

Chapter 3 Fluid Mechanics

✚ Properties of Bulk Matter (Modulus)

✚ Pascal Principle

✚ Archimede's Principle

Modulus is the ratio of stress to strain: **Elastic Modulus** = $\frac{\text{Stress}}{\text{Strain}}$

Stress is the applied force that acts on area of the object, **S = F/A implies F = SA.**

Strain is a measure of the degree of **deformation** of the object in length, area and volume.

Length strain $s = \Delta L/L_0$, Area strain $s = \Delta A/A_0$ Volume strain $s = \Delta V/V_0$

What is deformation? List and define types of deformation.

We consider three types of deformation and define an elastic modulus for each:

1. **Young's modulus**, which measures the resistance of a solid to a change in its length
2. **Shear modulus**, which measures the resistance of a solid to a change in its area due to a solid sliding past each other
3. **Bulk modulus**, which measures the resistance of solids or liquids to changes in their volume

Change	Strain	Modulus	Formula	
Length	$s = \Delta L/L_0$	Young's	$Y = \frac{F/A}{\Delta L/L_0}$	$Y = \frac{FL_0}{A\Delta L}$
Area	$s = \Delta A/A_0$	Shear	$S = \frac{F/A}{\Delta A/A_0}$	$S = \frac{FA_0}{A\Delta A}$
Volume	$s = \Delta V/V_0$	Bulk Modulus	$B = \frac{F/A}{\Delta V/V_0}$	$B = \frac{FV_0}{A\Delta V}$

1. The ratio of stress to strain up to the material's limit of proportionality is
A. Modulus B. Shear modulus C. Young's modulus D. Bulk modulus
2. The extension ΔL divided by the wire's original length L_0 is known as
A. Shear Stress B. Tensile strain C. Young's modulus D. Tensile stress
3. The measures the resistance of a solid to a change in its length is
A. Modulus B. Shear modulus C. Young's modulus D. Bulk modulus
4. A 200kg load is hung on a wire with a length of 4m, a cross-sectional area of $2 \times 10^{-4} \text{ m}^2$, and a Young's modulus of $8 \times 10^{10} \text{ N/m}^2$. What is its increase in length ΔL ?
5. A 20N force applied to the ends of a wire 4m long, and produces an extension of 0.5m. if the diameter of wire is 2cm a. Find the stress on the wire b. Find the strain c. Young's modulus

➤ Pressure in static fluid

The pressure P in a fluid is the force per unit area exerted by the fluid $P = \frac{F}{A}$. The SI unit of pressure is Pascal (Pa). In static fluid, pressure depends only on the depth or height (h) of the fluid

$$P = \rho gh$$

ρ is the density of the liquid. For example density of water is $\rho = 10^3 \text{ kg/m}^3$

Example 1. Find the pressure of water in the container of 10m height.

Solution: Given that pressure $P = \rho gh = 10^3 \text{ kg/m}^3 \times 10 \text{ m/s}^2 \times 10 \text{ m} = \underline{10^5 \text{ Pa}}$

Pressure on the large body of water like big lake, sea or ocean is given by

$P = P_{\text{atm}} + \rho gh$ P_{atm} is atmospheric pressure on the sea and ocean: $1 \text{ atm} = 76 \text{ cmHg}$

2. Calculate the pressure at an ocean depth of 100m. $P_{\text{atm}} = 101.3 \text{ kPa}$.

3. Define absolute pressure, gauge pressure and specific gravity, $\rho_{\text{SG}} = \rho_{\text{s}}/\rho_{\text{w}}$.

4. $P_{\text{ab}} = P_{\text{atm}} + P_{\text{g}}$

+ Pascal Principle

Pascal principle states that the pressure applied to an enclosed fluid is transmitted undiminished to every point in the fluid and to every point on the walls of the container.

Its application is hydraulic press: $\frac{F_1}{A_1} = \frac{F_2}{A_2}$ or $\frac{A_2}{A_1} = \frac{F_2}{F_1}$

6. The small piston of a hydraulic lift has an area of 2.0 m^2 and an engine that weights $2.0 \times 10^4 \text{ N}$ placed on the larger piston which has an area of 6.0 m^2 , then the force applied on the small piston is

A. $6.67 \times 10^3 \text{ N}$ B. $6.0 \times 10^4 \text{ N}$ C. $4.0 \times 10^3 \text{ N}$ D. $6.0 \times 10^3 \text{ N}$ E. None

7. $F_1 = 20 \text{ N}$ with $A_1 = 6 \text{ m}^2$ of a kirk that lift a car on $A_2 = 12 \text{ m}^2$. Find F_2

+ Archimede's Principle

When an object is partially or fully submerged in a fluid, the fluid exerts on the object an upward force called the buoyant force. Buoyant force is the upward force of a liquid on an immersed object.

Archimedes's principle states that, the buoyant force F_B is equal to the weight of the fluid displaced by the object. Buoyant force = the weight of displaced liquid,

$F_B = \rho V_d g$ V_d is volume displaced water.

If an object is fully immersed into fluid, the volume of an object V_o is equal to the volume of fluid displaced V_d , that is $V_o = V_d$ equal volumes.

1. Define buoyant force.
2. State Archimedes' principle.
3. Why objects float or sink.
4. Which of the following statements best describes the buoyant force on an object submerged in water?
 - A. The buoyant force is equal to the weight of the water displaced by the object
 - B. The buoyant force is equal to the weight of all of the water
 - C. The buoyant force is equal to the volume of water displaced by the object
 - D. The buoyant force is equal to the weight of the object submerged in water
5. A body of 4 kg mass displaces 100cm^3 of water when fully immersed in water. The volume of a body is
 - A. 400cm^3
 - B. 25cm^3
 - C. 100cm^3
 - D. 4cm^3
6. If two pieces of metals fully immersed into a liquid have equal upthrust on them; then both pieces of metals have equal
 - A. Masses
 - B. Densities
 - C. Volumes
 - D. Weights

Bernoulli's Equation: Conservation equation: Mass flow into is equal to Mass flow out ($M_{in} = M_{out}$) implies $A_1 v_1 = A_2 v_2$ continuity equation). Energy Conservation: $E = \Delta k + \Delta U$ implies $PV = \Delta k + \Delta U$, gives us

$P_1 + \frac{1}{2} \rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2} \rho v_2^2 + \rho g h_2$

1. Water flows through a fire hose of diameter 6cm at a rate of $2\text{m}^3/\text{s}$. The fire hose ends in a nozzle with an inner diameter of 2cm. What is the speed at which the water exits the nozzle?

Properties of **ideal fluid** are; non-viscous (no friction in the fluid), incompressible (constant density) and that the fluid's motion is a steady flow (constant velocity) with no rotation.

Chapter 4 Thermodynamics

- ✚ Temperature
- ✚ Heat, Heat Capacity and Specific Heat Capacity
- ✚ Heat Transfer Mechanisms
- ✚ Thermal Expansion of solids, liquids and gases
- ✚ First Law of Thermodynamics

Temperature and heat

What is Heat?

Heat is a transfer of energy from hotter regions to colder regions. It is one form of energy and its unit is joule.

What is temperature?

Temperature is a measure of hotness or coldness. It indicates the direction in which heat energy will spontaneously flow from hotter body to a colder body.

The temperature of a substance is a measure of the average kinetic energy of the particles within the substance. If the particles in a substance have a higher average kinetic energy then the object is at a higher temperature.

Temperature scales

Kelvin scale (K), Celsius scale ($^{\circ}\text{C}$) and Fahrenheit scale ($^{\circ}\text{F}$) are known as temperature scales. The SI unit of temperature is Kelvin. These temperature scales related using freezing and boiling point of water as standard conversion relationship.

Kelvin scale is a temperature scale that uses absolute zero as one of its fixed points.

Absolute zero is the temperature at which a substance has no thermal energy. It's the minimum possible temperature in nature.

Water	Kelvin (K)	Celsius (°C)	Fahrenheit (°F)
Freezing point	273.15	0	32
Boiling point	373.15	100	212

- Kelvin scale T_K and Celsius scale T_C can be related as

$$T_K = T_C + 273.15 \text{ and } T_C = T_K - 273.15$$

Example: 10 °C temperature is equal to 283K

- Celsius scale T_C and Fahrenheit scale T_F relationship calculated by comparing their freezing and boiling point.

$$\frac{100 - 0}{212 - 32} = \frac{T_C - 0}{T_F - 32}, \text{ this gives us}$$

$$T_C = \frac{5}{9}(T_F - 32), T_F = \frac{9}{5}T_C + 32 \text{ and } T_K = \frac{5}{9}(T_F - 32) + 273.15$$

Convert the following

1. 20 °C to °F and K
2. 70 °F to °C and K
3. At what temperature the reading on Celsius is equal to the reading on Fahrenheit?
4. At what temperature in Kelvin and Celsius a substance has no thermal energy?

Questions

5. What is the SI unit of temperature?
6. What are the different temperature scales? What are fixed points in each scale?
7. Explain the meanings of lower and upper fixed points?
8. How many divisions are there between the lower and the upper fixed points, in each scale?

What is Thermal Equilibrium?

Thermal Equilibrium is situation where there is no net movement of heat energy between bodies. 5 | 19

State the Zeros law of thermodynamics.

- If two bodies are in thermal equilibrium, they will also be at the same temperature.
- When bodies are in thermal contact, heat energy flows from hot object to cold object until thermal equilibrium is reached and the bodies are at the same temperature.
- No heat exchange between two systems in thermal contact if they are in thermal equilibrium?
- Heat transfer obeys the law of conservation of energy (if no heat is lost to the surroundings):
 $Q \text{ lost from hotter object} = Q \text{ gained by colder object}$

Heat, specific heat capacity and heat capacity

Energy that flows from a warmer object to a cooler one because of the difference in temperature is called heat energy (Q).

Heat capacity (C)

Heat capacity is the heat energy Q required to raise the temperature of a given substance by 1K or 1°C,

$$C = \frac{\Delta Q}{\Delta T} \Rightarrow \Delta Q = C\Delta T$$

Specific heat capacity (c)

Specific heat capacity is the heat energy Q required to raise the temperature of 1kg of a given substance by 1K.

$$c = \frac{\Delta Q}{m\Delta T} = \frac{C}{m} \text{ implies that } C = mc, \text{ and } \Delta Q = cm\Delta T$$

 The SI unit of specific heat capacity c is $\frac{\text{J}}{\text{Kg.K}}$

Latent Heat (L)

The heat required to change the phase of substance at constant temperature is called Latent Heat (L).

$$Q = mL$$

Example

1. The specific heat capacity of water is 4200 J/kg/k. How much energy will be needed to warm 800g of water from 17°C to 27°C?

$$\Delta Q = cm\Delta T$$

$$C = 4200 \text{ J/kg/k}, m = 800\text{g} = 0.8\text{kg}, \Delta T = 27^\circ\text{C} - 17^\circ\text{C} = 10^\circ\text{C} = 10\text{K}$$

$$\Delta Q = cm\Delta T = 4200 \text{ J/kg/k} \times 0.8\text{kg} \times 10\text{K} = 33,600\text{J}$$

1. A circular copper plate of uniform thickness has a circular hole in its center. The plate expands when it is heated from 20°C to 300°C. Does the hole expand?
2. A new temperature scale is called Z. On Z scale, the boiling point of water is 150°Z and the freezing point is -10°Z. Find the corresponding 70°Z in Celsius (°C).
3. On unknown scale X, the ice point temperature is 50°X and the steam point temperature is 200°X. If the temperature is 60°C, what is the reading in °X?
4. A 5kg of water at an initial temperature of 15°C is mixed with a 2kg of water at 95°C. What is the final temperature of the mixture?

$$\text{Heat exchange: Heat lost} = \text{Heat gained}, -Q_{\text{lost}} = Q_{\text{gained}} \Rightarrow -cm(T_f - T_i) = cm(T_f - T_i)$$

$$\Rightarrow -c2\text{kg}(T_f - 95^\circ\text{C}) = c5\text{kg}(T_f - 15^\circ\text{C}) = 190^\circ\text{C} - 2T_f = 5T_f - 75^\circ\text{C} \Rightarrow T_f = 37^\circ\text{C}$$

5. What amount of heat is required to raise temperature of:
 - a) 2kg of water from 20°C to 40°C
 - b) 3kg of copper from 20°C to 50°C
 - c) 2kg ice at -10 °C to water at 20°C
6. What is the heat capacity of a 3kg of copper?
7. The amount by which unit length of a material increases when the temperature is raised one degree is called _____.
8. The amount of heat energy required to raise the temperature of unit mass of a substance by 1°C is called_____.
9. A 4g of water at 50°C is poured into a well-insulated 30g of copper calorimeter at 20°C. The temperature of water at equilibrium is _____.

Heat Energy Transfer Mechanisms

Heat energy can be transferred from one place to another in three ways:

1. **Conduction** is mechanism of energy transfer by a physical touch of solids each other. Conduction can be viewed as an exchange of kinetic energy between colliding molecules or electrons.
2. **Convection** is energy transferred by the movement of molecules of a warm substance. Only take place in liquids and gases.
3. **Radiation** is energy emitted in the form of electromagnetic waves: When electromagnetic waves fall on a body, the energy may be absorbed, transmitted or reflected.
4. **Direct burning**

Thermal Expansion: There are three types of thermal expansion: Linear expansion, Area expansion and volume expansion

Key words?

- **Expand** to increase in size
- **Thermal contact** when there is a movement of heat energy
- **Thermal expansion** the increase in size of a substance as a result of heating

Linear expansion: the increase in length of a solid is proportional to its initial length l_0 and the change in its temperature ΔT .

Linear expansion: $\Delta l = \alpha l_0 \Delta T \Rightarrow l = l_0 (1 + \alpha l_0 \Delta T)$

Area Expansion: $\Delta A = \beta A_0 \Delta T \Rightarrow A = A_0 (1 + \beta \Delta T)$

Volume expansion: $\Delta V = \gamma V_0 \Delta T \Rightarrow V = V_0 (1 + \gamma \Delta T)$

1. Find the change in volume of a 1m^3 block of copper when it is heated from 10°C to 100°C .
2. The amount by which unit length of a material increases when the temperature is raised by one degree is A. area expansion B. volume expansion C. cubic expansion D. linear expansion

First Law of Thermodynamics

Heat (Q), Work (W) and Internal Energy (U)

Heat and work are two possible ways of transferring energy from one system to another. Work (W) is a non-spontaneous energy transfer into or out of a system due to force acting through a displacement.

The **first law of thermodynamics** states that when a system undergoes a change from one state to another, the change in its internal energy ΔU is

$$\Delta U = Q + W$$

where Q is the energy transferred into the system by heat and W is the work done **on** the system, (if work done **by** the system, -W). Heat added or absorbed: +Q and heat released or leaves: -Q

Thermodynamic Processes

1. **Cyclic process** (one that originates and terminates at the same state), $\Delta U = 0$ and, therefore, $Q = -W$. That is, the energy transferred into the system by heat equals the negative of the work done on the system during the process.
2. **Adiabatic process**, no energy is transferred by heat between the system and its surroundings ($Q = 0$). In this case, the first law gives $\Delta U = W$. That is, the internal energy changes as a consequence of work being done on the system
3. **An isobaric process** is one that occurs at constant pressure. The work done on a gas in such a process is $W = -P(V_f - V_i)$, then $\Delta U = Q - P(V_f - V_i)$.
4. **An isochoric process** is one that occurs at constant volume, $V_f = V_i$. No work is done in such a process, so $\Delta U = Q$.
5. **An isothermal process** is one that occurs at constant temperature. In an isothermal process involving an ideal gas, $\Delta U = 0$, then $Q = -W$. No change in the internal energy of the system occurs in an isothermal process. The work done on an ideal gas during an isothermal process is $W = nRT \ln \left(\frac{V_i}{V_f} \right)$.

Unit Work sheet

Unit 4

1. The temperature of 45°C is equivalent to
A. 31°F B. 81K C. 318K D. 45°F
2. The process of changing a substance from solid to liquid state is
A. Freezing B. Melting C. Sublimation D. Evaporation
3. The main source of heat energy by radiation is A. Moon B. Venus C. Star D. Sun

4. 0.1kg water at 20°C is mixed with 0.1kg water at 40°C. What is the temperature of a mixture? A. 20°C B. 40°C C. 30°C D. 60°C
5. The amount of heat energy required to raise the temperature of unit mass of a substance by 1°C is called
A. latent heat B. latent heat of fusion C. specific heat capacity D. heat capacity
6. The change in volume of a 2m³ block of copper when heated from 10°C to 60°C
7. An aluminum plate has a circular hole at its center. If the temperature of the plate increases, what happens to the size of the hole?
A) Increases C) Stays the same
B) Decreases D) Increases the top half of the hole
8. Which one of the following is **not** heat transfer mechanism?
A. Conduction B. Induction C. Emission D. Radiation
9. At what temperature should the Celsius and Fahrenheit scales read the same value? A) 0°
B) 37° C) -40° D) 50°
10. In which of the following process the increase in internal energy of a system is equal to the work done on the system.
A. Isochoric B. Adiabatic C. Isobaric D. Isothermal
11. In liquids and gases, heat transmission is primarily caused by
A. Radiation B. Convection C. Conduction D. Absorption
12. 200J of heat **leaves** the system and 250J of work is **done on** the system. What is the change in internal energy of the system? A. 450J B. 50J C. 100J D. 200J
13. A gas expands doing 400J of work. How much heat energy must be added to this system for its internal energy increased by 500J? A. 100J B. -100J C. 900J D. -900J
14. If a thermodynamic system undergoes a process in which its internal energy increased by 400J while doing 200J of work on its surrounding, then what is the energy absorbed in the from heat?
15. The length of a 100 mm bar of metal increases by 0.3 mm when subjected to a temperature rise of 100 K. The coefficient of linear expansion of the metal is:
A) $3 \times 10^{-3} \text{ K}^{-1}$ B) $3 \times 10^{-4} \text{ K}^{-1}$ C) $3 \times 10^{-5} \text{ K}^{-1}$ D) $3 \times 10^{-6} \text{ K}^{-1}$
16. A process in which the working substance neither receives nor gives heat to its surroundings during expansion or compression is called A) Isothermal process C) Isobaric process
B) Adiabatic process D) Isochoric process
17. Pressure in static fluid depends only on _____
18. A 40cm tall glass is filled with water to a depth of 30cm. Find the pressure.
19. _____ is the upward force exerted on an object wholly or partly immersed in a fluid.

20. Which one the following factors affect buoyant force?
- A. the density of the fluid B. the volume of the fluid displaced C. the local acceleration due to gravity D. all
21. What is the unit of **buoyant** force? Newton
22. A boat floats by a buoyant force of $4 \times 10^6 \text{ N}$ on seawater with a density of 1026 kg/m^3 . Find the volume of displaced seawater.
23. An object total submerged in water displaces 100 m^3 water. What is the buoyant force exert on an object?
24. For an adiabatic process, the first law of thermodynamics becomes _____.

Chapter 6 Electrostatic

-  Coulomb's Law and Electric Fields
-  Electric Potential
-  Current, Resistance and Ohm's Law
-  Electrical Energy and Power
-  Equivalent Resistance and Kirchhoff's Rule

Electrostatic means charge at rest. **Charge (q)** is basic property of physical matter.

Properties of electric charges:

1. Like charges repel each other
2. unlike charges attract each other,
3. charge is conserved
4. charge is quantized (that is integral multiple of elementary charge), which is charge of electron or proton $e = 1.6 \times 10^{-19} \text{ C}$. Thus, $q = ne$, where $n = 1, 2, 3, \dots$. The charge of electron or proton is smallest unit of charge known to exist in nature.

One Coulomb is equal to the charge of 6.2×10^{18} number of electrons, that is $1 \text{ C} = 6.2 \times 10^{18} e$.

Coulomb's Law

Coulomb's Law states that electric force exerted by a charge q_1 on a second charge q_2 is

$$F_e = K q_1 q_2 / r^2$$

Where, r is the distance between the two charges q_1 to q_2 . The constant K called the Coulomb constant, has the value $K = 9 \times 10^9 \text{ N.m}^2/\text{C}^2$

Electric field E

The electric field E at some point in space is defined as the electric force F_e that acts on a small positive test charge placed at that point divided by the magnitude of the test charge q_0 :

$$E = F_e / q_0 = K q / r^2$$

at a distance r from a point charge q . The SI unit of Electric field is N/C.

$F_e = qE$ is electric force.

➤ Describe Electric Field Lines

Electric Potential Difference

Electric potential create when electric field set by an arbitrary charges, then the potential difference in a uniform electric field is $V = Ed$, where d is the distance between charges. The Electric Potential Due to Point Charge is

$$V = Kq / r$$

The potential difference $\Delta V = V_A - V_B$ between two points A and B in an electric field.

The Electric Potential Energy

Electric potential energy is a stored energy due charge. The electric potential energy, U is derived from the definition of work done:

$$W = FS = qEd = qV, \text{ but } W = \Delta U, \text{ then } \Delta U = q\Delta V$$

$$\text{Potential Difference } \Delta V = \Delta U / q$$

The SI unit of both electric potential and potential difference is joules per coulomb, which is defined as a volt (V).

Example

1. A particle of 4C charge experiences a force of magnitude 12N when it is placed in an electric field E at a point. What is the electric field at that point?
2. A 4V motorcycle battery that can move 7 μ C of charge, and a 10V car battery that can move 100C of charge. How much energy does each deliver?
3. A charge $q_1 = 2.0\mu$ C is located at the origin, and a charge $q_2 = -6.0\mu$ C is located at (0, 3.0) m. Find the total electric potential due to these charges at the point (4.0, 0) m.
4. A uniform electric field of magnitude 250 V/m is directed in the positive x direction. A 12.0 μ C charge moves from the origin to the point $(x, y) = (20.0 \text{ cm}, 50.0 \text{ cm})$. a) What is the change

- in the potential energy of the charge–field system? b) Through what potential difference does the charge move?
25. Which one of the following is **correct** about properties of charges?
- A. Like charges are attract each other C. Unlike charges are attract each other
B. Unlike charges are repel each other D. Charge is not quantized
26. A 2m conducting rod is fixed perpendicularly to a uniform electric field of 200N/C. The potential difference between the ends of a rod is:
- A. 400V B. 0V C. 300V D. -400V
27. A light bulb has a resistance of 3Ω when operating at a voltage of 18V. What is the current through the light bulb? A. 21A B. 6A C. 54A D. 15A
28. What is the electric force between two **protons** which are separated by 1.6×10^{-15} m ($k = 9 \times 10^9$, $|e^+| = 1.6 \times 10^{-19}$ C)
- A. Zero. B. 90N, attractive C. 1.6N, repulsive D. 90N, repulsive
29. Which alternative is **wrong** about electric field lines?
- A. Electric field lines start from positive charge C. Electric field lines cross each other
B. Electric field lines end at negative charge D. Electric field lines are imaginary lines
30. A battery has an e.m.f. of 3 V and an internal resistance of 1Ω . What current will it give if it is connected to a circuit of resistance 2Ω .

Ohm's Law

Consider a system of electric charges in motion. Whenever there is a net flow of charge through some region of cross-sectional area A , a current is produced, $I = \Delta Q / \Delta t$ implies charges in motion through an area A . The time rate at which charge flows through the area is the current I .

The SI unit of current is the ampere (A): $1A = 1C/1s = 6.25 \times 10^{18}$ electrons. That is, 1A of current is equivalent to 1C of charge passing through the surface area in 1s. It is conventional to assign to the current the same direction as the flow of positive charge. That is, in a conductor the direction of the current is opposite the direction of flow of electrons. Consider a conductor (σ) of length ℓ and cross-sectional area A carrying a current I . The current density J in the conductor is defined as the current per unit area, $J = I/A$, where J has SI units of A/m^2 . Charges moving in a conductor produce a current under the action of an electric field, which is maintained by the connection of a battery across the conductor of conductivity, σ . Thus, the current density is proportional to the electric field: $J = \sigma E = I/A$, the proportionality constant σ is called the conductivity of the material of which the conductor is made.

The inverse of σ is known as resistivity $\rho = 1/\sigma$. We know that $E = \Delta V / \ell$, substituting for E , we find that,

$$\sigma E = I/A, \sigma \Delta V / \ell = I/A \Rightarrow \Delta V / I = \ell / \sigma A = R$$

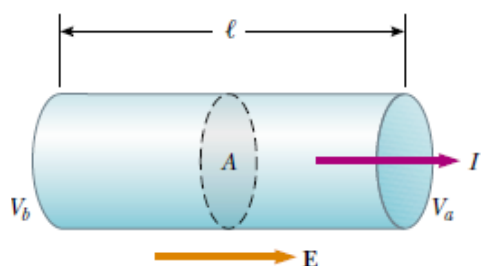
Then, **Ohm's** is:

$$\Delta V / I = R$$

Where, $R \equiv \ell / \sigma A$ is resistance of the conductor with resistivity $\rho = 1/\sigma$.

Therefore, Ohm's law states that current through a closed circuit is proportional to the voltage drop across a circuit.

Resistance R has SI units of volts per ampere. One volt per ampere is defined to be 1ohm (Ω): $1\Omega = 1V/1A$. Figure .1 a uniform conductor of length ℓ and cross-sectional area A . A potential difference $\Delta V = V_b - V_a$ maintained across the conductor sets up an electric field E , and this field produces a current I that is proportional to the potential difference.



$$\Delta V = V_b - V_a = E \ell$$

1. Calculate the resistance R of an aluminum cylinder that is 10cm long and has a cross-sectional area of $2 \times 10^{-4} \text{ m}^2$.
2. The resistance per unit length of a Copper wire, which has a radius of 0.321 mm, is _____. How much current does the wire carry when connected to a 120V source of potential difference?
3. Calculate the current density and electric field in the wire when it carries a current of 2.2A.
4. A light bulb has a resistance of 240Ω when operating at a voltage of 120 V. What is the current through the light bulb?
5. A 0.9V potential difference is maintained across a 1.5m length of tungsten wire that has a cross-sectional area of 0.6 mm^2 . What is the current in the wire?
6. A conductor of uniform radius 1.20 cm carries a current of 3.00A produced by an electric field of 120 V/m. What is the resistivity of the material?

Electrical Energy and Power

The electrical energy, U produced by a current of I amperes flowing through a p.d. of V volts for a time t seconds is given by:

$$U = qV = ItV.$$

Power is the energy produced by an electrical appliance in one second. Thus,

$$\text{Power } P = U/t = VI.$$

1. If the potential difference across a working electrical motor is 50 V and the current is 2 A, calculate the power of the motor.

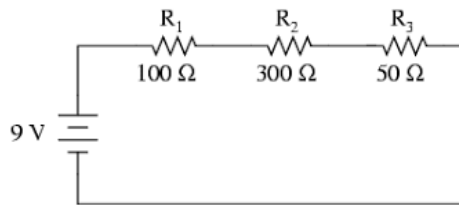
Equivalent Resistance R_{eq}

Combination of Resistors

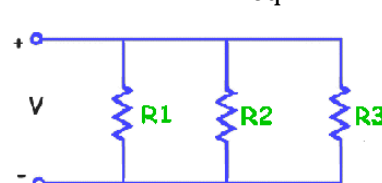
1. **Series combination:** Equivalent resistance R_{eq} is the sum of individual resistors in the circuit. $R_{eq} = R_1 + R_2 + R_3 + \dots + R_n$, the equivalent resistance of three or more resistors connected in series.

Series Circuits

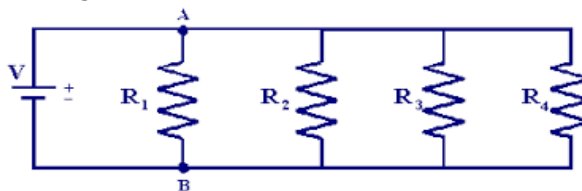
-  The current is the same in every resistor; this current is equal to that in the battery.
-  The sum of the voltage drops across the individual resistors is equal to the voltage rating of the battery.
-  The overall resistance of the collection of resistors is equal to the sum of the individual resistance values, $R_{tot} = R_1 + R_2 + R_3 + \dots$



2. **Parallel combination:** when resistors are connected in parallel, the potential differences across them are the same, then equivalent resistance of two resistors in parallel is given by $\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$



Parallel connection



Parallel Circuits

-  The voltage drop is the same across each parallel branch.
-  The sum of the current in each individual branch is equal to the current outside the branches.
-  The equivalent or overall resistance of the collection of resistors is given by the equation $1/R_{eq} = 1/R_1 + 1/R_2 + 1/R_3 \dots$

1. Three resistances of 10Ω, 15Ω and 30Ω are connected in parallel. The equivalent resistance of the combination is A) 10Ω B) 15Ω C) 5Ω D) 30Ω

2. The resistance of a parallel circuit consisting of two branches is 12Ω . If the resistance of one branch is 18Ω , the resistance of the other branch is A) 64Ω B) 48Ω C) 18Ω D) 36Ω

3. Two resistors are said to be connected in series when A) same current passes in turn through both resistors B) both carry the same value of current C) equivalent resistance is sum of each resistance

4. Three resistors 1Ω , 2Ω and 3Ω are connected in parallel and attached to a 12V source. Find a) R_{eq} b) total current c) current in each resistor d) calculate the power dissipated by each resistor e) Find the power output of the source ($P = I_t V = I^2 R_{eq}$)

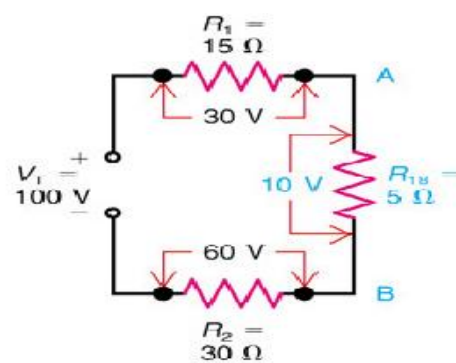
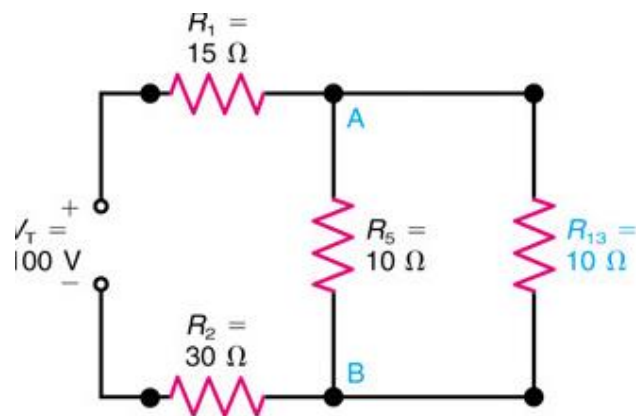
5. A stove is rated at 600W when connected to a 120V source. What current does the stove carry, and what is its resistance?

6. A hydroelectric turbine delivers 1500hp ($1\text{hp} = 745\text{W}$) to a generator, which in turn converts 80.0% of the mechanical energy into electrical energy. Under these conditions, what current does the generator deliver at a terminal potential difference of 2000V ?

Generator input = $1500 * 745\text{W} = 1117500\text{W}$. Generator output = $1117500\text{W} * 80.0\% = 894000\text{W}$.

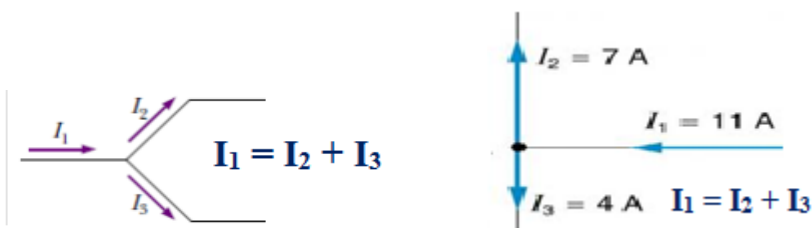
Current = $894000\text{W} / 2000\text{V} = 447\text{A}$.

7. Find the equivalent resistance and current through each resistor



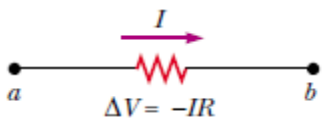
Kirchhoff's Rules (Hali888)

1. The sum of the currents flowing into a junction/node must be equal to the sum of the currents flowing out of the junction: $\Sigma I_{in} = \Sigma I_{out}$

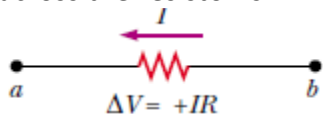


2. The sum of the potential differences across all elements around any closed circuit loop must be zero: $\Sigma \Delta V = 0$

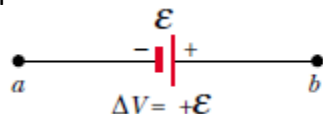
- A. If a resistor is traversed in the direction of the current, the change in potential ΔV across the resistor is $-IR$



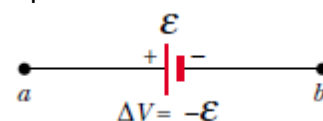
- B. If a resistor is traversed in the direction *opposite* the current, the change in potential ΔV across the resistor is $+IR$



- C. If a source of emf $\mathcal{E}$ is traversed in the direction of the emf (from $-$ to $+$), the change in potential ΔV is $+\mathcal{E}$



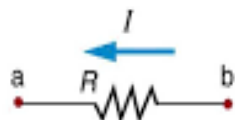
- D. If a source of emf is traversed in the direction opposite the emf (from $+$ to $-$), the change in potential ΔV is $-\mathcal{E}$



Direction of traverse $a \longrightarrow b$ Direction of traverse $a \longrightarrow b$

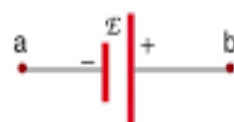


$$\Delta V = V_b - V_a = -IR$$

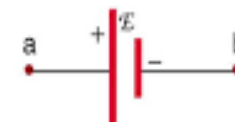


$$\Delta V = V_b - V_a = +IR$$

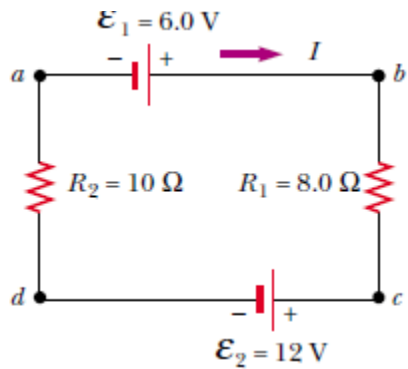
Direction of traverse $a \longrightarrow b$ Direction of traverse $a \longrightarrow b$



$$\Delta V = V_b - V_a = +\mathcal{E}$$



$$\Delta V = V_b - V_a = -\mathcal{E}$$



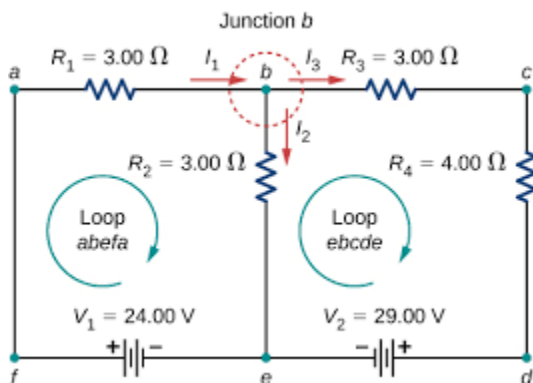
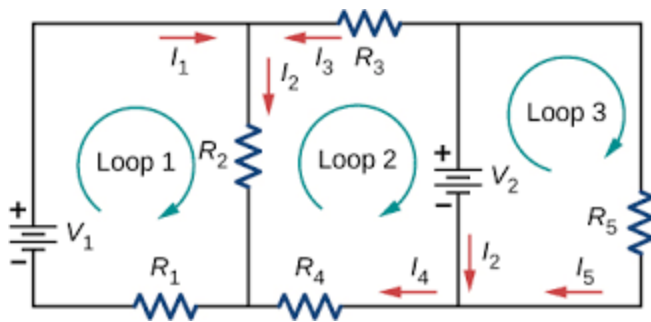
$$\Sigma \Delta V = 0$$

$$\mathcal{E}_1 - IR_1 - \mathcal{E}_2 - IR_2 = 0 \Rightarrow I = (\mathcal{E}_1 - \mathcal{E}_2) / (R_1 + R_2) = -0.33 \text{ A}$$

Power delivered to each resistor: $P_1 = I^2 R_1$, $P_2 = I^2 R_2$.

$$P_1 = (0.33 \text{ A})^2 (8 \Omega) = 0.87 \text{ W}, \quad P_2 = (0.33 \text{ A})^2 (10 \Omega) = 1 \text{ W}$$

Loop Rule



Loop abefa: $-I_1 R_1 - I_2 R_2 + V_1 = 0 \Rightarrow V_1 = I_1 R_1 + I_2 R_2$

$$\Rightarrow 24 = 3I_1 + 3I_2, \quad I_1 = I_2 + I_3 \quad \& \quad 24 = 6I_2 + 3I_3 \dots \text{eq1}$$

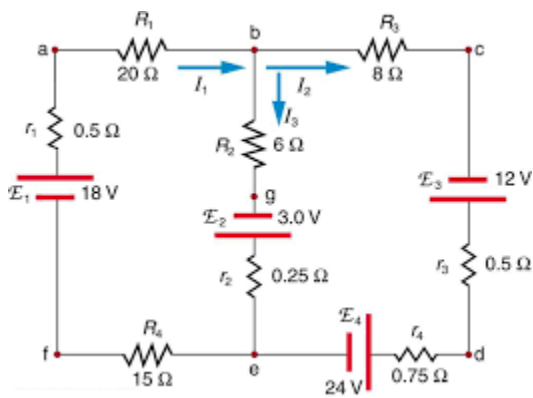
Loop ebcde: $I_2 R_2 - I_3 R_3 - I_4 R_4 - V_2 = 0 \Rightarrow 29 = 3I_2 - 3I_3$

$$-4I_3 \Rightarrow 29 = 3I_2 - 7I_3 \dots \text{eq2, solving eq1 \& eq2}$$

$$24 = 6I_2 + 3I_3$$

$$-2(29 = 3I_2 - 7I_3)$$

$$-34 = 10I_3 \Rightarrow I_3 = -3.4 \text{ A}, \quad I_2 = 5.7 \text{ A}, \quad I_1 = 2.3 \text{ A}, \quad I_2 = I_1 + I_3$$



1. Three resistances of 7Ω , 5Ω and 12Ω are connected in series. What is the equivalent resistance of the combination? A. 23Ω B. 24Ω C. 2.4Ω D. 2.3Ω
2. Which alternative is **wrong** about electric field lines?
 - A. Electric field lines start from positive charge
 - C. Electric field lines cross each other
 - B. Electric field lines end at negative charge
 - D. Electric field lines are imaginary lines
3. According to Ohms law, electric field (E) and current density (J) related as
 - A. $E \sim J^{-1}$
 - B. $E \sim J$
 - C. $E \sim \frac{1}{J^2}$
 - D. $E \sim \frac{1}{J}$
4. The sum of the potential differences across all elements around any closed circuit loop must be zero is known as
 - A. Kirchhoff's first rule
 - C. Kirchhoff's second rule
 - B. First law of thermodynamics
 - D. Second law of thermodynamics
5. How much heat energy is required to change a 100g ice cube from a solid at 10°C to liquid water at 60°C ?
6. For the circuit given below, find the equivalent resistance in current across each resistors

