UACE PHYSICS SEMINAR SLATED FOR 30^{th}

SEPTEMBER 2023 AT

KISUBI MAPEERA SECONDARY SCHOOL

Physics Paper one (P510/1)

MECHANICS

1 (a) (i) Define angular velocity and state its unit

(ii) Derive an expression for angular velocity, $\boldsymbol{\omega}$ in terms of linear speed, $\boldsymbol{v}$ and arc radius, $\boldsymbol{r}$

(b) A curve of radius 30 m is to be banked so that a car may make a turn at a speed of 13 ms^{-1} without depending on friction. Calculate the slope of the curve

(c) (i) State Kepler's laws of planetary motion

(ii) Show that Newton's law of universal gravitation is in agreement with Kepler's third law of planetary motion

(d) Explain what happens if mechanical energy of the earth's satellite is decreased

2 (a) (i) State the law of conservation of linear momentum

(ii) Derive the law of conservation of linear momentum from Newton's laws of motion

(b) Explain why long jumpers fold their knees when landing

(c) A 7500 kg truck traveling at 5.0 ms^{-1} eastwards collides with a 1500 kg car moving at 20 ms^{-1} in a direction S60°W. After collision, the two vehicles remain tangled together. Calculate the

(i) Common velocity of the vehicles

(ii) Loss in kinetic energy of the vehicles

(d) (i) Explain how an increase in weight affects friction between two bodies in contact

(ii) Describe an experiment to determine coefficient of static friction

3 (a) (i) Distinguish between stress and strain

(ii) State Hooke's law of elasticity

(b) With the aid of a labeled diagram, describe an experiment to determine Young's modulus of steel

(c) Derive an expression for the energy stored in a stretched wire of length, $\boldsymbol{L}$ and extension, $\boldsymbol{e}$ having Young's modulus, $\boldsymbol{E}$.

(d) A mass of 20 kg is suspended from a copper wire of diameter 2 mm and the wire suddenly breaks

(i) Explain briefly why the wire becomes hot after breaking

(ii) Calculate the change in temperature of the wire

4 (a) (i) Briefly explain stable and unstable equilibrium of a body.

(ii) A horizontal rod AB is suspended at the end by strings. The rod is 0.8 m long and a mass of 5 kg is attached 0.6 m away from A so that a body attains horizontal equilibrium. Find the tension in each string.

(b) (i) Define surface tension and free surface energy

(ii) Show that surface tension and free surface energy are numerically equal

(iii) Derive an expression for pressure difference between the pressure inside and outside an air bubble of radius R in a liquid of surface tension, $\boldsymbol{\gamma}$.

(c) Two soap bubbles of radii 1.5 mm and 2.5 mm coalesce under isothermal conditions. If the surface tension of the soap solution is 2.5×10^{-2} N m^{-1}, calculate the excess pressure inside the resultant bubble.

HEAT

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5. (a) (i) Define thermal conductivity.

(ii) Describe an experiment to determine thermal conductivity of a copper.

(b) The external wall of a brick house is of area 16 m^2 and thickness 0.3 m. The indoor and outdoor temperatures are 20°C and 0°C respectively. Find;

(i) The rate at which heat is lost through the wall.

(ii) The amount of heat lost in one hour when the internal surface of the wall is covered with expanded polystyrene tiles of thickness 20 mm.

(iii) The temperature of the brick-tile interface.

(Thermal conductivity of, brick $= 0.5\text{Wm}^{-1}\ \text{K}^{-1}$, polystyrene $= 0.03\text{Wm}^{-1}\ \text{K}^{-1}$)

(c) (i) Define a thermometric property.

(ii) State four examples of thermometric properties.

(d) The electrical resistance in ohms of a certain thermometer varies with temperature T kelvin according to the approximate law $\text{R} = \text{R}_0[1 + 5 \times 10^{-3}(\text{ T} - \text{T}_0)]$. The resistance is 101.6ohms at the triple point of water and 165.5ohms at 600.5 K. What is the temperature when the resistance is 123.4ohms ?

6. (a) (i) State Boyle's law and Charles' law

(ii) Describe an experiment to verify Boyle's law of ideal gases (06 marks)

(iii) Use Boyle's law and Charles' law to derive an equation of state for $\boldsymbol{n}$ moles of an ideal gas

(b) (i) Define a reversible adiabatic process

(ii) Give one condition for an adiabatic expansion to occur

(c) Five moles of neon gas at a pressure of 2.02×10^5 pa and a temperature of 27°C is compressed adiabatically and reversibly to one third of its initial volume. Taking the ratio of molar heat capacities of the gas as 1.67, determine the;

(i) final pressure and temperature of the gas

(ii) external work done on the gas

7. a) (i) Give the difference between *heat capacity* and *specific heat capacity* of a substance, and explain why water is used in a car radiator other than any other liquid.

(ii) Write down the measurements that need to be made in the determination of the specific heat capacity of a solid by the method of mixtures, pointing out the quantities to be given to you and the precautions to be taken.

(b) (i) What is meant by a black body?

(ii) State Stefan's law of black body radiation.

(iii) Draw a graph of relative intensity against wavelength for a black body at three different temperatures and use it to explain why the centre of a furnace appears white.

(c) Two spherical stars, A and B emit black body radiations. The radius of A is 400 times that of B and A emits 10^4 times the power from B. Calculate the ratio of wavelengths of the radiations emitted at maximum intensity of A to B

MODERN PHYSICS

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8 (a) (i) Define isotopes

(ii) Describe briefly how isotopes can be distinguished

(b) (i) Give two differences between $\boldsymbol{\alpha}$-particle and $\boldsymbol{\beta}$ - particle

(ii) Uranium, (${}^{2s}_{\mathrm{N}}U$) is radioactive and decays by emitting the following particles in succession before reaching a stable form; $\boldsymbol{\alpha}, \boldsymbol{\beta}, \boldsymbol{\beta}, \boldsymbol{\alpha}, \boldsymbol{\alpha}, \boldsymbol{\alpha}, \boldsymbol{\alpha}, \boldsymbol{\alpha}, \boldsymbol{\beta}, \boldsymbol{\beta}, \boldsymbol{\alpha}, \boldsymbol{\beta}, \boldsymbol{\beta}$ and $\boldsymbol{\alpha}$. What is the final stable nuclide?

(c) With the aid of a labeled diagram, describe how an ionization chamber is used to detect the presence of a radioactive source

(d) A source of radiations which produces one $\boldsymbol{\beta}$ - particle per decay has a count rate of 8.4β - particle per second with a mass of 2.5mg. The atomic mass of the nuclides in the source is 230. Calculate the half-life of the substance in the source

(e) Give one medical application of radioisotopes

9 (a) State the Bohr model of an atom

(b) (i) The total energy of an electron, $\boldsymbol{E}_{\mathrm{n}}$ in a hydrogen atom is expressed as

$$E_n = \frac{-k}{n^2}, \text{ where } k = \frac{me^4}{8\varepsilon_{\mathrm{a}}{}^2h^2}$$

Identify the quantities m and n in the expression and show that

$$E_n = \frac{-21.8 \times 10^{-19}}{n^2}\ \mathrm{J}$$

(ii) Calculate the ionization energy in meV of the hydrogen atom in (b)(i) above

(c) (i) What is meant by nuclear binding energy

(ii) Sketch a graph of binding energy per nucleon against mass number and use it to explain nuclear fusion and nuclear fission

(d) Calculate in meV, the energy released when $^{225}_{x}U$ undergoes fission reaction according to the equation;

(mass of $^{23}_{92}U = 235.051u$, mass of $^{148}_{57}L_a = 148.016u$, mass of $^{85}_{35}\mathrm{Br} = 84.903u$, mass of $^{1}_{0}n = 1.009u$, $1u = 1.66 \times 10^{-27}$ kg)

(e) Explain briefly how nuclear reaction can aid the production of electricity in a nuclear power plant

10. (a) (i) What is meant by photoelectric effect?

(ii) State one characteristic of photoelectric emission

(b) With the aid of a labeled diagram, describe a simple experiment to determine stopping potential of a metal

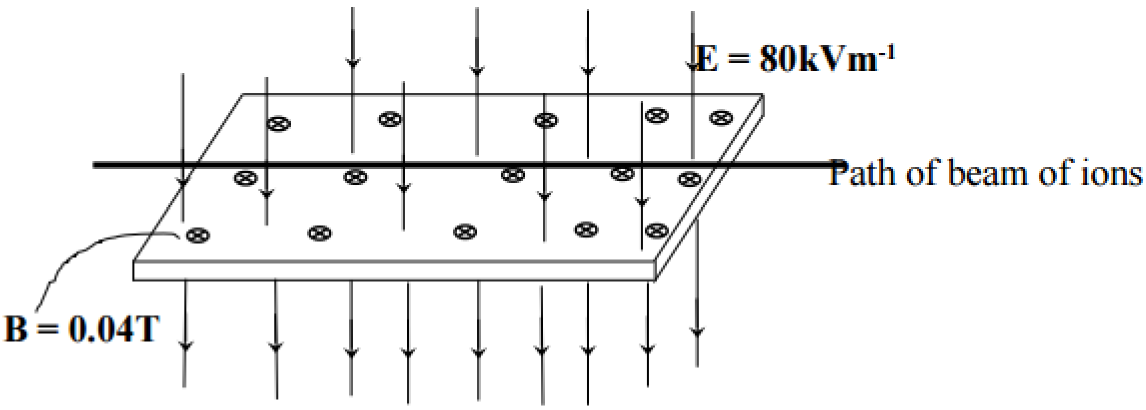
(c) (i) What are X - rays?

(ii) State two properties of X rays

(iii) Give the energy changes that occur during X ray production(02 marks)

(iv) In an X ray tube, 99% of the electrical power supplied to the tube is dissipated as heat at a rate of 742.5 W. If the tube voltage is 80kV, find the number of electrons arriving at the anode per second

(d) A charged beam of ions of specific charge $2.0 \times 10^7 \mathrm{Ckg}^{-1}$ enters a region where an electric field is uniform and downwards. Its value is $80\mathrm{kVm}^{-1}$ as shown in Fig:1



Perpendicular to $\boldsymbol{E}$ is $\boldsymbol{B} = \mathbf{0.04T}$, the beam goes straight through the fields without changing speed or direction. The electric field E is then switched off and the beam describes a circular arc. Determine the;

(i) speed of the beam

(ii) the radius of the circular arc

11. (a) With the aid of a labelled diagram and relevant equation, describe Millikan's experiment for determining the charge on an electron.

(b) An oil drop carried a charge 24e and is between two plates 4 mm apart. The drop falls under gravity with a velocity of 6.0×10^{-4} m s^{-1} and a p.d of 1600V applied between the plates makes the drop to rise with a steady velocity *v*. If the viscosity of air is 1.8×10^{-5} Ns m^{-2} and the density of oil is 900 kg m^{-3}, Calculate

(i) The radius of the drop

(ii) The value of *v*

(c) (i) State and derive Bragg's law of X-ray diffraction .

(ii) A second order diffraction image is obtained by reflection of rays at atomic planes of a crystal for a glancing angle 11.4^{o}. If the atomic spacing of the planes is 2.0×10^{-10} m, calculate the wavelength.

LIGHT

1. (a) Define the terms ***refraction*** of light and ***refractive index*** of an optical medium.

(b) A liquid $\mathbf{L_1}$ of maximum thickness 0.25 cm is placed inside a concave mirror resting on a flat horizontal surface. An optical pin clamped horizontally directly above the liquid, coincides with its own image at a height of 20.0 cm above the pole of the mirror. When the liquid $\mathbf{L_1}$ is replaced with liquid $\mathbf{L_2}$ coincidence between the pin and its image is attained at a height of 21.3 cm above the liquid surface If the refractive index of liquid $\mathbf{L_2}$ is 1.20 Determine the;

(i) refractive index of liquid $\mathbf{L_1}$

(ii) radius of curvature of the concave mirror.

(c) Describe how a plane mirror and a convex lens of known focal length can be used to measure the focal length of a concave lens.

(d) A convex lens L1 of focal length 10.0 cm, a concave lens L2**,** a real point object O and a plane mirror M are arranged co-axially, so that L1 and L2 are 5.0 cm apart as shown in the figure 1.

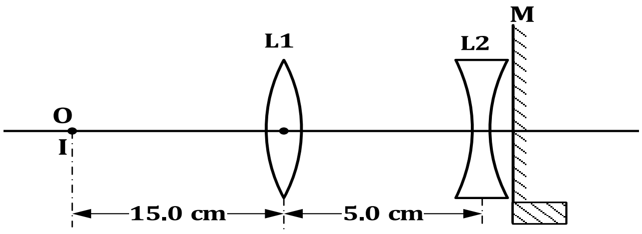


Fig. 1

When object O is displaced towards L1 so that the separation between O and L1 is 15.0 cm, the object O coincides with its own image I by no parallax.

(i) Determine the focal length of the concave lens L2.

(ii) Sketch a ray diagram showing the actions of the lenses.

2. (a) Define the following terms as applied to optical instruments.

(i) Visual angle

(ii) Angular magnification

(b) An insect that is 5.00 cm long is placed at a distance of 10.0 cm from a converging lens with a focal length of 12.0 cm.

(i) Determine the size of the image.

(ii) What is the angular magnification of the lens used.

(c) Describe the structural adjustments necessary to transform a compound microscope into an astronomical telescope.

(d) (i) Draw a labelled diagram of a slide projector.

(ii) A slide projector, using slides of width 5.08 cm, produces an image that is 2.00 m wide on a screen 3.50 m away. What is the focal length of the projector lens?

WAVES AND PHYSICAL OPTICS

3. (a) Distinguish between progressive waves and stationary waves.

(b) A transverse wave on a string in the x – direction is described by the equation, $y = 0.005\cos[4.0\pi t - 1.0\pi x]\ metres$ where t is the time in seconds. Determine the maximum speed and maximum acceleration of a vibrating wave particle at a point and sketch the corresponding graphs for one cycle of displacement against time, velocity against time and acceleration against time at the point x = 0.

(c) (i) Define the term ***Doppler effect***.

(ii) The front and hind wagons of a train moving at a speed u_s are fitted with sirens sounding at a frequency f. A boy running just besides the railway track at a speed u_0 between the two wagons from the direction of the front wagon towards that of the hind wagon, hears beats of frequency, f_b. Show that, the beat frequency f_b , heard by the boy assumed to be running in a straight line between the wagons is given by the equation,

$$f_b = \frac{2vf(u_0 + u_s)}{(v^2 - u_s^2)}$$

(d) (i) What is an end correction?

(ii) Describe an experiment to determine the end correction of a pipe open on both sides.

4. (a) (i) State the superposition principle of waves.

(ii) Explain using the superposition principle and Huygens's principle the occurrence of interference fringes in a double slit.

(b) Use Huygens's principle to derive an expression for Snell's law as light waves travel from an optical medium of lower refractive index to that of higher refractive index.

(c) (i) Distinguish between polarized light and un polarized light.(3 marks)

(ii) Give two uses of polarized light.

(d) (i) Explain how newton's rings are produced.

(ii) A lens whose surface has a radius of curvature R is placed on a flat plate of glass to test whether its surface is smooth and spherical and is illuminated from above by light of wavelength, λ. Show that the radius r_m of its m^{th} dark ring is given by, $r_m = \sqrt{m\lambda R}$

MAGNETISM AND A.C

5. (a) Define the following terms as used in magnetism.

(i) Magnetic variance.

(ii) Magnetic meridian.

(iii) Angle of dip.

(b) A flat circular coil of wire of 20 turns and of radius 10.0 cm is placed with its plane vertical and at 45° to the magnetic meridian. Assuming that horizontal component of the earth's magnetic flu density = 2.0 × 10 $^{-8}$ T, $\mu_0 = 4\pi \times 10^{-7} Hm^{-1}$

Calculate the current in the coil, if a compass needle, that is free to move in a horizontal plane, points in the East – West direction, when placed at the centre of the coil.

(c) (i) Write down an expression for the magnetic flux density at a perpendicular distance, d, from a straight wire carrying a current I in air.

(ii) Figure 2 shows three identical straight and parallel wires W_1, W_2, and W_3 of infinite length arranged along the x – axis and carrying currents of 5A, 2A and 5A respectively as shown.

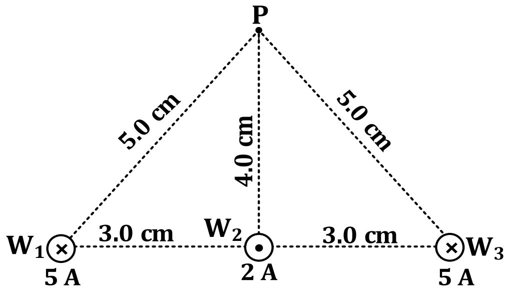


Fig. 2

(i) Determine the resultant magnetic flux density at point **P**. (5 marks)

(ii) A fourth wire of mass 4 mg and of length 0.250 m carrying a current of 4.5A into the plane of the paper is now placed at point **P**, deduce the acceleration of this wire from the result of (i) above.

(d) The diagram in the figure 3 shows a cuboid of a conductor of length **L**, breadth, **b** and thickness, **t**, placed with its largest face PQVW perpendicular to the horizontal component of the Earth's magnetic field of flux density $\mathbf{B_H}$. A current, **I** is passed through it as shown.

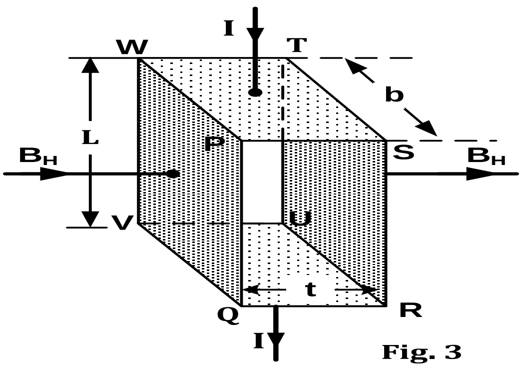


Fig. 3

(i) Account for the occurrence of a large potential difference across faces PQRS and UVWT and derive an expression for this voltage in terms of B_H, b and the average velocity of the charge carriers, v.

(ii) If the Earth's magnetic field at the location of the conductor is 2.0×10^{-4} T, the angle of dip is 60°, the breadth of the conductor is 5 cm and the mean speed of the electrons is 4.0×10^{-2} ms^{-1}. Calculate the potential difference across faces PQRS and UVWT.

6. (a) (i) What is electromagnetic induction?

(ii) State the laws of electromagnetic induction.

(b) A straight conductor of length L is moved perpendicularly across a uniform magnetic field of flux density, B at a velocity, v. Derive an expression for the e.m.f. induced across the conductor.

(c) Two metal rods **PQ** and **ST** each of length 0.500 m have resistances of 1 Ω and 2 Ω and are moving at 2.0 m s $^{-1}$ and 5.0 m s $^{-1}$ respectively in the same direction along smooth parallel conductors that are joined at the end with a resistor of 4 Ω. A uniform downward magnetic field of flux density 0.85 T threads the plane of the rails normally as shown in figure 4

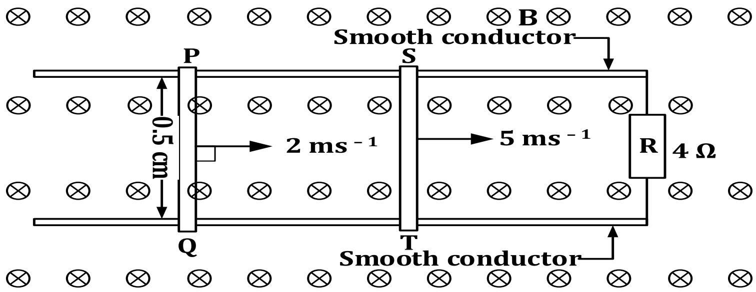


Fig. 4

Determine the;

(i) E.m.f induced in each rod. (3 marks)

(ii) Current passing through the resistor power dissipated in the 4Ω resistor labelled R. (5 marks)

(d) (i) Distinguish between self induction and mutual induction. (2 marks)

(ii) An a.c transformer operating on a 240 V mains has 1200 turns in the primary coil and gives a voltage of 18 V across the secondary coil. Determine, the number of turns in the secondary and the current flowing in the primary circuit, if a load of resistance of 50 Ω is connected across the secondary coil, assuming the efficiency of the transformer is 90%.

7. (a) (i) Define self-inductance of a coil?

(ii) A power supply unit of a laptop computer consists of a resistor of resistance R, connected in series to an ideal inductor of inductance, L, all connected to an ideal a.c. input source. The power unit is labelled as

" 45W AC Adapter, AC input: 1.0A max, 120V, 60 Hz"

Determine the values of L and R when the power supply draws the maximum current of 1.0A.

(b) (i) What is a diode?

(ii) Explain how a single diode is used to produce direct current through a resistor when connected to an a.c. source.

(c) (i) Describe the structure and mode of operation of a repulsion type of moving iron ammeter.

(ii) State two advantages of a moving iron ammeter over a moving coil ammeter.

(d) (i) Define the term impedance.

(ii) A pure inductor of self-inductance 5.0 mH is connected in series with a resistor of resistance 2.0 Ω and both are across a 240V a.c mains of frequency 50 Hz. Determine the impedance of the circuit.

8. (a) (i) State Coulomb's law of electrostatics.

(ii) Two positive point charges of +6 μC and +8 μC are placed 10.0 cm apart in free space. Determine the position between the point charges at which a charge of – 4 μC should be placed so that the net force on it is zero.

(b) (i) State Gauss's law of electrostatics.

(ii) Use Gauss's law to show that the capacitance, C, of a parallel plate Capacitor of plate separation, d, and of effective area, A, when placed in free space is given by, $C = \frac{\varepsilon_0 A}{d}$

(c) (i) What is an equipotential surface?

(ii) Explain why does the distance between the successive equipotential surfaces due to an isolated positive point charge in space increases away from the point charge if the p.d between adjacent surfaces is constant?

(iii) Sketch equipotential surfaces due to two opposite point charges placed near each other in free space.

(d) (i) What is lightning?

(ii) Two cows A and B each with a spacing of 1.8 m between a pair of front legs and the hind legs stand under a tall tree facing one direction at different points during a lightning storm as shown on the sketch in figure 5. Where P, Q, R, are equipotential surfaces at successive p.ds of 400V apart. The tree is then struck by lightning at a potential of 1000V. Explain giving reasons which cow and why one of the cow is likely to be struck dead by lighting and yet one is likely to just get a shock.

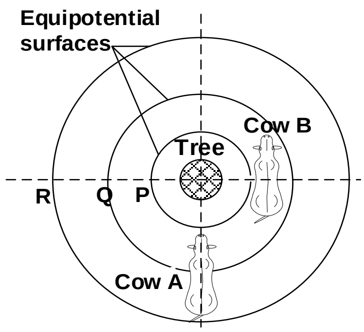


Fig. 5

9. (a) (i) What is corona discharge?

(ii) Describe one industrial application of corona discharge.

(b) (i) Distinguish between electric field intensity and electric potential

(ii) A Van de Graaff generator is charged to an electric potential of 240V with respect to the earth and a minimum electric field of 8.0×10^5 NC^{-1} ionizes the air in the neighborhood and eventually allowing the charge to leak off the Van de Graaff. Find the value of the minimum radius of the conducting sphere under these conditions.

(c) (i) Define the term capacitance of a capacitor.

(ii) A 6.2 cm by 2.2 cm parallel plate capacitor has its plates separated by a distance of 2 mm. When 4.0×10^{-11} C of charge is placed on the capacitor, determine the electric field intensity between the plates.

(d) (i) Derive an expression for the capacitance of an isolated positively charged metal sphere of radius, R, placed in free space.

(ii) The moon having a radius of 1737.4 km and a surface charge of $2.0 \mu C\ m^{-1}$ has its surface tightly wrapped with a thin aluminum foil. What is the capacitance of the moon in this case and electric field on its surface?

10. (a) (i) Define resistance of a conductor.

(ii) Two immersion Heaters A and B, are both connected to a 240V supply. Heater A can raise the temperature of 1.0 litre of water from 20.0°C to 90.0°C in 2 minutes, while heater B can raise the temperature of 5.0 litres of water from 20.0°C to 90.0°C in 5 minutes. What is the ratio of the resistance of heater A to the resistance of heater B.

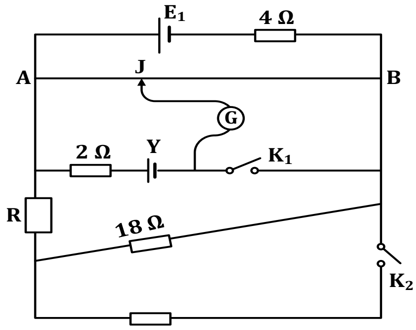


Fig. 7

(b) (i) Derive an expression for the effective resistance of two resistors arranged in parallel when they are connected to a battery.

(ii) The figure 6 shows a wire of length L used to make a closed loop ABCHA through which a current I enters at A and leaves at C. AB is part of a quadrant having an arc of radius, r, while AHC is a semi-circular arc of radius r, with O as its centre. If d, is the diameter of copper wire used for the loop AHC.

Show that the effective resistance of the loop is given by the expression,

$R = \frac{8\rho(\pi+2\sqrt{2})}{d^2(3\pi+2\sqrt{2})^2}$ where ρ is the electrical resistivity of the copper wire used.

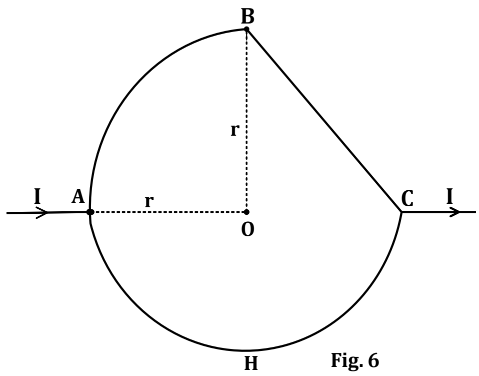


Fig. 6

(c) A potentiometer circuit shown has a driver cell of e.m.f, $\mathbf{E_1}$, and negligible internal resistance. AB is a uniform resistance wire 1.0 m long having a resistance of 8 Ω. Y is standard cell of e.m.f.1.48 V and having internal resistance of 0.2 Ω. When both switches K_1 and K_2 are open, the centre zero galvanometer G, shows no deflection when, AJ = 88.8 cm. When switch K_1 is closed while switch K_2 is open, the centre zero galvanometer G, shows no deflection when, AJ = 81.3cm. When resistors Q and R are interchanged and both switches K_1 and K_2 closed the balance length changes to 76.4 cm. Determine the,

(i) current flowing through the slide wire.

(ii) e.m.f. of the driver cell E_1.

(iii) values of resistances R and Q.

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