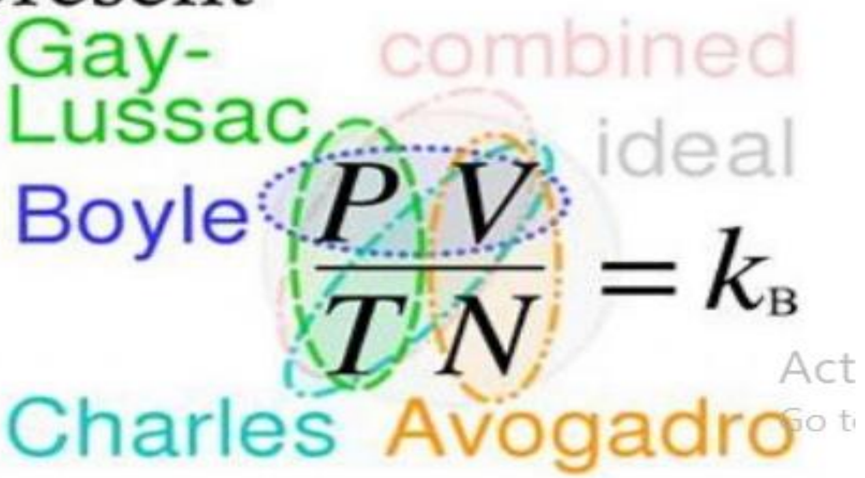
where **n** is the number of moles of gas present

R is the ideal gas constant.

$= 8.31$ J/mole.K

$= 0.082$ L.atm/mole.K

T is the temperature of the gas



- **Boyle's law**: The volume V of a given mass of a gas is inversely related to pressure when the temperature is constant.

$$V = \frac{nRT}{P} = \frac{\text{constatnt}}{P}$$

$$V \, \alpha \, \frac{1}{P}$$

So $$P_1V_1 = P_2V_2$$

- **Charles's law**: The volume V of a given mass of a gas, at constant pressure P , is directly proportional to it's temperature T.

$$V = \text{constatnt } T$$

$$V \propto T$$

So $$V_1 / T_1 = V_2 / T_2$$

- **Avogadro's law**: States that the volume occupied by an ideal gas is directly proportional to the number of molecules of the gas present in the container.
- The relation is given by:

$$V = \text{constatnt } n$$

So $$V_1/n_1 = V_2/n_2$$

- **Gay-Lussac's law**: It states that , for a given mass and constant volume of an ideal gas, the pressure exerted on the sides of its container is directly proportional to its absolute temperature.

$$V = \text{constatnt } T$$

So $$P_1/T_1 = P_2/T_2$$

Example

- A 12 g sample of gas occupies 19.2 L at STP. What is the molecular weight of this gas?

$$PV = nRT$$

$$(1\ \text{atm})\ (19.2\ \text{L}) = (n)\ (0.082)\ (273\ \text{K})$$

$$n = 0.8570518\ \text{mol}$$

- What is the temperature of One mole of CH_4 gas that occupies 20L at 1atm pressure in Kelvin?

$$PV = nRT$$

$$T = PV/nR$$

$$T = 1\text{atm}\times 20\text{L}/1\text{mol}\times 0.082$$

$$T = 244\text{K}$$

Work

- In thermodynamics, **work** performed by a system is energy transferred by the system to its surroundings, by a mechanism through which the system can spontaneously exert macroscopic forces on its surroundings.

$$W = F \cdot d$$

where: W: is the work,

F: is the force,

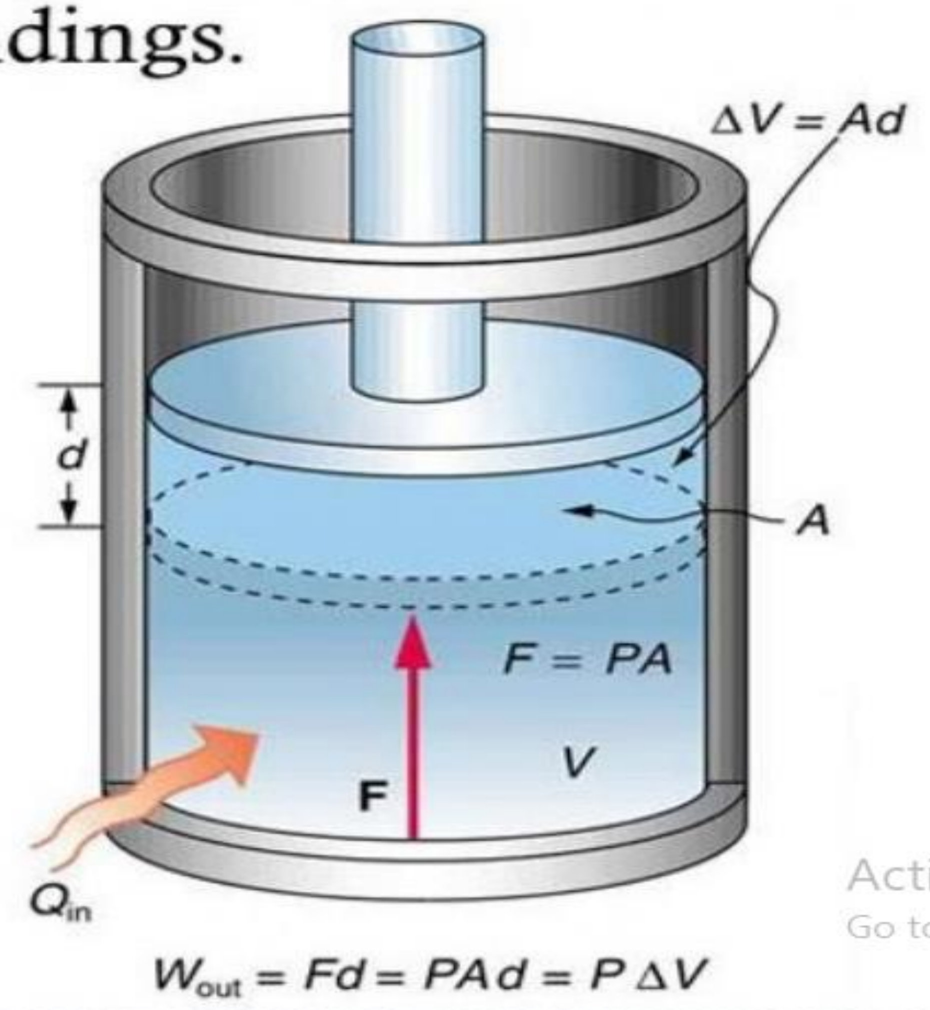
d: is the displacement.

- Because $P = F/A$ >> $F = PA$

So:

$$W = PAd$$

$$W = P\Delta V$$

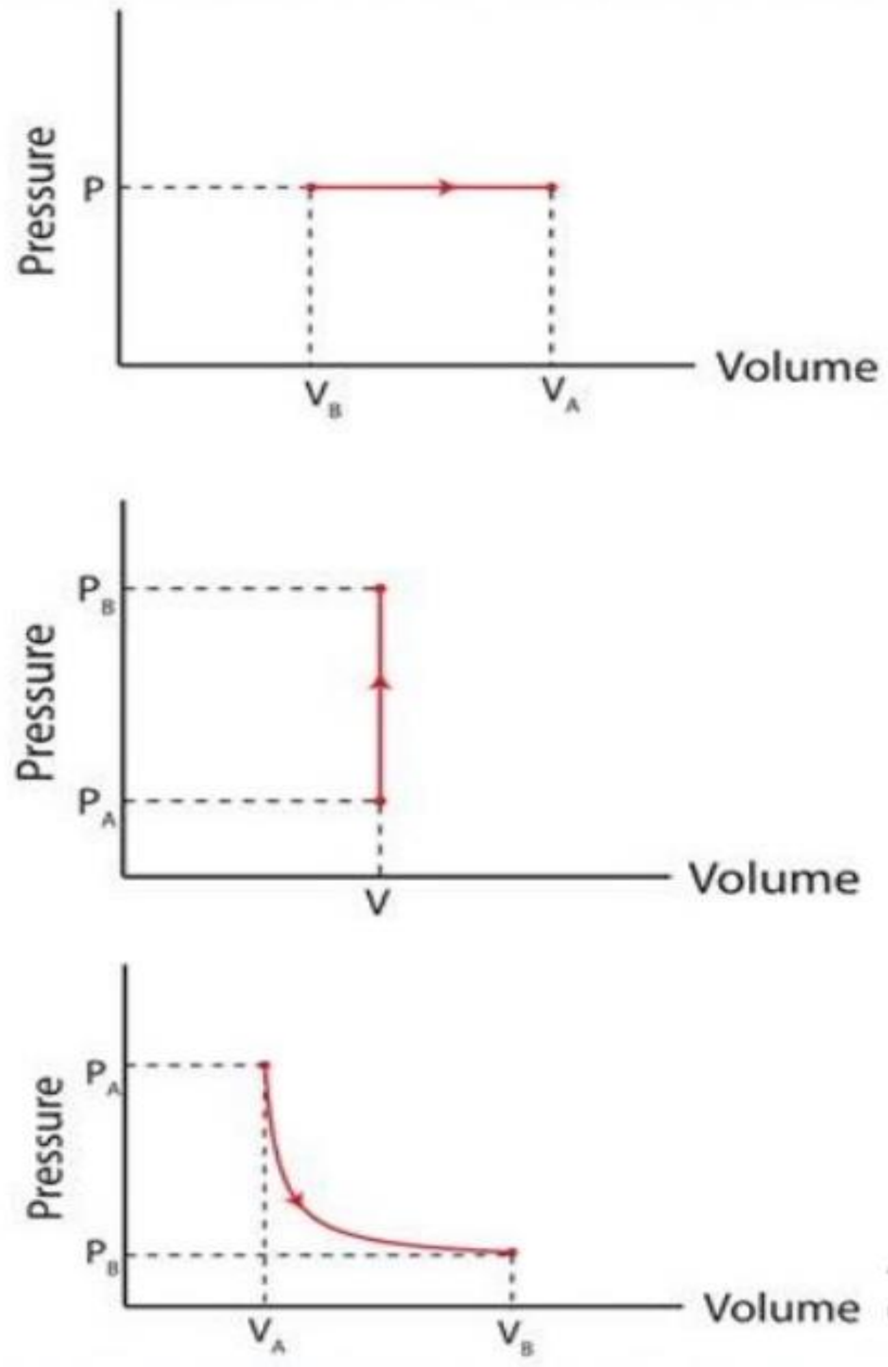


Thermodynamics Processes

- A process in which a gas does work on its environment at *constant* **pressure** is called an **isobaric process**,
- While one in which **volume** is kept

constant is called an **isochoric process**.

- Where **Isothermal Processes** is a change of a thermodynamic system, in which the **temperature** remains constant.



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Lecture 7

07

Thermodynamics
Conservation of Energy

Conservation of Energy:

- The total energy is neither increased nor decreased in any process.
- Energy can be transformed from *one form to another*, and transferred from *one object to another*, but the total amount remains constant.
- When a **system** and its **surroundings** undergo a transition from an *initial* state to a *final* state, the change in energy is zero,

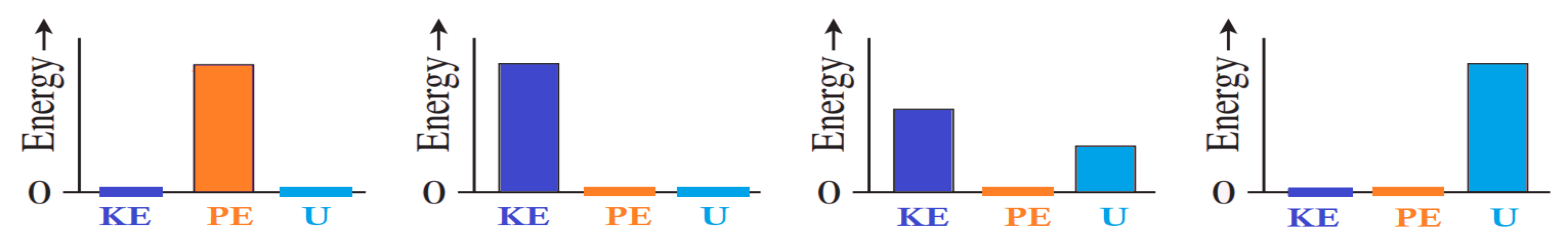
$$\Delta E = \Delta E_{system} + \Delta E_{surroundings} = 0$$

- Our second type of "energy accounting" involves macroscopic or mechanical energy, which has two types: **kinetic energy,** and **potential energy**.

- Accounting for internal energy leads to a broader statement of energy conservation.

$$\Delta KE + \Delta PE + \Delta U = 0$$

This equation shows that the sum of the kinetic, potential, and internal energy of an isolated system doesn't change even though energy may be converted among these three different forms.



Intermediate bar charts show gradual conversion of mechanical energy into internal energy.

1. **Kinetic Energy:** The energy that an object possesses because its moving. It is defined as:

$$KE = \frac{1}{2} M\, V^2$$

where M is the mass of the object, V is the magnitude of its velocity.

2. **Potential Energy:** The energy due to an object's position (stored energy) known as potential energy. It is defined as:

$$PE = mgz$$

where m is the mass, z is the is the elevation, g is the gravitational acceleration.

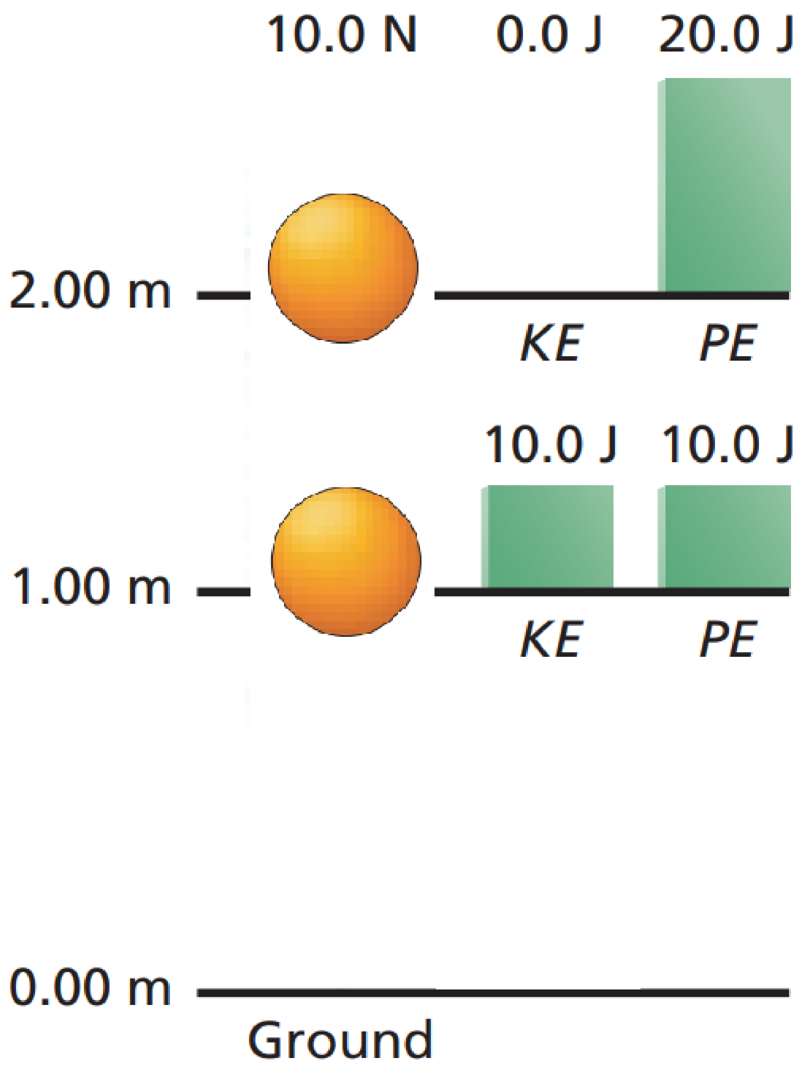
note

The height to which the object has risen is determined by using a reference level.

- In any given system, if no other forms of energy are present, so the energy is mechanical energy:

$$E = KE + PE$$

- Imagine a system consisting of a 10N ball and Earth.



- Suppose the ball is released from 2m above the ground. Because the ball is not yet moving, it has no kinetic energy.

$$PE = mgz = 10\ \text{N} \times 2\ \text{m} = 20\ \text{J}$$

- As the ball falls, it loses PE and gains KE. When the ball is 1m above Earth's surface:

$$PE = 10\ \text{N} \times 1\ \text{m} = 10\ \text{J}$$

What is the ball's kinetic energy when it is at a height of 1m?

- The system consisting of the ball and Earth is closed and isolated because no external forces are acting upon it. Hence, the total energy of the system (E) remains constant at 20 J.

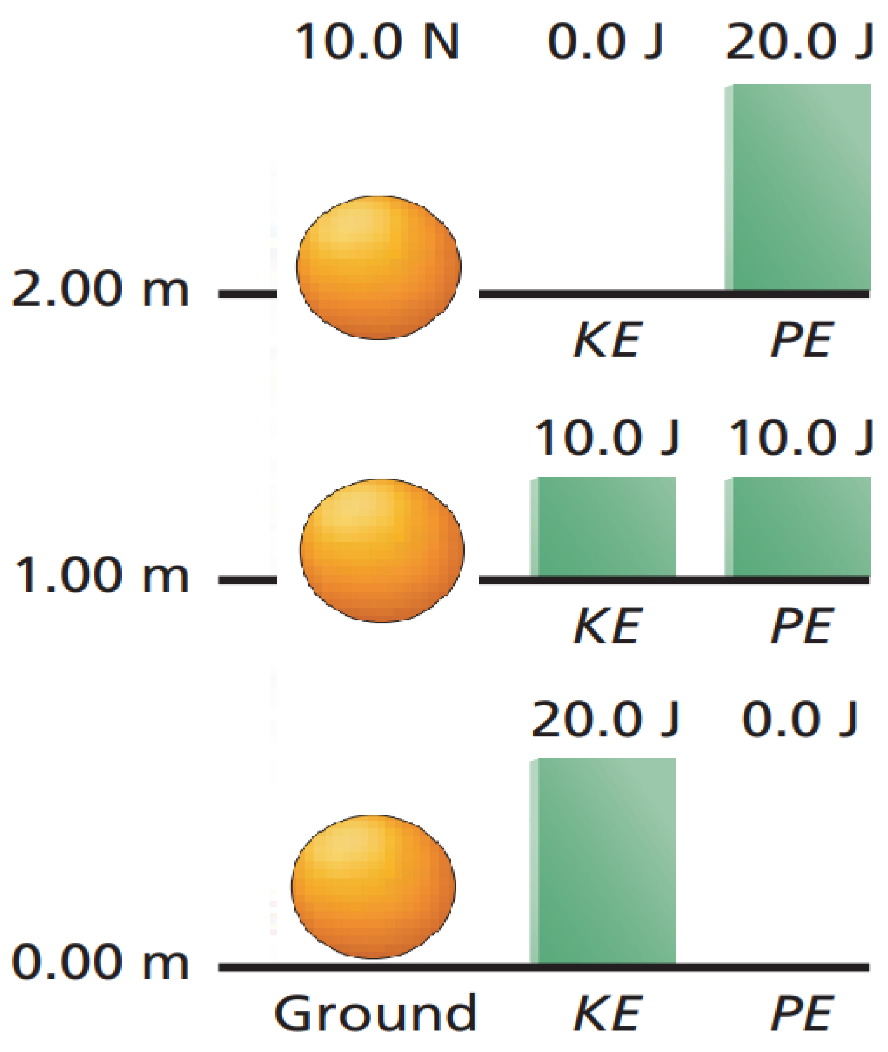
$$E = KE + PE \quad \text{so} \quad KE = E - PE$$

$$\therefore KE = 10\ J$$

- When the ball reaches ground level:

$$PE = 0$$

$$KE = 20\ J$$

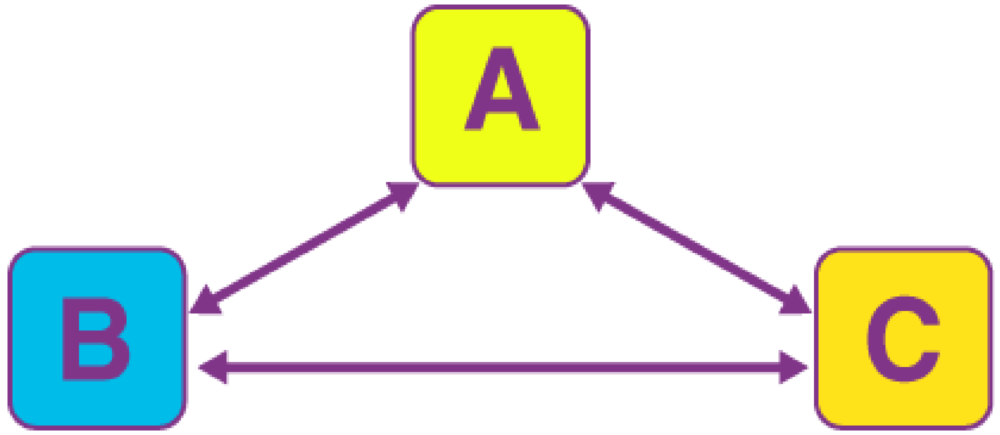


Check the velocity of ball .

Energy Conservation in Thermodynamic

- **Thermodynamics** studies **conversion of energy** from one form to the other, such as chemical to heat, heat to mechanical, hydraulic to electrical ….. est.
- The field of study of thermodynamics is based on **three laws** of thermodynamics and **Zeroth's law**.
- **Zeroth's Law of Thermodynamics** states that if two bodies are in thermal equilibrium with third body, then they are in thermal equilibrium with each other.

   - *For example*, if temperature of body **A** is equal to temperature of body **C** and temperature of body **B** is also equal to temperature of body **C**, then temperature of body **A** is equal to that of **B**.

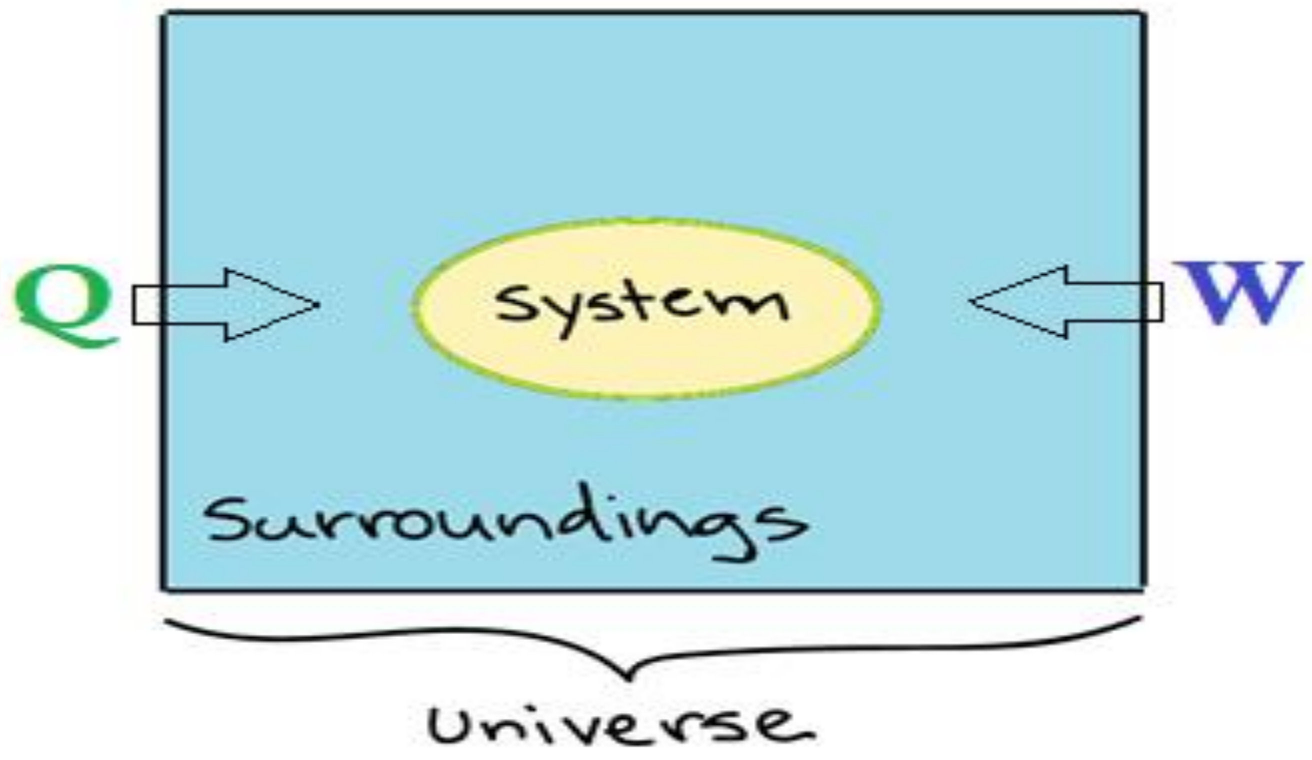


- **1st Law of Thermodynamics:** Energy can neither be created nor be destroyed, it can only be transferred from one form to another.
- **2nd Law of Thermodynamics:** The entropy of any isolated system always increases.
- **3rd Law of Thermodynamics:** The entropy of a system approaches a constant value as the temperature approaches absolute zero.

note

- ✓ **Entropy** is the measure of the number of possible arrangements the atoms in a system can have.
- ✓ **Enthalpy** is the measurement of energy in a thermodynamic system.

- For thermodynamics, the 1^{st} law is an expression of the principle of conservation of energy.
- It states that the change in thermal energy (ΔU) of an object is equal to the heat (Q) that is added to the object minus the work (W) done by the object.



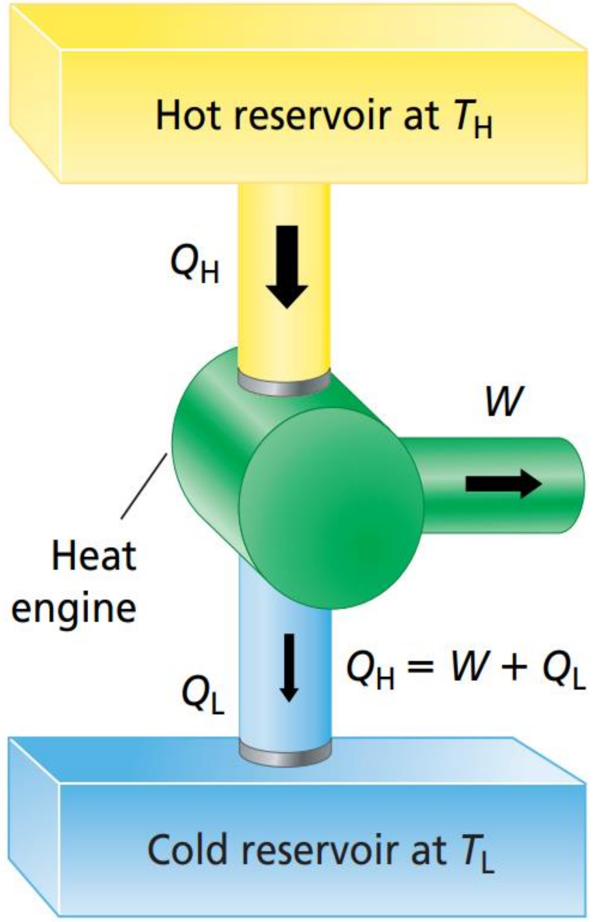
$$\Delta U = Q - W$$

- Because Universe = System + Boundary + Surroundings, and the 1^{st} law states that the energy of the universe is a constant, so : $\Delta E_{Universe} = 0$

$$\Delta E_{System} = -\Delta E_{Surroundings}$$

Example: Heat engines

- A device that is able to continuously convert thermal energy to mechanical energy. It requires :
  - a high-temperature source from which thermal energy can be removed;
  - a low-temperature receptacle, called a sink, into which thermal energy can be delivered;
  - and a way to convert the thermal energy into work.
  - Q_H is the input heat.
  - Where $Q = Q_H - Q_L$, and $\Delta U = Q - W = 0$, Thus, the work done by the engine is $W = Q_H - Q_L$.



Example:

Q- A gas in a closed container is heated with 50 J of energy, causing the lid of the container to rise. If the change in energy of the system is 30 J, how much work was done by the system?

For this problem, use the first law of thermodynamics:

$$\Delta U = Q - W$$

We are given the total change in energy and the original amount of heat added. Using these values, we can get:

$$30\ J = 50\ J - W$$

$$-20\ J = -W$$

$$20\ J = W$$

H.W.

1. A 10.0-kg test rocket is fired vertically from Cape Canaveral. Its fuel gives it a kinetic energy of 1960 J by the time the rocket engine burns all of the fuel. What additional height will the rocket rise?

2. A physics book of unknown mass is dropped 4.50 m. What speed does the book have just before it hits the ground?

3. A gas in a closed container is heated, causing the lid of the container to rise. The gas performs 3J of work to raise the lid, such that is has a final total energy of 15J. How much heat energy was added to the system?

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Lecture 8

08

Applications of Electricity and Magnetism in Medicine

ELECTRICAL SHOCK

When an electrode is connected to each hand and 60 Hz currents of different levels are passed through the body. The amount of current depends on the resistance of body between two points due to Ohms law

$V = I \times R$

As the current is increased from zero, the level at which we can just feel the current- the perception level is reached. About 50% of adult men fell a 60 Hz current of about 1 mA. For women about one third lower than those fell. The perception level is frequency dependent; it rise as the frequency increases above 100 Hz. As a 60 Hz current is increased above the perception level it causes a tingling sensation in the hands.

1. At current of 10 to 20 mA

A sustained muscular contraction takes place in hands and many subjects cannot let go of the electrodes. (Note that this current is higher at both low and high frequency) in (Fig. 6). As the current increased still further, pain and some cases fainting occur.

2. Near the 100 mA

level the portion of the 60 Hz current passing through the heart is sufficient to cause ventricular fibrillation. (rapid, irregular, and ineffectual contraction of the ventricles).

3. For a 60 Hz shock

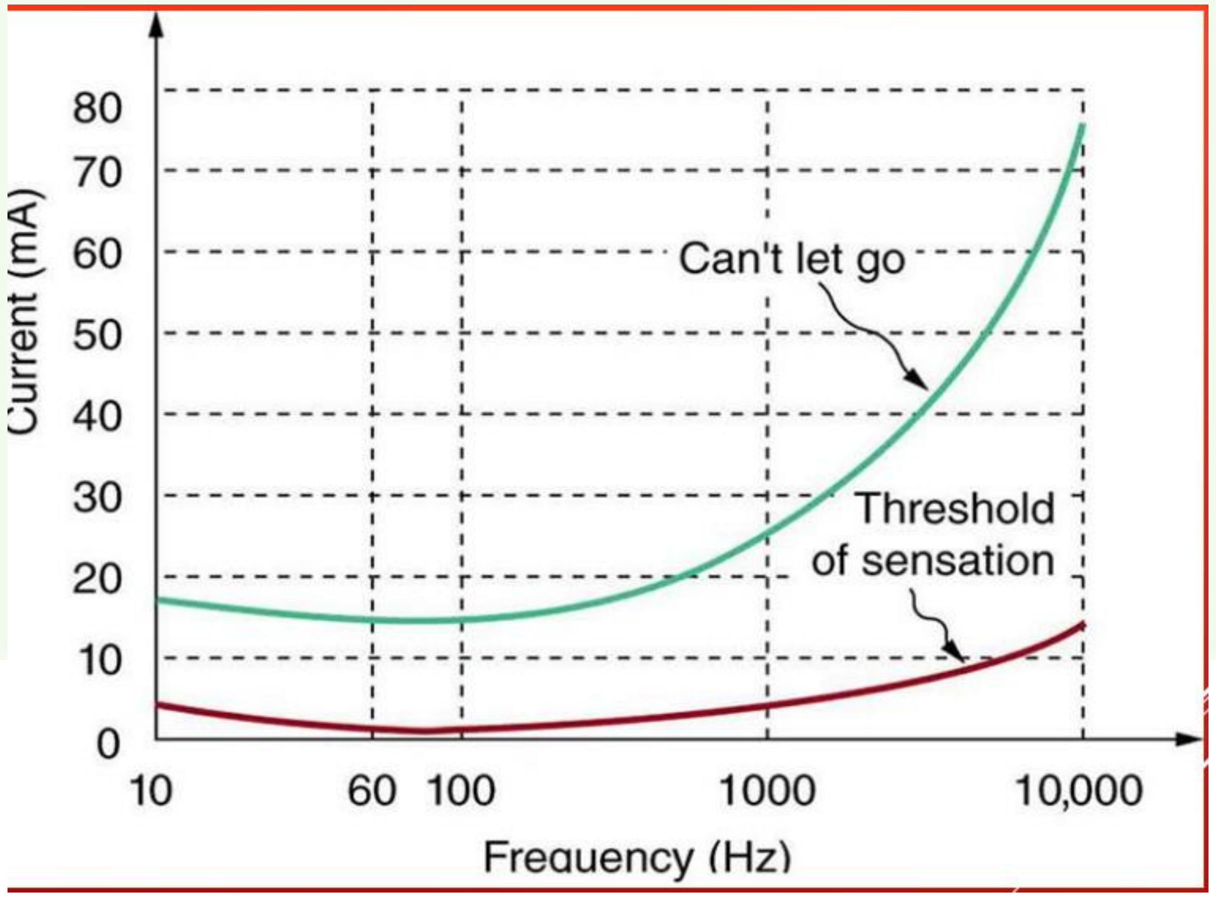
, the estimated maximum current that will not induce fibrillation in man is given by (116/t1/2) mA, where t is the time (in seconds) the shock tests. For example: if t = 1 s the safe current is 116 mA If t = 4 s the safe current is 58 mA

4. Current levels of 6 A

and above cause sustained muscular contraction of the heart similar to the (cannot let go) behavior of the hands. Defibrillators make use of such current levels. If a potential has ventricular defibrillation, a brief shock from a defibrillator usually restores normal coordinated pumping in the heart

The defibrillator uses a brief pulse of up to 10 Kv. A defibrillator can also be used to synchronize the heart to its normal rhythm when a patient has atrial fibrillation, in this case the electrical pulse is applied after R wave but before T wave

5. Continuous currents above 6 A can cause temporary respiratory paralysis and serious burns. The damage depends upon the individual, the dampness of the skin, and the contact of the skin with the conductor.



MACROSHOCK Which occurs when electrical contact is made on the surface of the body. **MICROSHOCK** When the current is applied inside the body,microshock results. In microshock, the current does not have to pass through the high resistance of the skin; it instead often follows the arteries and passes directly through the heart. Ventricular fibrillation can be induced with microshock current levels that are much smaller than the current levels needed to induce it under macroshock conditions. It has been estimated that about 30 µA cause ventricle fibrillation. It is possible for microshock to occur in a medical situation, hazards of this sort are correct by modern power cords have three wires-two that supply the ac power and one that serves as ground wire. If either of power wires breaks the equipment will not operate, and if these wires touch (short) a fuse will blow and the failure will be obvious. A break in the ground wire may go undetected and present a serious electrical hazard to patient internal electrodes, some current flow from the ac power parts to the metal case of the instrument is called Leakage current, usually flows to ground through ground wire in the power cord. The main source of the Leakage current is capacitance between the power wires and ground or between power transformer and its case.

he impedance Xc of a capacitance C for applied voltage frequency f is

$$Xc = 1/\ 2\ \pi\ f\ c$$

A typical Leakage capacitance is 2 x 10^{-2}µf.

If the ac potential V is 110 v at a frequency of 60 Hz, then the capacitive reactance is 1.3 x 110^{5}Ω and

Leakage current $I = V / Xc = 110 / 1.3 \times 10^{5} = 8.5 \times 110^{-4}$ A = 850 µA

Let us consider what would happen if this Leakage current were in a ECG instrument with broken ground wire and the unit were connected to a patient in an intensive care units who also had a pacemaker connected. Since the Leakage current could not flow to ground through the broken ground wire it would flow through the implanted cardiac pacemaker to ground. microshock current could result in ventricular fibrillation and death. There are a number of ways that shock hazards could be reduced.

1- The body is less sensitive to direct current than to 60 Hz current. Since $Xc = \infty$ if $f = 0$

There would be no Leakage current due to stray capacitance if we operated our electrical equipment with direct current.

2- Hazards could also reduce at frequencies much higher than 60 Hz where the sensitivity of the heart to ventricular fibrillation is much less.

HIGH-FREQUENCY ELECTRICITY IN MEDINCINE

The heating effects produced by electrical diathermy.

1- In short wave (30 MHz) diathermy two methods are used to get electromagnetic energy into the body: the capacitance methods and inductance method. In both methods the body part to be heated becomes a part of resonant electrical circuit.

2- In microwave (2450 MHz) diathermy.

Low-frequency electricity and magnetism in medicine

When an electrical conductor is moved perpendicular to a magnetic field, a voltage is induced in the conductor proportional to the product of the magnetic field and the voltage of the conductor (Faradays Low). This law, which also holds for a conducting fluid moving perpendicular to a magnetic field, is the basis of magnetic blood flow meters.
BLOOD ACTS AS A CONDUCTING FLUID. IF IT PASSES WITH MEAN VOLTAGE V THROUGH A MAGNETIC FIELD B AS SHOWN IN (FIG.7), A VOLTAGE V IS INDUCED BETWEEN THE ELECTRODES SUCH THAT V =BDV, D IS DIAMETER OF VESSEL

The volume of blood Q through the vessel can then be calculated. Since Q is product of mean velocity times the area of the vessel πd2 /4 . Or

$$Q = \frac{\pi d^2}{4} * \frac{V}{Bd}$$

EXAMPLE

A magnetic blood flow meter is positioned across blood vessel 5 x 10^{-3}m in diameter. With a magnetic field 3 x 10^{-2} T, and induced voltage of 15 x 10^{-6}V is measured.

a.Find the mean velocity in the vessel.

$$V = Bdv,$$

$$v = V/Bd$$

$$= 1.5 \text{ x } 10^{-5}/(3\text{x } 10^{-2})(5 \text{ x } 10^{-3}) = 0.1 \text{ m/s.}$$

a.What is the volume flow rate.

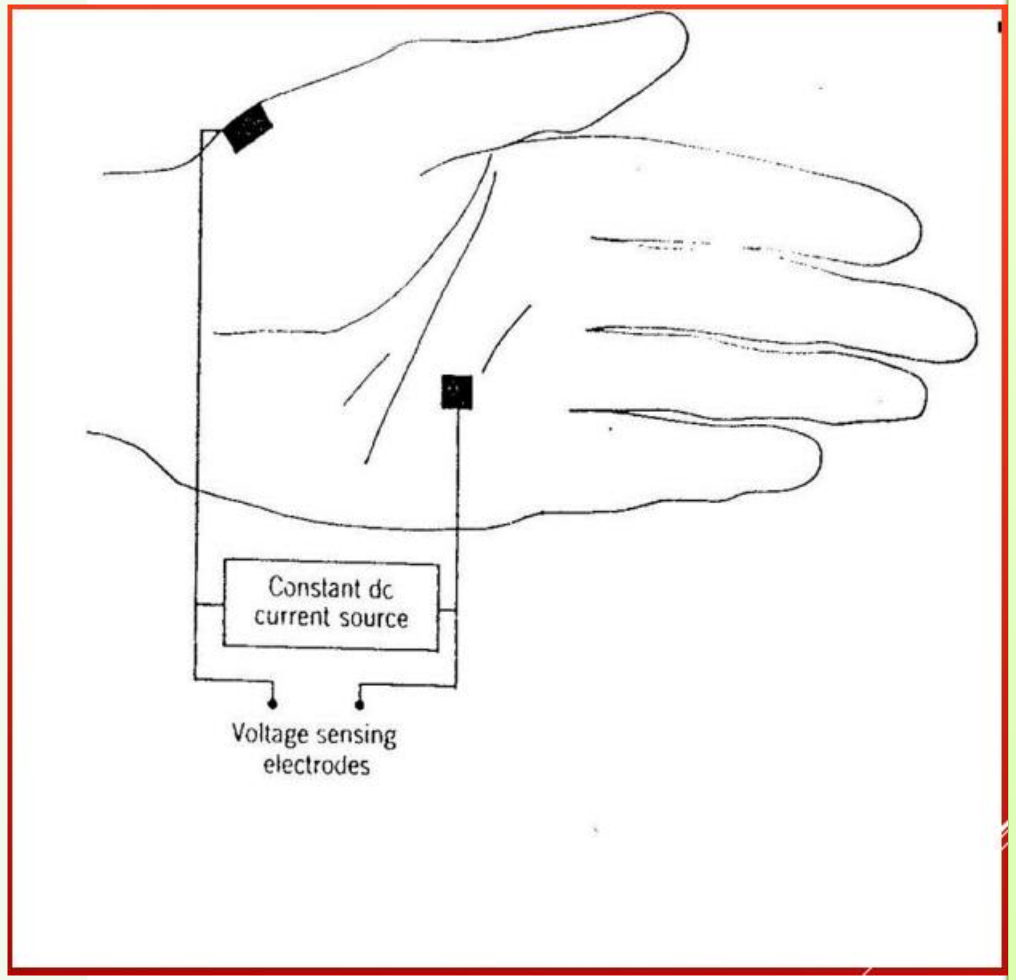
$$Q = \frac{\pi d^2}{4} * \frac{V}{Bd}$$

$$Q = \pi d2\ V/4\ Bd = \pi\ (1.5 \text{ x } 10^{-5})^2\ 0.1\ /\ 4$$

$$= 1.9 \text{ x } 10^{-6}\ m^3/\text{s} = 1.9\ cm^3/\text{s}$$

GALVANIC SKIN RESPONSE (GSR)

GALVANIC SKIN RESPONSE (OR GSR), ALSO KNOWN AS ELECTRODERMAL RESPONSE (EDR) OR PSYCHOGALVANIC REFLEX (PGR), IS A METHOD OF MEASURING THE ELECTRICAL RESISTANCE OF THE SKIN AND INTERPRETING IT AS AN IMAGE OF ACTIVITY IN CERTAIN PARTS OF THE BODY.



Changing in perspiration (sweat gland activity) are related to skin resistance: the variation the skin resistance due to psychological changes or external stimuli is called the galvanic skin response (GSR). A decrease in skinresistance indicates increased sweat gland activity. Increase in skin resistance indicates reduced sweat gland activity. GSR measuring by two electrodes one placed on the palm of hand and other on the wrist. A constant direct current (~ 10 µA/cm2) is passed: resulting voltage indicates the GSR

H.W

Choose the right answer –

1-How long the body could safely tolerate a macroscopic shock of 50 mA

A- 5.38 second B- 5.38 millisecond

C- 5.38 microsecond D- 54 millisecond

2-When the current is applied inside the body. Which of the followings is false?

A- Microshock results B- Macroshock results

C- The current does not have to pass through the high resistance of the skin, it instead often follows the arteries and passes directly through the heart. D- Ventricular fibrillation can be induced with microshock current

3- Galvanic skin response (or GSR), is a method of measuring the electrical resistance of the skin

a- A decrease in skin resistance indicates reduced sweat gland activity b- A decrease in skin resistance indicates increased sweat gland activity.

c- Increase in skin resistance indicates increased sweat gland activity

d- A constant direct current

(~ 100 A/ cm2) is passed: resulting voltage indicates the GSR

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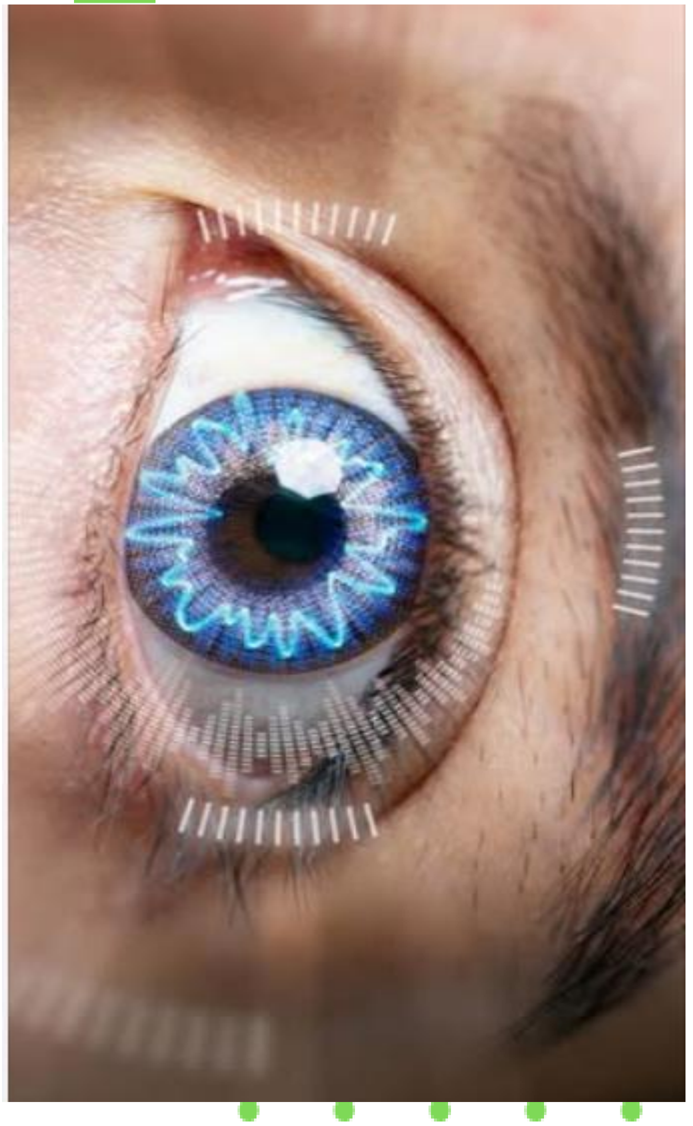
Lecture 9

09

PHYSICS OF EYES AND VISION

He sense of vision consists of three major components:

1-The eyes that focus an image from outside world on the light sensitive retina.
2-The system of millions of nerves that carries the information deep into the brain.
3-The visual cortex-that part of the brain where, it is all put together.
Blindness results if any one of the parts does not function. The physics of the first part far better than the physics of the other two parts

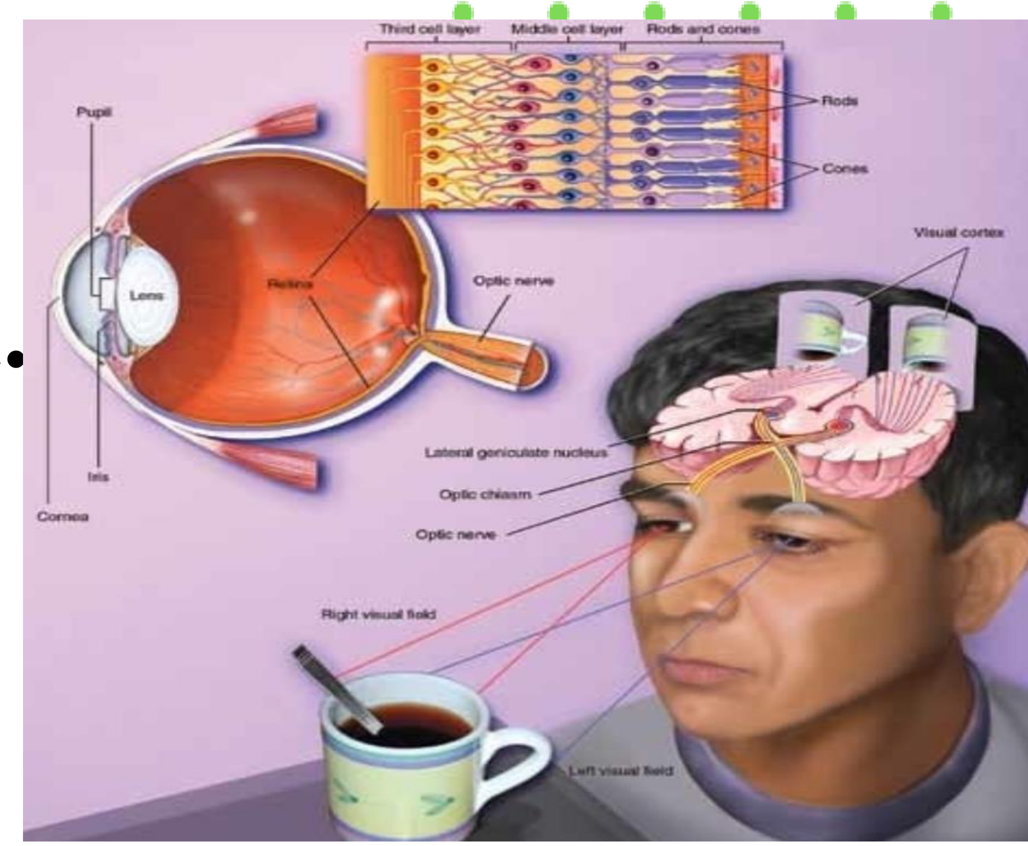


FOCUSING ELEMENTS OF THE EYE

The eye has two major focusing components:
1-The cornea is a fixed focus element.
2-The lens is variable in shape and has the ability to focus objects at various distances.

The cornea focuses by bending (refracting) the light rays. The amount of bending depends on the curvatures of its surfaces and the speed of light in the lens compared with that in the surrounding material. The index of refraction is nearly constant for all corneas, but the curvature varies considerably from one person to another and is responsible for most our defective vision.

1-If the cornea is curved too much the eye is near sighted.
2-Not enough curvature results in far sightness.
3-Uneven curvature produces astigmatism.



The lens has a flexible cover that is supported under tension by suspension fibers.

1-When the focusing muscle of the eye is relaxed this tension keeps the lens somewhat flattened and adjusted to its lowest power, and the eye is focused on distant objects. The point at which distant objects are focused when the focusing muscle is relaxed is called the far point.

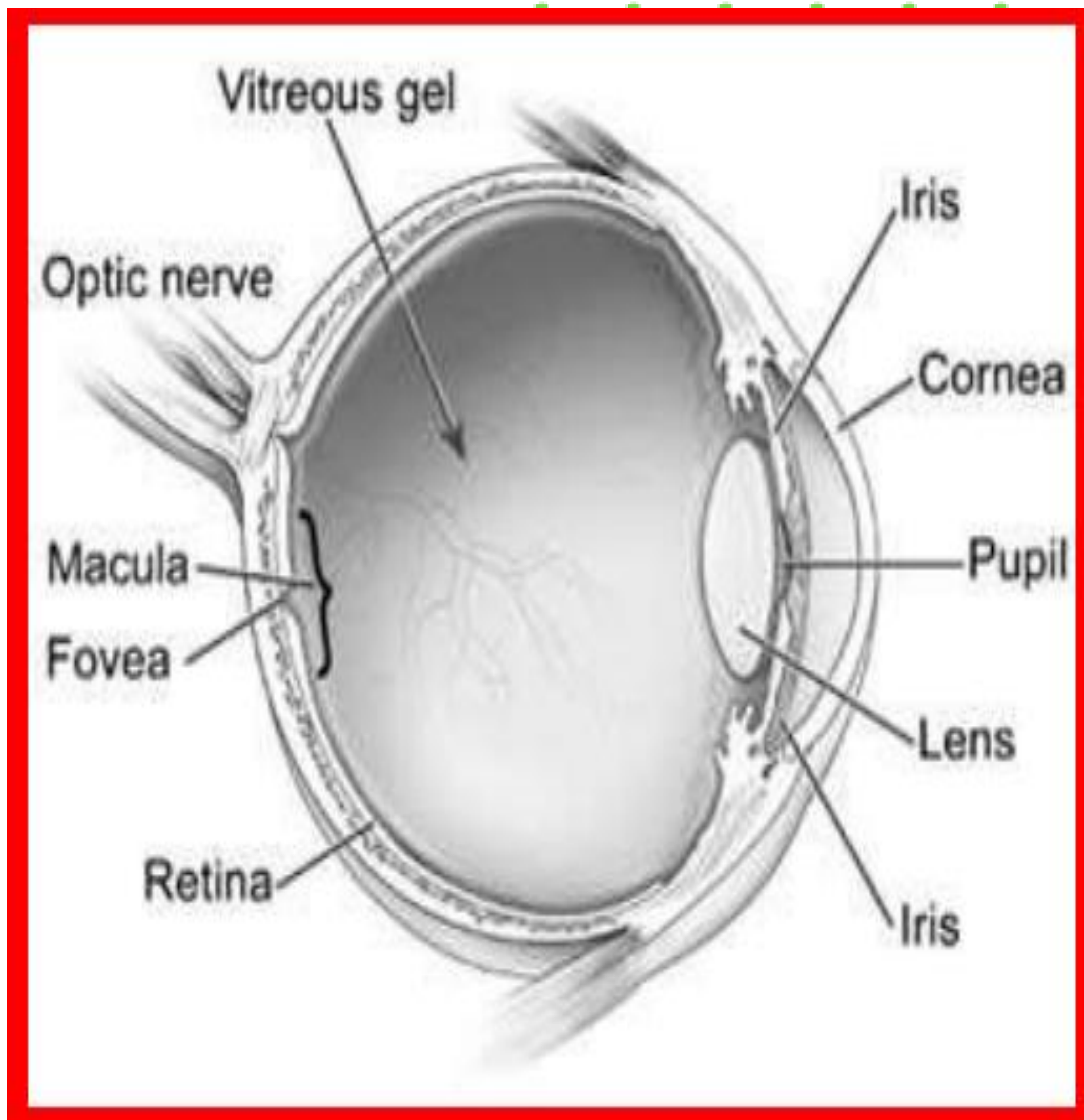
2-For a near sighted, the circular muscle around the lens contracts into a smaller circle and takes some or all of the tension off the lens. The lens then has a greater focusing power, the closest point at which objects can be focused when the lens is its thickest is called the near point.

3-Young children have very flexible lenses and can focus on very close objects. The ability to change the focal power of the eye is called accommodation.

4-As people get older, their lenses lose some accommodation, presbyopia (old sight) results when the lens has lost nearly all of its accommodation.

SOME OTHER ELEMENTS OF THE EYE

Pupil is the opining in the center of the iris where light enters the lens. It appears black because essentially all of the light that enters is absorbed inside the eye. Under average light condition, the opining is about 4mm in diameter. It can change from about 3mm in diameter in bright light to about 8mm in diameter in dim light. The iris does not respond instantly to a change of light levels; about 300 s are needed for it fully open, and about 5 s are required for it to close as much as possible. Aqueous humor fills the space between the lens and the cornea. This fluid, mostly water, is continuously being produced, and the surplus escapes through a drain tube. Vitreous humor is a clear jelly that fills the large space between the lens and the retina. It helps keep the shape of the eye fixed and essentially permanent. Sclera is the tough, white, light-tight covering over all of the eye except the cornea.



, THE RETINA-THE LIGHT DETECTOR OF THE EYE

The retina, the light sensitive part of the eye, converts the light images into electrical nerve impulses that are sent to the brain. The absorption of a light photon in photoreceptor triggers an electrical signal to brain-an action potential. The light photon apparently cause a photochemical reaction in the photoreceptor which in some way initiates the action potential. The photon must be above a minimum energy to cause the reaction.

1-Infrared photons have insufficient energy and thus are not seen.

2-Ultraviolet photons have sufficient energy, but absorbed before they reach the retina and also are not seen.

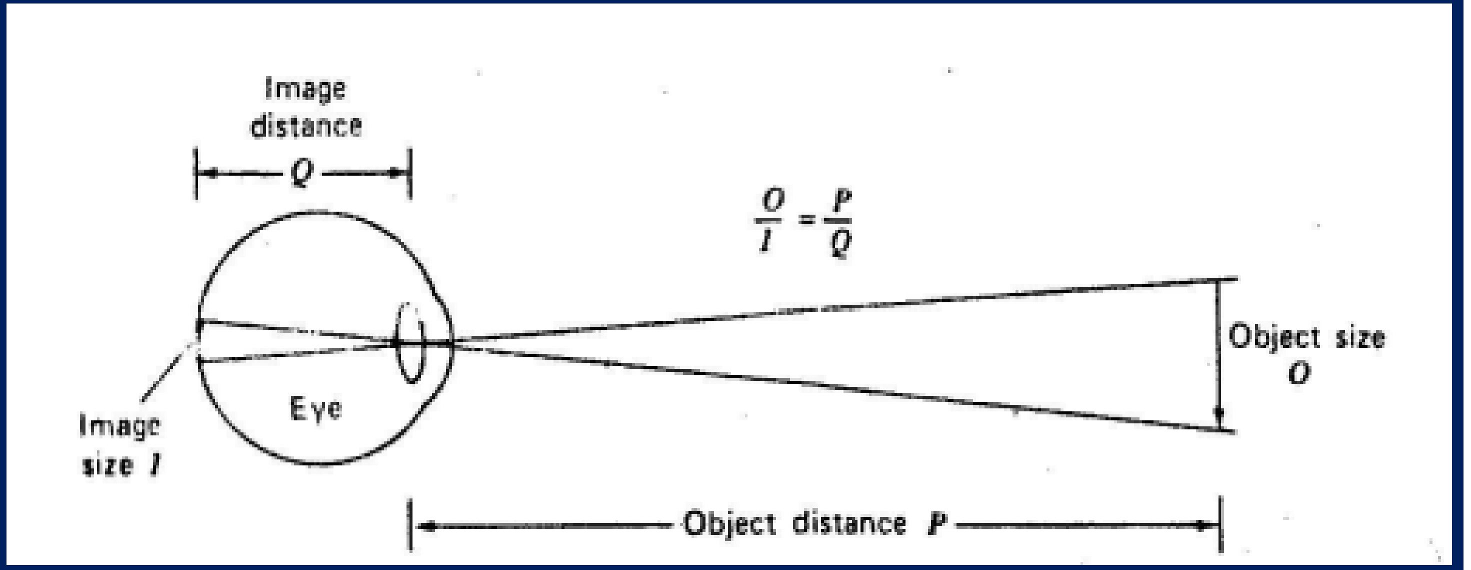
The retina covers the black half of the eyeball. While this large expanse permits useful" warning" vision over a large angle, most vision is restricted to a small area called the macula lutea, or yellow spot. All detailed vision takes place in a very small area in the yellow spot (~0.3mm in diameter) called the fovea centralis . The image on the retina is very small. A convenient equation for determining the size of image on the retina comes from the ratios of the lengths of the sides of similar triangles.

EXAMPLE

: **How big is the image on the retina of a fly on a wall 3.0m away?**
Assume the fly is 3mm in diameter and Q=0.02m.

$$\frac{O}{P} = \frac{I}{Q}$$

$$I = \frac{O * Q}{p} \quad = I = \frac{3 * 0.02}{0.03} = 2\text{m}$$



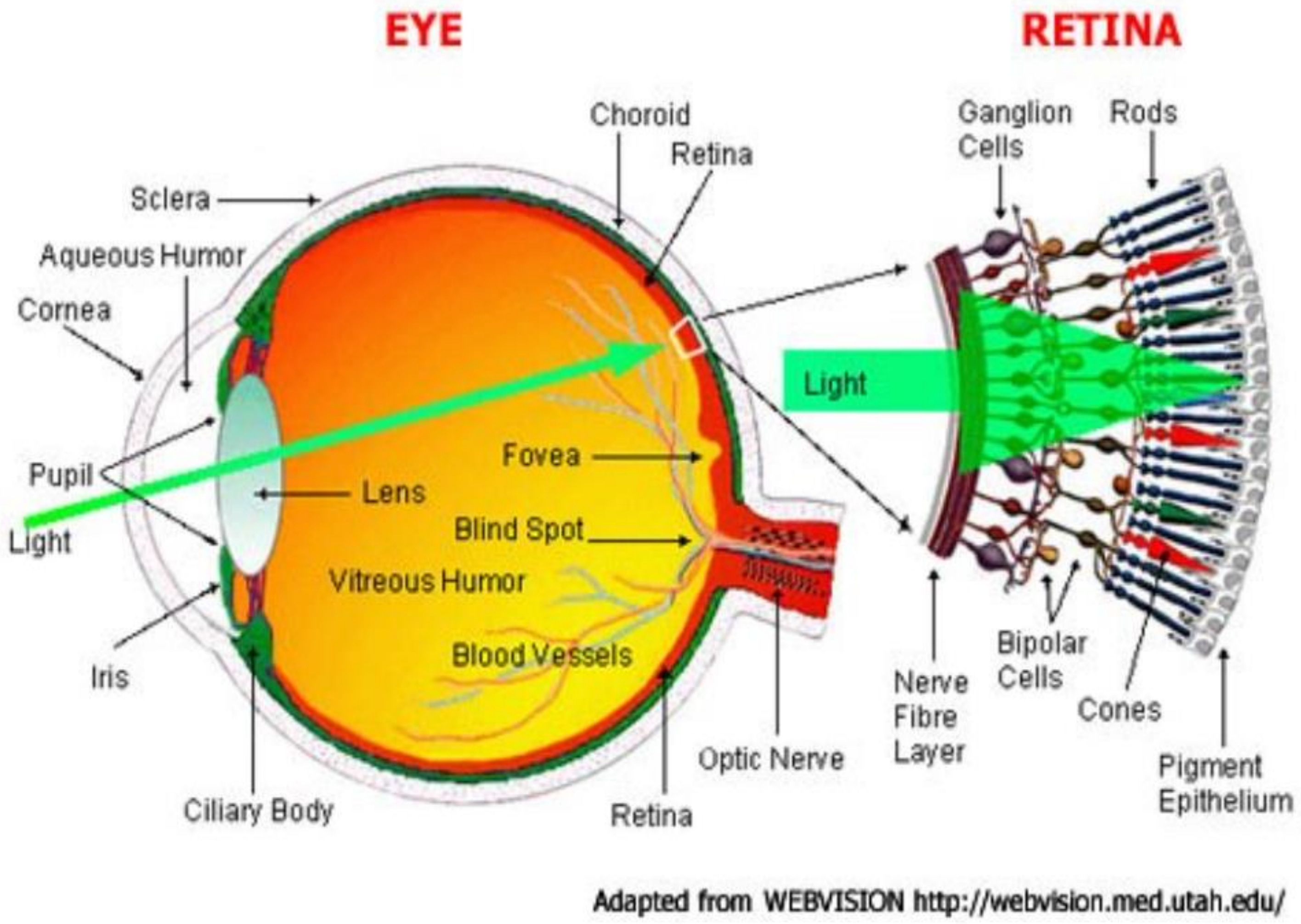
I: is image size Q: is image distance
O: is object size P: is object distance

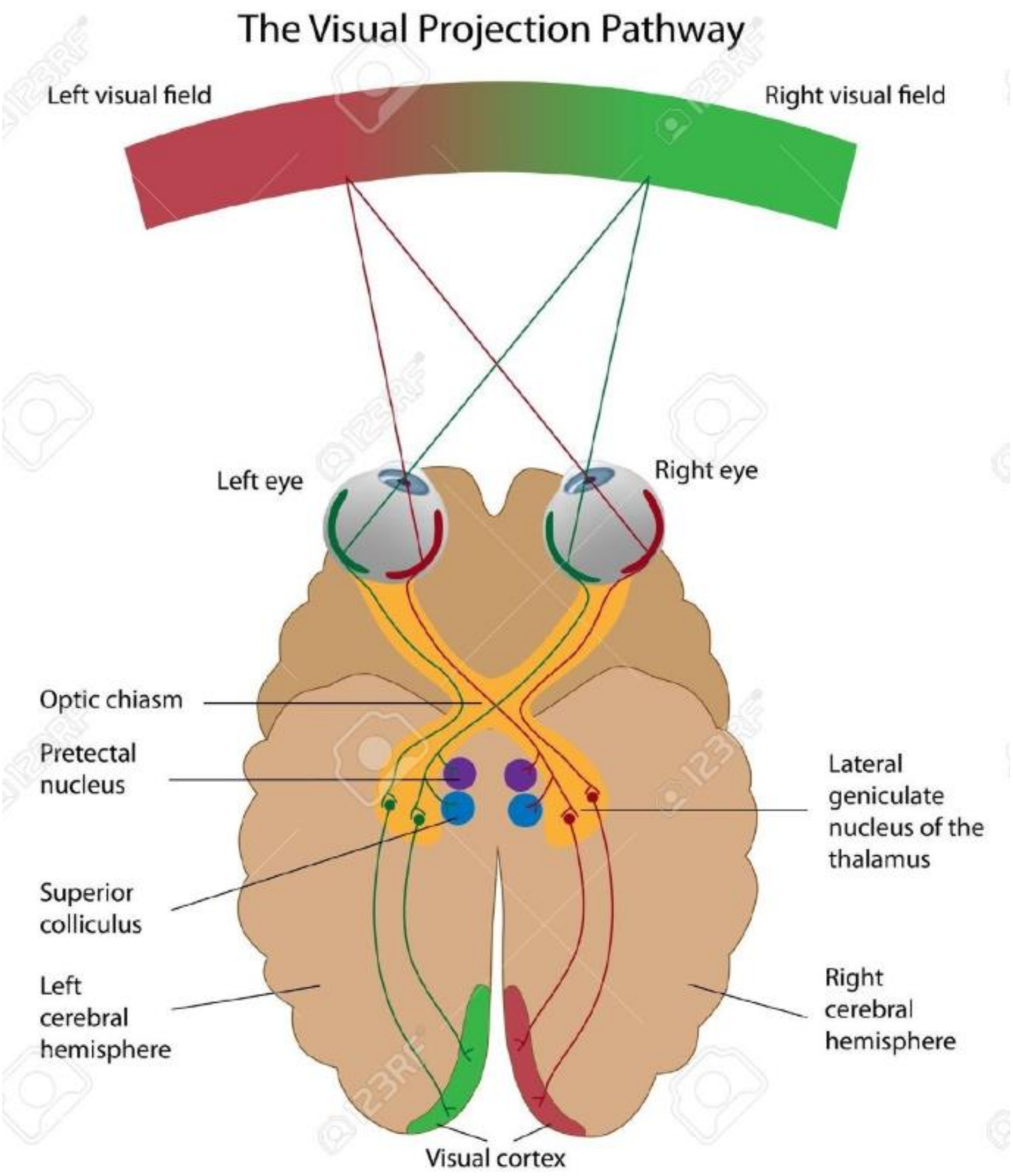
Thus we can write O/P=I/Q

Blind spot:

THAT HAS NEITHER RODS NOR CONES.

THAT THERE IS A REGION FROM ABOUT 13 TO 18



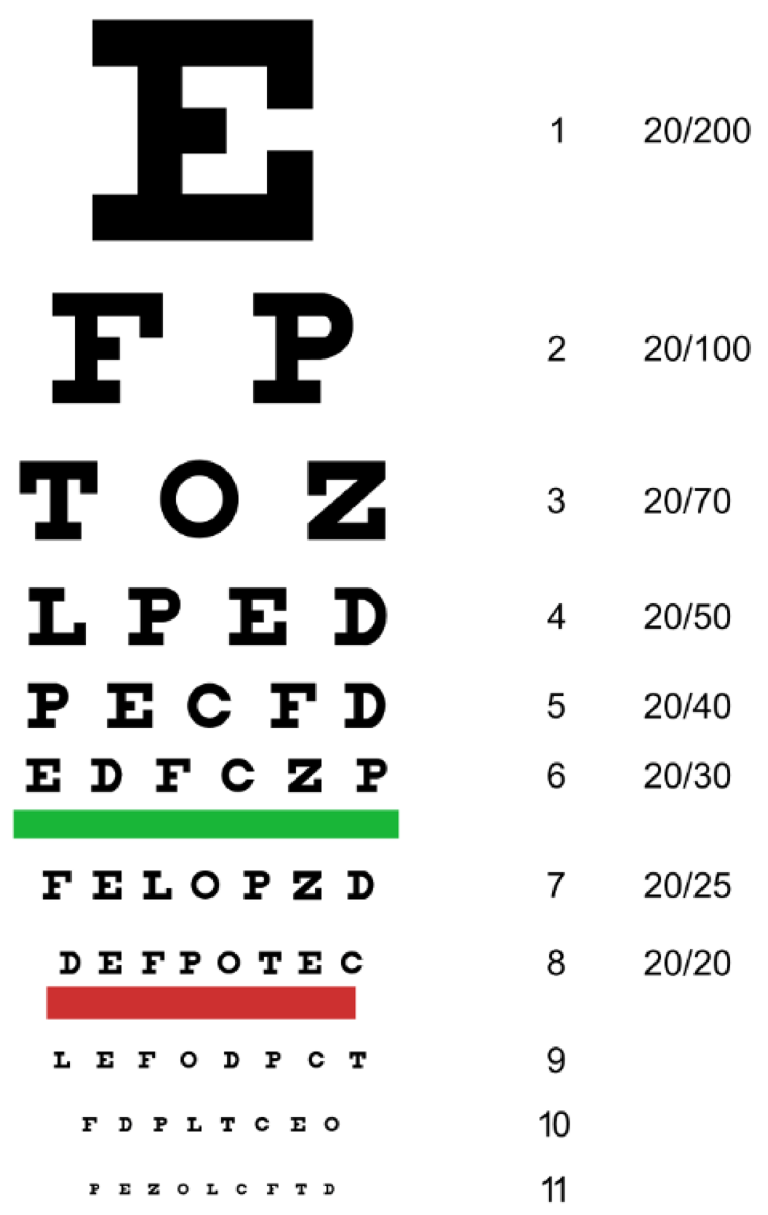


HOW SHARP ARE YOUR EYES

The optometrist usually uses a snellen chart to test visual acuity. If he tells you that your eyes test normal at 20/20, he means that you can read detail from 20 ft that person with good vision can read from 20 ft. If your eyes test at 20/40, you can just read from 20 ft the line that a person with good vision can read from 40 fthe ability of the eye to recognize separate lines also depends on the relative "blackness "and "whiteness" , the contrast between two areas is defined as optical density OD

$$OD = \text{Log}\ (I_o / I)$$

Where Io is the light intensity without absorber and I is intensity with absorber.



A piece of film that transmits 10% of the incident light has an optical density

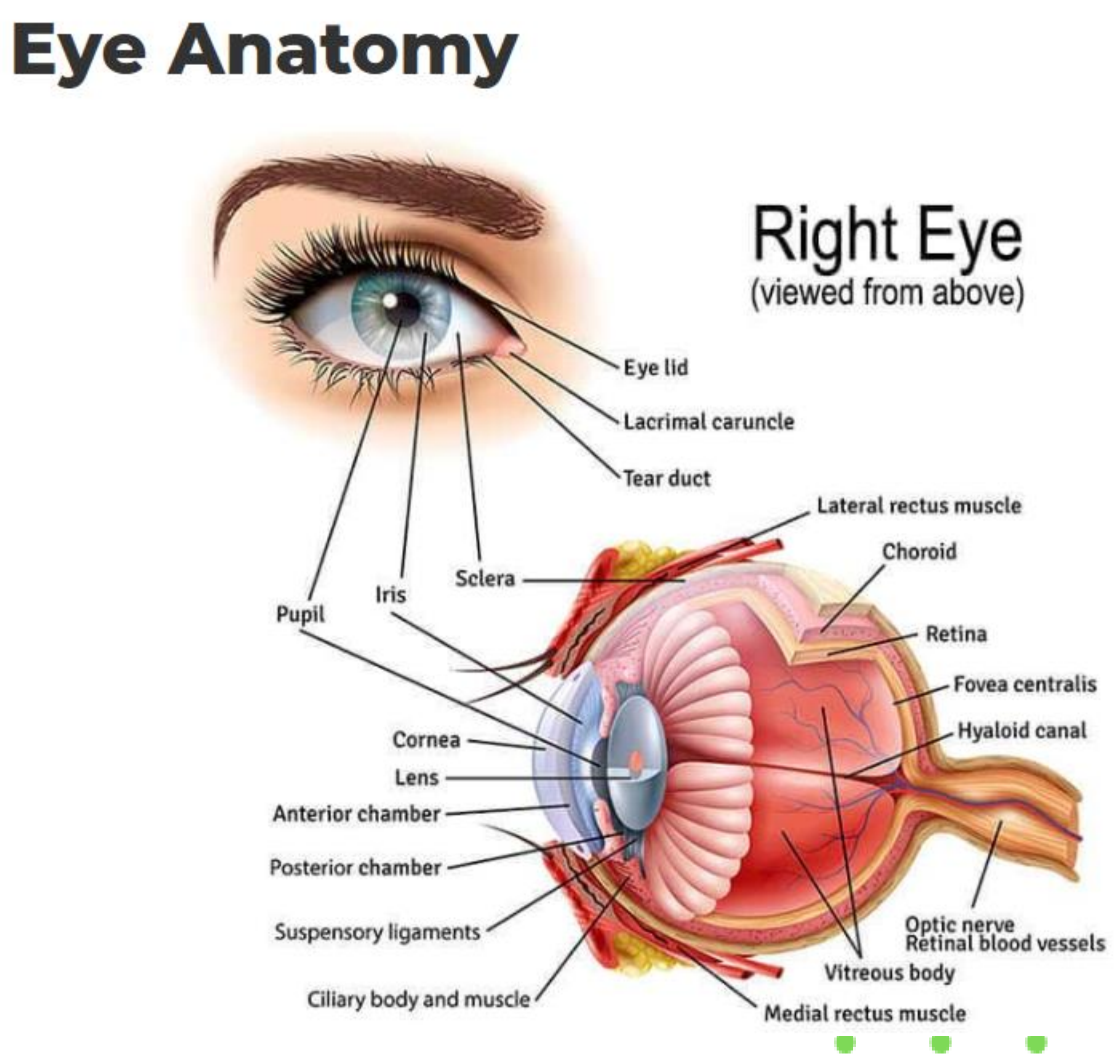
OD = Log(1/0.1) = 1.0

A film that absorbs 99% of the light has an optical density

OD = Log(1/0.01) = 2.0

An OD=3 means that only 0.001 of the light transmitted.

EXAMPLE

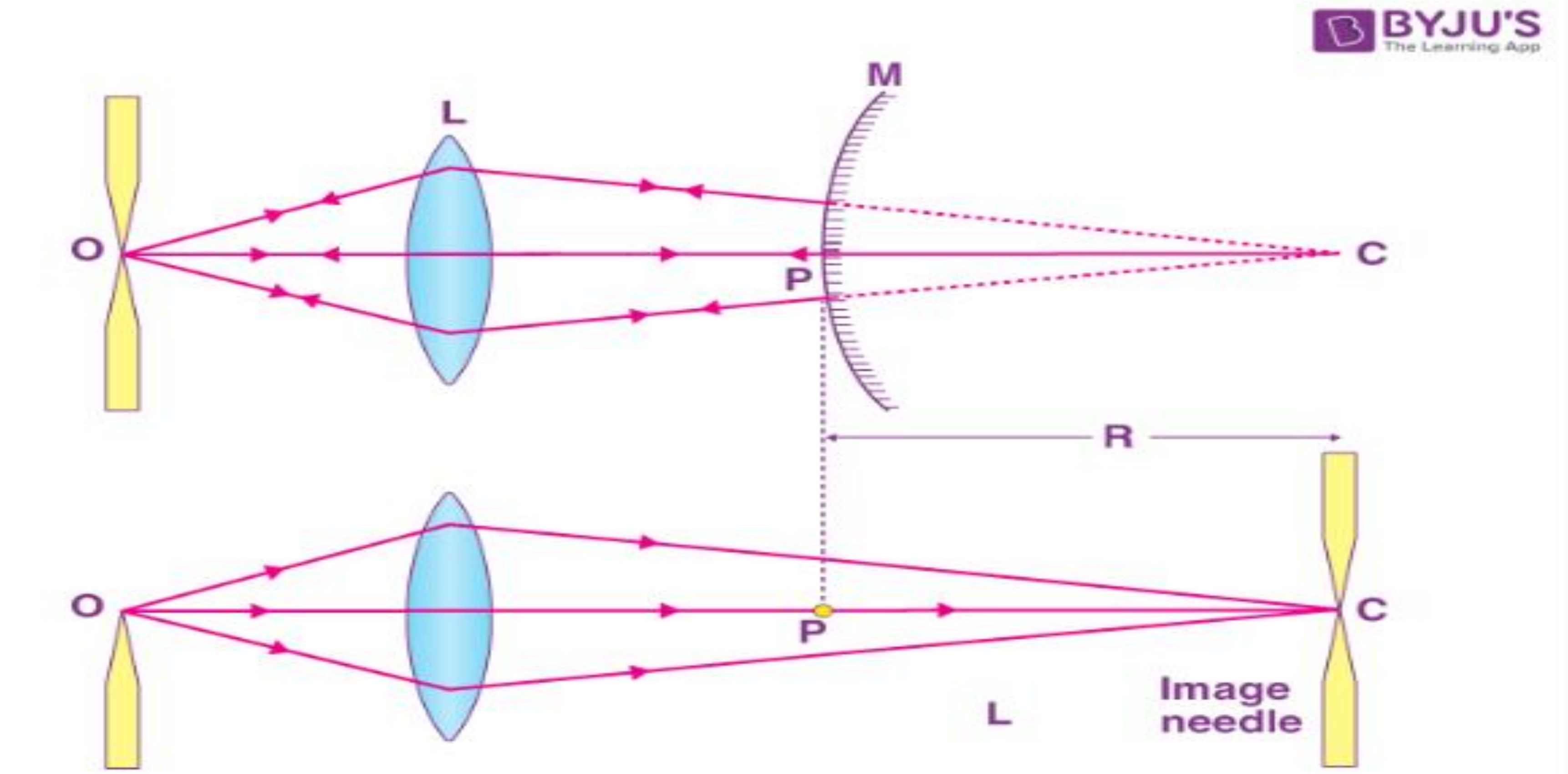


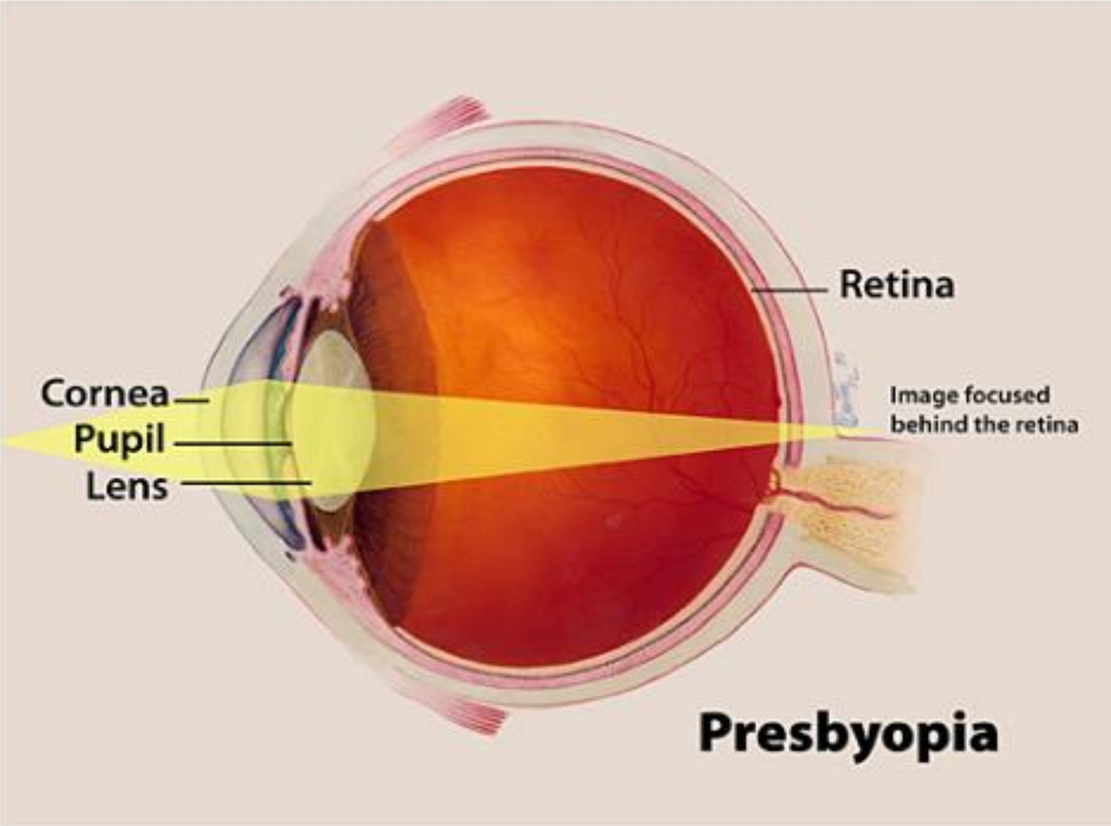
DEFECTIVE VISION AND ITS CORRECTION

There is a simple relationship between the focal length F, the object distance P, and the image distance Q of the lens

$$1/F = 1/P + 1/Q$$

If F is measured in meters, then 1/F is the lens strength in diopters (D).



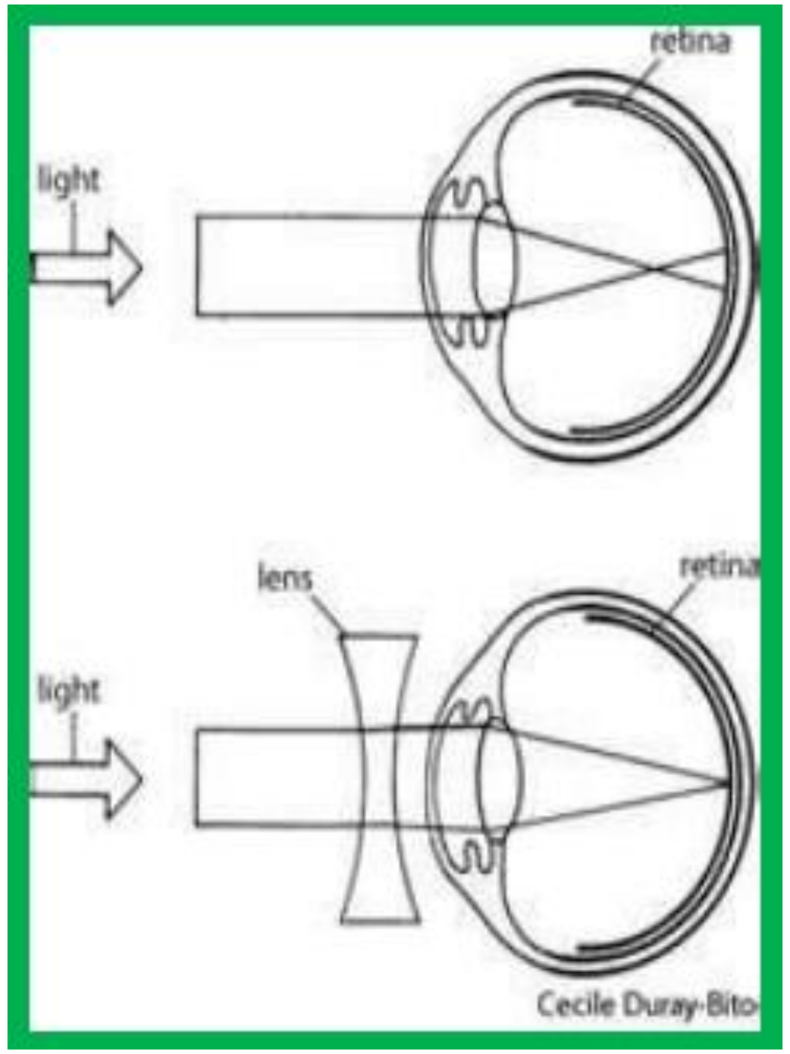


he ability of the eye to focus on objects over a wide range is called accommodation.
Power of accommodation of normal eye

$$= 1\backslash F = 1\ \backslash near\ point\ -\ 1\backslash\ far\ point$$

$$= 1\backslash\ 0.25m - 1\backslash\ \infty = 4 \text{ Diopter}$$

The eyeball is too long, and parallel rays are focused by the relaxed eye to a position in front of the retina. Only near objects can therefore be seen clearly. This defect can be corrected by diverging lenses. If the spectacle lens is chosen to have a focal length equal in magnitude to the distance to the far point (F), then parallel rays striking the spectacles appear to the eye to diverge from the far-point. Note that the least distance of distinct vision for the spectacled eye is no longer d but increased to x

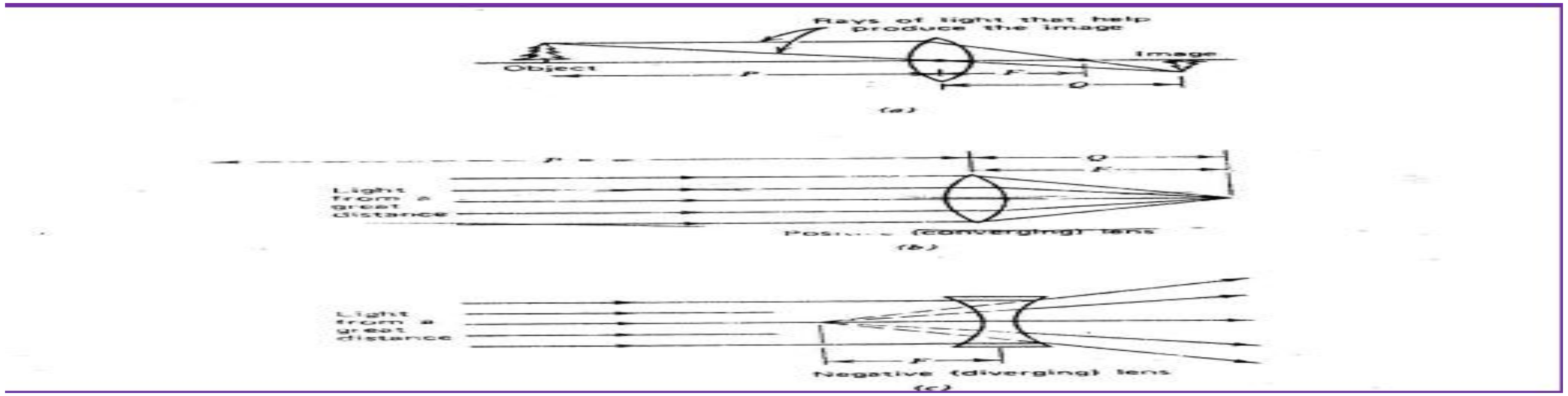


where $1\backslash -F = 1\backslash x - 1\backslash d$

An object at distance x must produce a virtual image at d in the spectacle lens in order just to be brought to focus by the eye.

This is the opposite effect. The eyeball is too short and parallel rays are focused to a point behind the retina, this defect is corrected by using converging spectacle lenses, if the near point is at d1 . Then an object at d requires the lens to produce a virtual image of it at d1 which will then be visible to the fully accommodation eye in the other words the focal length of the spectacle lenses must be F. Where

$$\frac{1}{F} = \frac{1}{d} - \frac{1}{d^{-1}}$$



EXAMPLE

EX 1: A man has a near point 50cm and far point infinity, what is his useful accommodating power. $P = 1 \backslash near\ point - 1 \backslash far\ point = 1 \backslash 0.5m - 1 \backslash \infty = 2\ Diopte$

EX 2: What spectacle lenses would be prescribed for the man of example 1.

1/F corrected = 1/n.p for normal eye – 1/n.p defected 1/F corrected =

1/0.25m -1/0.5m = 2 Diopter

F =1/2 Diopter = 0.5m = 50cm

EX3: A myopic male has near and far point of 20cm and 250 cm respectively. What spectacle lens is prescribed for his defect and where is his near point.

1/F corrected = 1/f.p for normal eye – 1/f.p defected

1/F corrected = 1/∞ – 1/2.5m = - 0.4 Diopter

F = -2.5m the lens is diverging

The near point when wearing the spectacles will be

1/F corrected = 1/n.p after wearing glass – 1/n.p without glass

1/-2.5m = 1/n.p after wearing glass – 1/0.2m

1/n.p after wearing glass =1/0.2m -1/2.5m

=5 Diopter – 0.4 Diopter = 4.6 Diopter

n.p after wearing glass =1/4.6 Diopter =0.217m = 21.7cm

اضغط على رابط الاسفل

https://drive.google.com/file/d/1NNrTXxpbSoU2MHAjqDE3vtpBDjaIgwdr/view?usp=sharing

شكرا لكم

Thank you

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