BASIC CIRCUIT ELEMENTS AND SOURCES, OHMS LAW

1

Module 1: Fundamentals of DC Circuits

EEE 1024 Fundamentals of Electrical and Electronics Engineering

BIOGRAPHY

- Dr. Kishore Bingi
- Assistant Professor Senior Grade 1
- School of Electrical Engineering
- PhD from Universiti Teknologi PETRONAS, Malaysia
- https://www.kishorebingi.co.in/
- kishore.bingi@vit.ac.in

MICROSOFT TEAMS & OTHERS

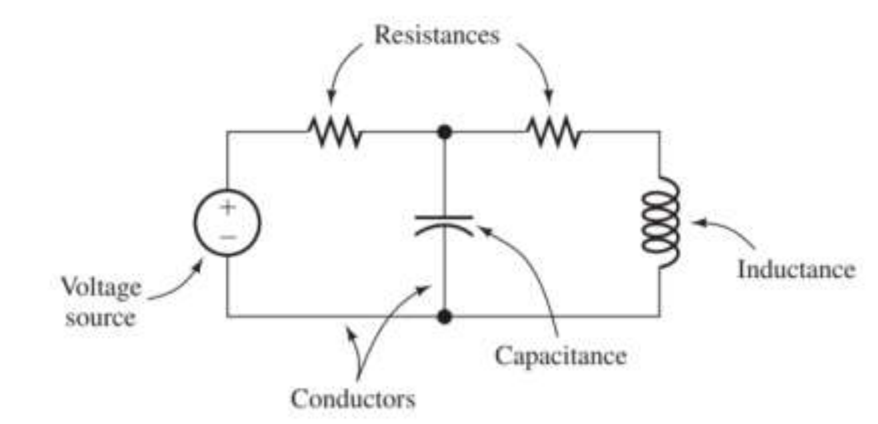
- Team Name: EEE1024 A2 Slot Monday & Wednesday Morning
- Syllabus: Teams - General – Files
- Material: Teams – Module – Files
- Attendance: Teams – Time in & Time Out – VTOP
- Questions during Presentation: Raise Hand
- Queries in General: Teams – Channel – Chat
- Assignments – End of each module through Moodle

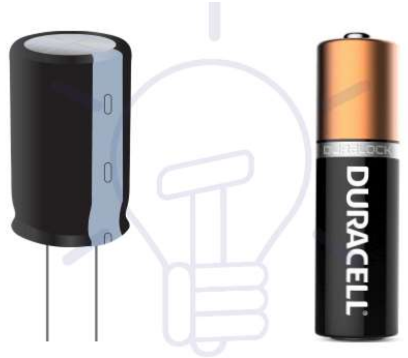
TOPICS

- Electrical Circuit
- Circuit Elements
- Charge
- Electrical Current
- Electrical Voltage
- Power & Energy
- Resistors and Ohm’s Law
- Ohm’s Law Triangle
- Power Triangle
- Ohm’s Law Pie Chart

ELECTRICAL CIRCUIT

- An **electrical circuit** consists of various types of circuit elements connected in closed paths by conductors.
- The circuit elements can be **resistances, inductances, capacitances, and voltage sources**, among others





CHARGE

- Charge flows easily through conductors, which are represented by lines connecting circuit elements.
- Voltage sources create forces that cause charge to flow through the conductors and other circuit elements.
- As a result, energy is transferred between the circuit elements, resulting in a useful function.

ELECTRICAL CURRENT

- Electrical current is the time rate of flow of electrical charge ($q(t)$) through a conductor or circuit element.

$$i(t) = \frac{dq(t)}{dt}$$

- The units are amperes (A), which are equivalent to coulombs per second (C/s).
- The charge on an electron is -1.602×10^{-19}C.
- To find charge given current, we must integrate.

$$q(t) = \int_{t_0}^{t} i(t)dt + q(t_0)$$

- t_0 is some initial time at which the charge is known.

EXAMPLE 1: DETERMINING CURRENT GIVEN CHARGE

- Suppose that charge versus time for a circuit element is given by

$$q(t) = \begin{cases} 0 & \text{for } t < 0 \\ 2 - 2e^{-100t} \text{ C} & \text{for } t > 0 \end{cases}$$

- Calculate $i(t)$ and Plot $i(t)$ and $q(t)$
- Solution:

$$i(t) = \frac{dq(t)}{dt}$$

For $t < 0 \;\rightarrow i(t) = \frac{dq(t)}{dt} \rightarrow 0$

For $t > 0 \;\rightarrow i(t) = \frac{dq(t)}{dt} \rightarrow \frac{d}{dt}(2 - 2e^{-100t}) \rightarrow 200e^{-100t} \;\text{ A}$

EXAMPLE 2: DETERMINING CURRENT GIVEN CHARGE

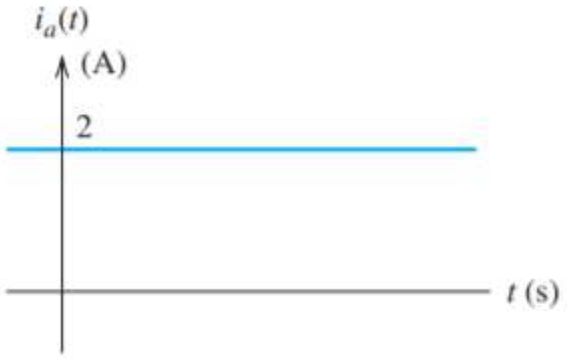
- The charge that passes through a circuit element is given by

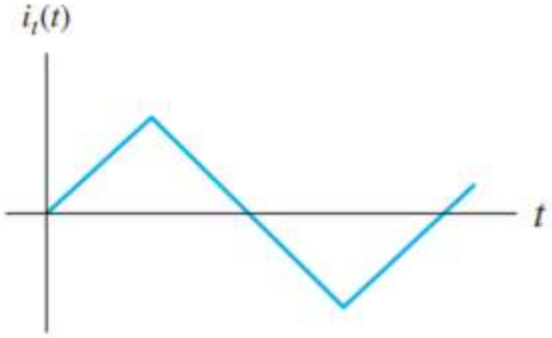
$$q(t) = 0.01\sin(200t)\ \mathrm{C}$$

- Find the current as a function of time.

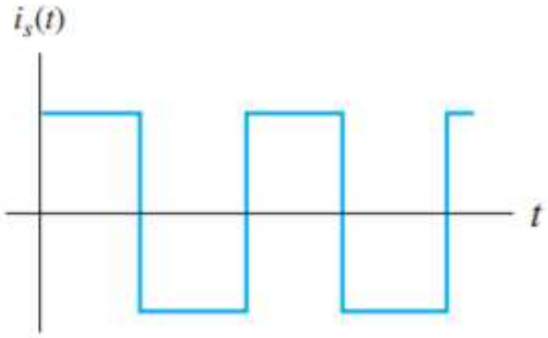
DIRECT CURRENT (DC) AND ALTERNATING CURRENT (AC)

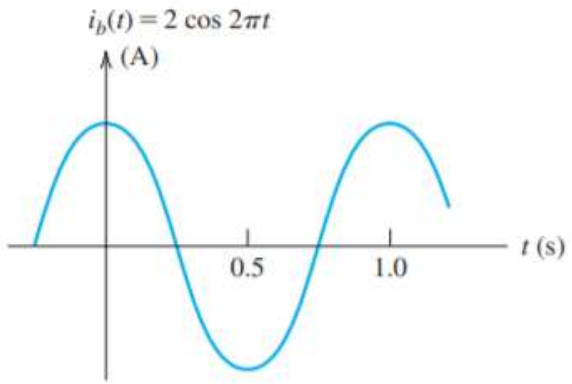
- When a **current is constant with time**, we say that we have **direct current**, abbreviated as **dc**
- When current that varies with time, reversing direction periodically, is called alternating current, abbreviated as **ac**.





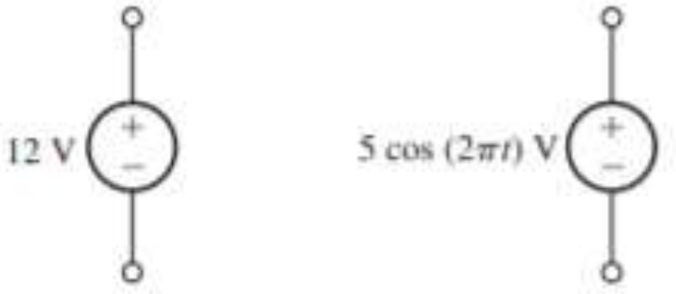
?





DIRECT VOLTAGE (DC) AND ALTERNATING VOLTAGE (AC)

- The **voltage** associated with a circuit element is the energy transferred per unit of charge that flows through the element.
- The units of voltage are volts (V), which are equivalent to joules per coulomb (J/C).
- Voltage constant with time is called **dc voltage**.
- Voltage that change in magnitude and alternate in polarity with time is called **ac voltage**.



(a) Constant or dc voltage source

(b) Ac voltage source

BASIC CIRCUIT ELEMENTS

- Resistance
- Inductance
- Capacitor

$$i(t) = \frac{dq(t)}{dt}$$

$$q(t) = \int_{t_0}^{t} i(t)dt + q(t_0)$$

SOURCES

- Voltage (V or J/C) – dc & ac
- Current (A or C/s) – dc & ac

POWER & ENERGY

- The current i is the rate of flow of charge and the voltage v is a measure of the energy transferred per unit of charge, the product of the current and the voltage is the rate of energy transfer.
- Thus, the product of current and voltage is power.

$$p = v * i$$

- Volts * Amperes = (joules/coulomb) * (coulombs/second) = joules/second = watts

POWER & ENERGY

- To calculate the energy w delivered to a circuit element between time instants t_1 and t_2, we integrate power

$$w = \int_{t_1}^{t_2} p(t)\, dt$$

- The units of energy is joules (J)

EXAMPLE 3 & 4: ENERGY & POWER

- Voltage is 12V and Current is 2 A. Calculate the power

$$p = v * i$$

$$p = 24 \text{ W}$$

- Voltage is 12V and Current is $2e^{-t}$. Calculate the power and energy for the intervals from $t_1 = 0$ to $t_2 = \infty$

$$p = 12 * 2e^{-t}$$

$$p = 24e^{-t} \text{ W}$$

- Energy:

$$w = \int_0^\infty 24e^{-t} dt$$

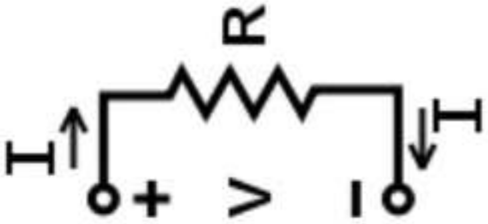
$$p = 24 \text{ J}$$

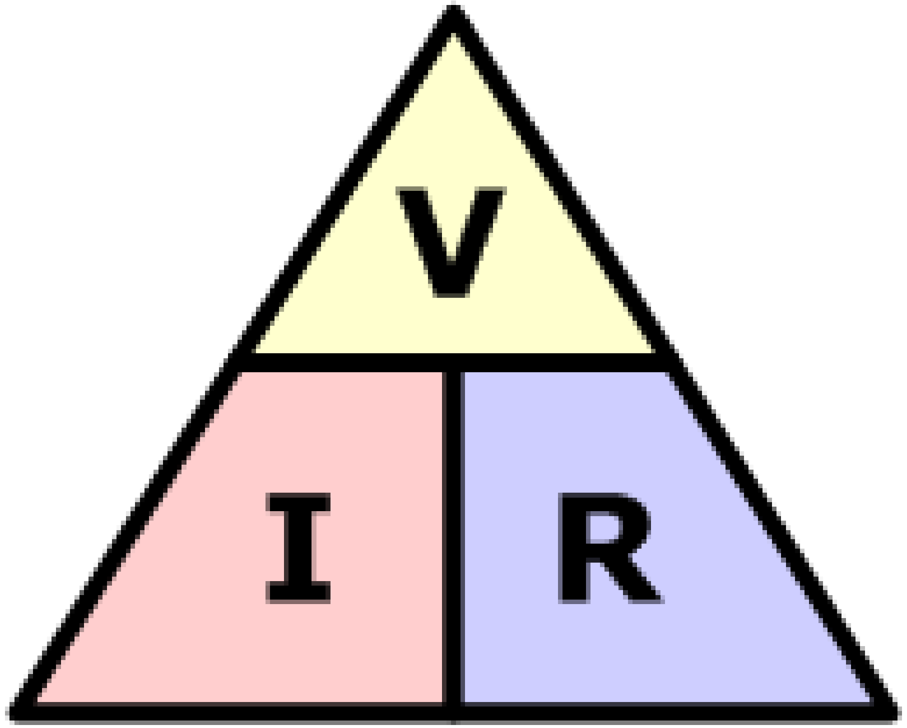
RESISTORS AND OHM'S LAW

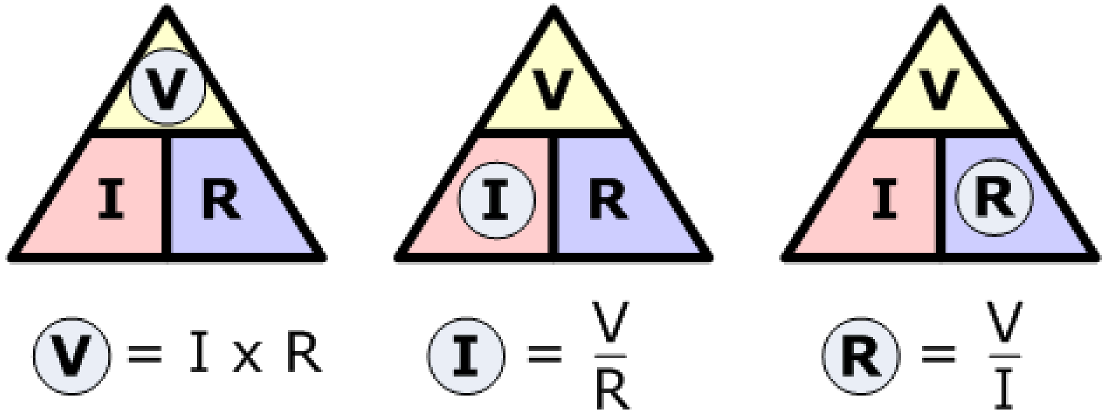
- The relationship between Voltage, Current and Resistance in any DC electrical circuit was firstly discovered by the German physicist Georg Ohm.
- The voltage $\boldsymbol{V}$ across an ideal resistor is proportional to the current $\boldsymbol{I}$ through the resistor $\boldsymbol{R}$.

$$\boldsymbol{V} = \boldsymbol{I} * \boldsymbol{R}$$

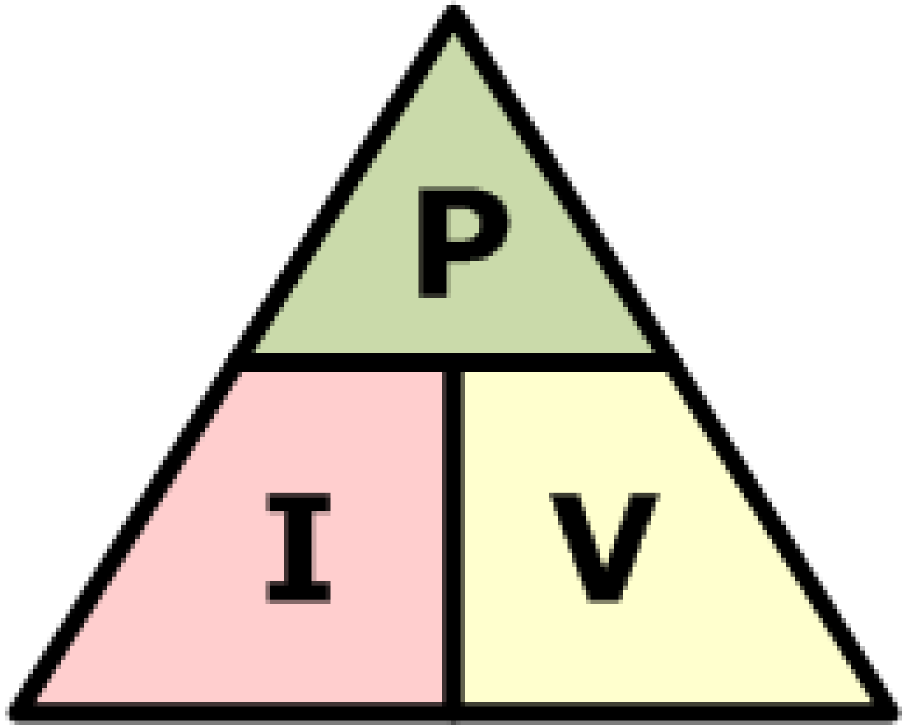
- The units of resistance are V/A, which are called ohms. The uppercase Greek letter omega (Ω) represents ohms.

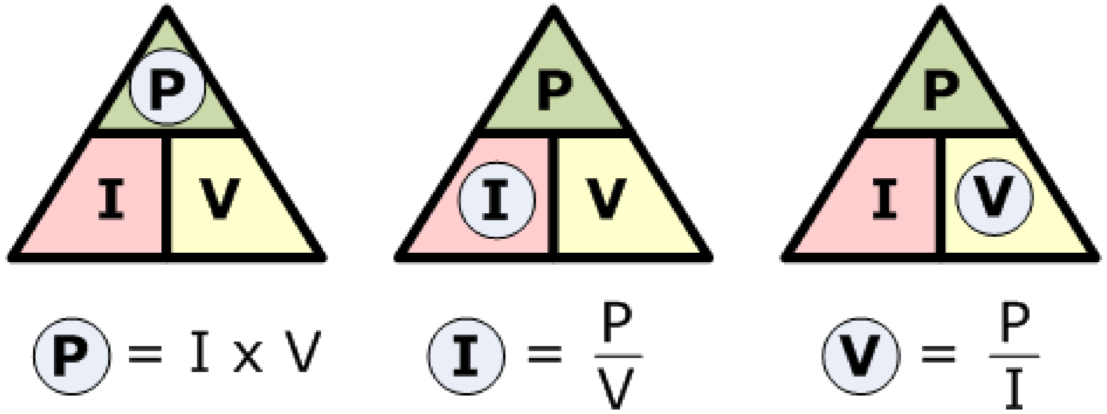






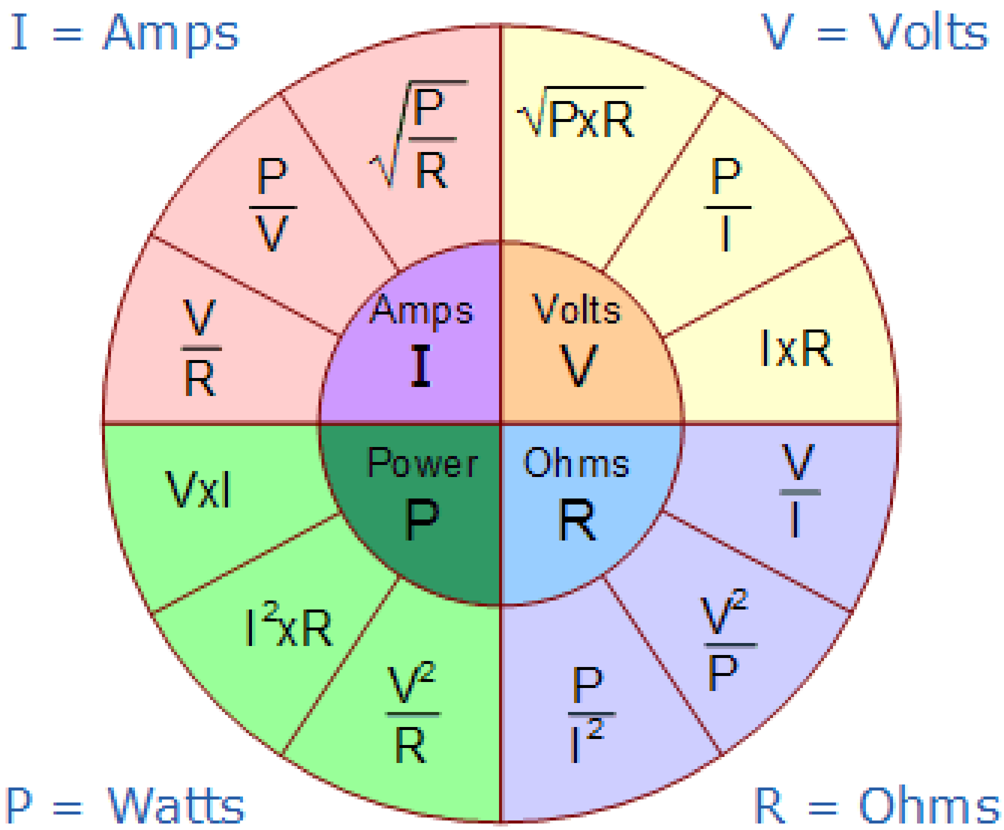
OHMS LAW TRIANGLE





POWER TRIANGLE

OHMS LAW PIE CHART



CONDUCTANCE

- Solving Ohm's law for current, we have

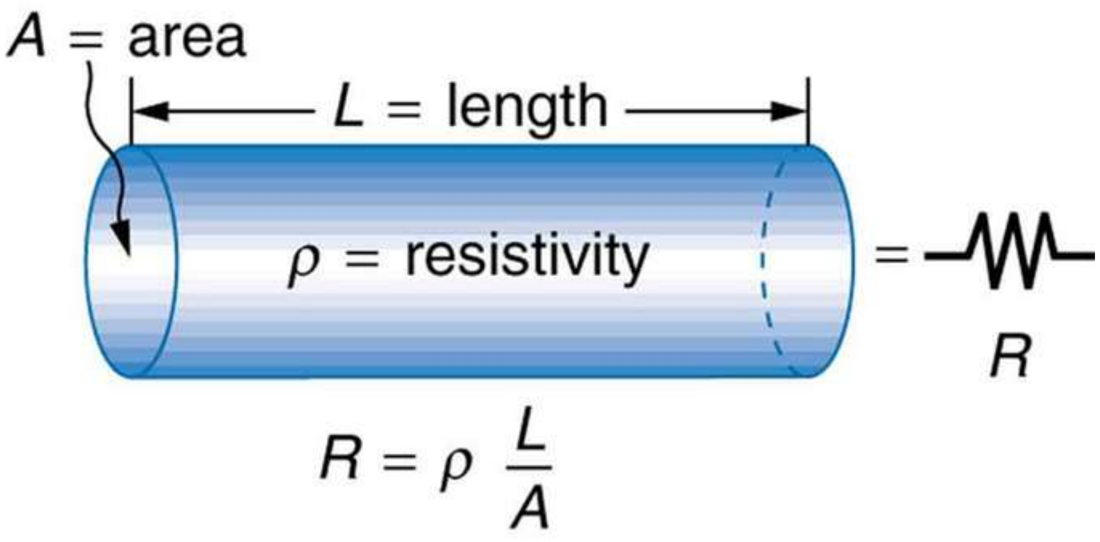
$$i = \frac{1}{R} v$$

- We call the quantity $\frac{1}{R}$ a conductance.
- It is customary to denote conductance with the letter G.

$$G = \frac{1}{R}$$

- Conductance's have the units of inverse ohms (Ω^{-1}), which are called siemens (abbreviated S). Thus, we can write Ohm's law as

$$i = G * v$$



- The cross-sectional area $\boldsymbol{A}$ is constant along the length of the cylinder or bar. If the length $\boldsymbol{L}$ of the resistor is much greater than the dimensions of its cross section, the resistance is approximately given by

$$R = \frac{\rho L}{A}$$

- ρ is the resistivity of the material used to construct the resistor.
- The units of resistivity are ohm meters (Ωm)

RESISTANCE RELATED TO PHYSICAL PARAMETERS

RESISTANCE RELATED TO PHYSICAL PARAMETERS

- Materials can be classified as **conductors**, **semiconductors**, or **insulators**, depending on their resistivity.
- **Conductors** have the **lowest resistivity** and **easily conduct electrical current**.
- **Insulators** have **very high resistivity** and **conduct very little current** (at least for moderate voltages).
- **Semiconductors** fall between conductors and insulators.

- Insulator
- conductors
- semiconductors

ASSIGNMENT 1: RESISTANCE CALCULATION

Compute the resistance of a copper wire having a diameter of 2.05 mm and a length of 10 m. Note the resistivity of a copper is given as $1.72 \times 10^{-8}\Omega$m.

ASSIGNMENT 2: MATCH THE FOLLOWING

1. Units of Voltage
2. Units of Current
3. Units of Power
4. Units of Resistance
5. Units of Charge
6. Units of Energy
7. Units of Conductance
8. Ohm's law
9. Power
10. Resistivity

a. Watt
b. V=I*R
c. Ohm (Ω)
d. Ampere (A or C/s)
e. Volt (V or J/C)
f. P=V*I
g. Siemens (S)
h. *(R*A)/L*
i. Joules (J)
j. C