SOLUTIONS FOR THE

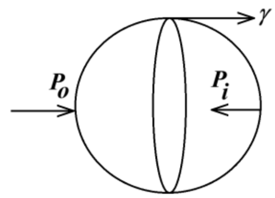
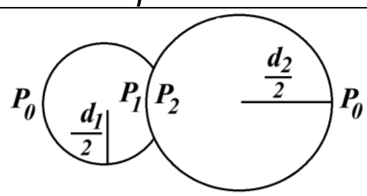
A' LEVEL PHYSICS SEMINAR

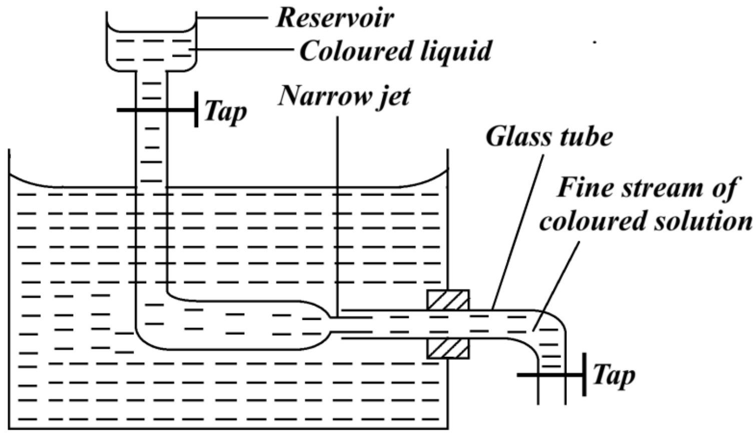
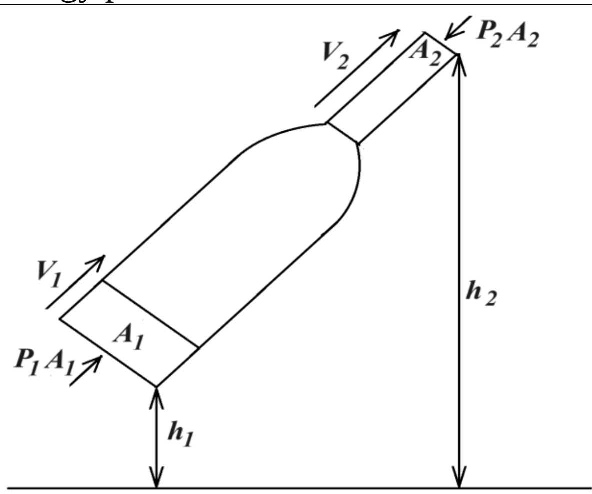
HELD AT UGANDA MARTYRS S.S NAMUGONGO

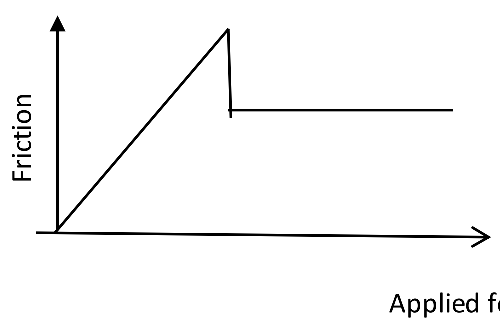
ON 5TH OCTOBER 2024

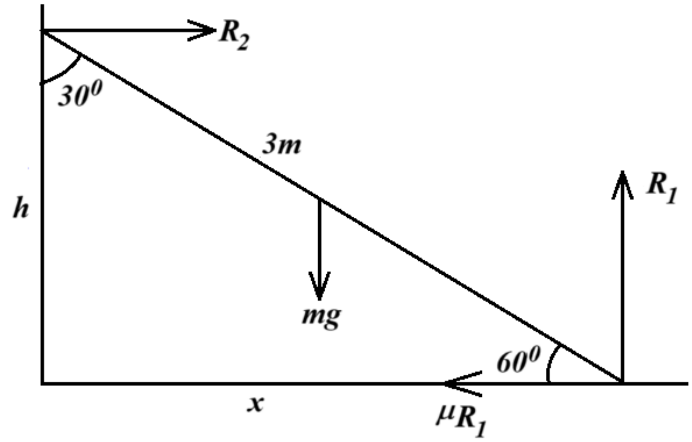
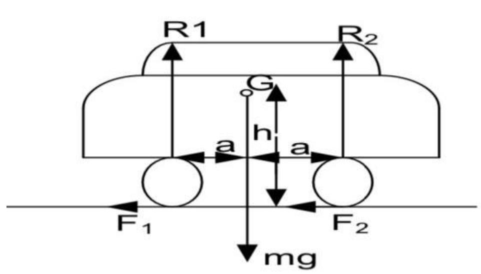
PHYSICS PAPER ONE

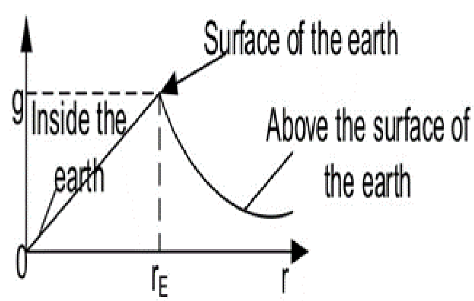
Qn.	*Approach*	*Remarks*
1. a i)	During an ***elastic collision***, kinetic energy is conserved but during an ***inelastic collision***, kinetic energy is not conserved	
ii)	***Momentum*** is the product of mass of a body and its velocity ***Impulse*** is the change is the momentum of a body.	
iii)	$F \propto \frac{mv - mu}{t}, \quad F = \frac{mv - mu}{t}, hence\ mv - mu = Ft$	
b i)	If no external force acts on a system of colliding bodies, their total momentum before collision is equal to their total momentum after collision.	
ii)	If two bodies of masses m_1 and m_2 moving with respective velocities $\boldsymbol{u_1}$ and $\boldsymbol{u_2}$ collide for a time $\boldsymbol{t}$ and move with velocities $\boldsymbol{v_1}$ and $\boldsymbol{v_2}$ after collision, then from Newton's 3rd law, $body1$ exerts a force $\boldsymbol{F_{12}}$ on $body2$ and $body2$ reacts with force $\boldsymbol{F_{21}}$ From Newton's **2nd** law $F_{12} = k\frac{(m_2v_2 - m_2u_2)}{t}\ and\ F_{21} = k\frac{(m_1v_1 - m_1u_1)}{t}$ From **3rd** law, $F_{12} = -F_{21}$ $k\frac{(m_2v_2 - m_2u_2)}{t} = -k\frac{(m_1v_1 - m_1u_1)}{t}$ $m_2v_2 - m_2u_2 = -m_1v_1 + m_1u_1$ $m_2v_2 + m_1v_1 = m_1u_1 + m_2u_2$	
c i)	$mgh = \frac{1}{2}mv^2, \ v = \sqrt{2gh} = \sqrt{2 \times 9.81 \times 3}\ \ \underline{\underline{= 7.67ms^{-1}}}$	
ii)	$u = \sqrt{2 \times 9.81 \times 5} = 9.90\ ms^{-1}$ $F = \frac{mv-mu}{t} = \frac{0.5(7.67+9.90)}{0.01}\ \underline{\underline{= 878.5N}}$	
d.	***Conservative forces*** are ones for which the work done to move a body through a closed loop is zero, whereas ***non-conservative forces*** are ones for which the work done to move a body through a closed loop is not zero e.g. Conservative – Gravitational force, magnetic force, electric force, non-conservative – Friction, Viscous force.	
2. a.	***Surface tension*** is the force acting normally per unit length on one side of a line drawn in the liquid surface.	
b.i)	Radius of the small drop = $0.5 \times 10^{-3}m$ Volume of the big drop $= 1000 \times \frac{4}{3} \times 3.14 \times (0.5 \times 10^{-3})^3 = \frac{4}{3} \times 3.14 \times R^3$ Radius of big drop = $[1000 \times (0.5 \times 10^{-3})^3]^{\frac{1}{3}} = 5 \times 10^{-3}m$ Surface area of big drop	

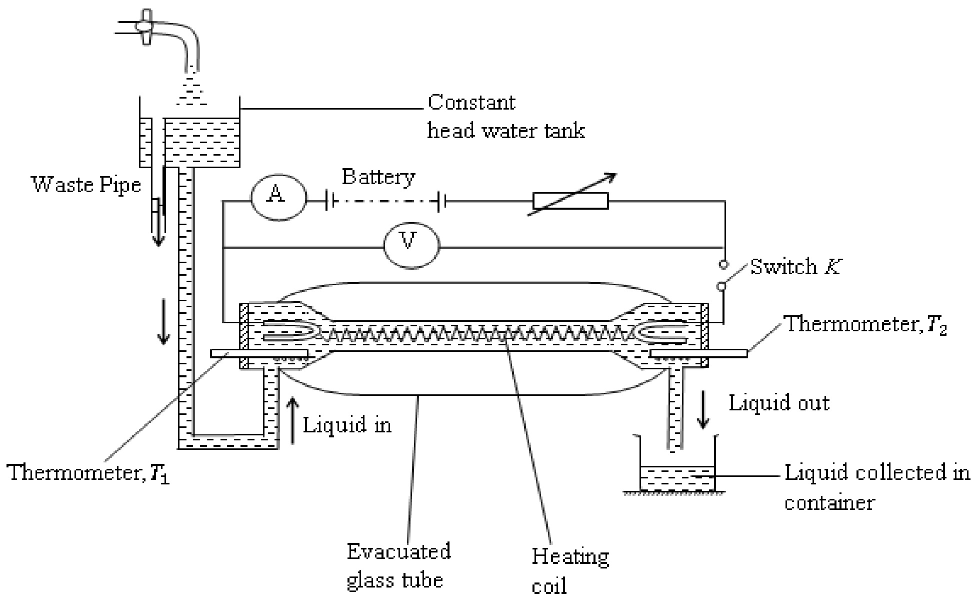
	$= 1000 \times 4 \times 3.14 \times (5 \times 10^{-3})^2 = 3.14 \times 10^{-4} m^2$ Area of small drops $= 1000 \times 4 \times 3.14 \times (0.5 \times 10^{-3})^2$ $= 3.14 \times 10^{-3} m^2$ Change in Area $= 3.14 \times 10^{-3} - 3.14 \times 10^{-4}$ $= 2.826 \times 10^{-3} m^2$ Energy released $= \gamma \Delta A = 2.826 \times 10^{-3} \times 7.2 \times 10^{-4}$ $\underline{\underline{= 2.035 \times 10^{-6} J}}$	
ii)	 $\pi r^2 P_0 + 2(2\pi r)\gamma = \pi r^2 P_i$ $\Rightarrow P_i - P_0 = \dfrac{4\gamma}{r}$	
iii)	 $P_2 - P_0 = \dfrac{4\gamma}{d_2/2} = \dfrac{8\gamma}{d_2}, \quad P_1 - P_0 = \dfrac{4\gamma}{d_1/2} = \dfrac{8\gamma}{d_1}$ $\dfrac{4\gamma}{r} = P_1 - P_0 = \dfrac{8\gamma}{d_1} - \dfrac{8\gamma}{d_2} = 8\gamma \dfrac{(d_2 - d_1)}{d_1 d_2}$ $\Rightarrow r = \dfrac{d_1 d_2}{2\gamma(d_2 - d_1)}$	
c i)	***Streamline flow*** is the flow of a fluid in which molecules that are equidistant from the axis of flow move with the same velocity parallel to the axis of flow while, ***Turbulent flow*** is the flow of a fluid in which molecules that are equidistant from the axis of flow move with different velocities	

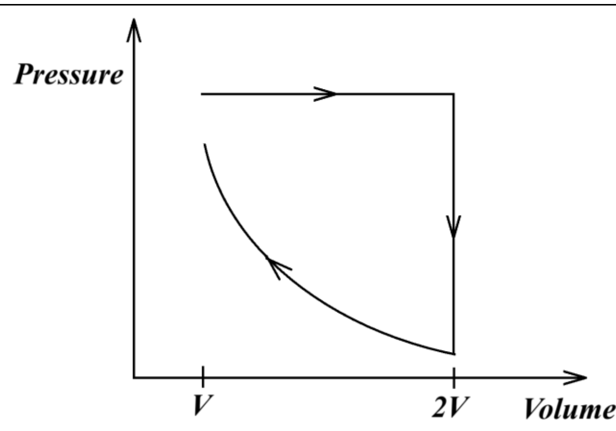
ii)	 • When the taps are opened at low velocities of flow, a thin coloured stream of liquid is observed flowing along the horizontal tube and this indicates streamline flow. • As the rate of flow of water is increased, a stage is attained when the colouring fills the whole tube and this indicates turbulent flow	
3. a. i)	***Bernoulli's principle*** states that the sum of the pressure at any of an incompressible non-viscous fluid under streamline flow plus the kinetic energy per unit volume plus the potential energy per unit volume is constant	
ii)	 $P_1A_1V_1 - P_2A_2V_2 \frac{1}{2}A_2V_2\rho V_2^2 - \frac{1}{2}A_1V_1\rho V_1^2 + A_2V_2\rho g h_2 - A_1V_1\rho g h_1$ But, $A_1V_1 = A_2V_2$ $Therefore,\ P_1 - P_2 = \frac{1}{2}\rho V_2^2 - \frac{1}{2}\rho V_1^2 + \rho g h_2 - \rho g h_1$ $P_1 + \frac{1}{2}\rho V_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho V_2^2 + \rho g h_2$	
b i)	***Coefficient of viscosity*** is the tangential force per unit area per unit velocity gradient. Units: $\text{Ns}m^{-2}$	

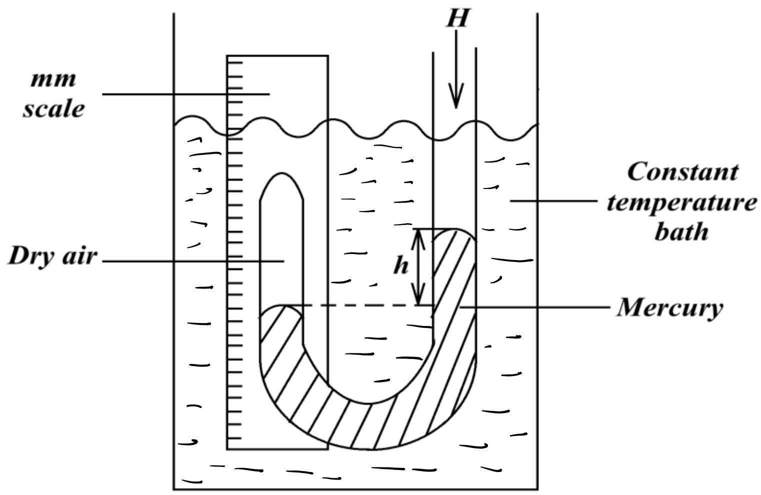
ii)	In liquids, viscosity depends on intermolecular forces of attraction. As temperature increases, the intermolecular forces reduce, hence viscosity reduces.	
iii)	$A_1V_1 = A_2V_2$ $10 \times 0.2 = 2.5V_2$ $V_2 = 0.8ms^{-1}$ $P_A - P_B = \frac{1}{2}\rho(0.8^2 - 0.2^2)$ $= \frac{1}{2} \times 1000 \times (0.8^2 - 0.2^2) \quad = 300Pa$	
c i)	***Lamina flow*** is the flow of a fluid in which layers of fluid that are equidistant from the axis of flow more with the same velocity parallel to the axis of flow. ***Turbulent Flow*** is the flow of a fluid in which layers of the fluid that are equidistant from the axis of flow move with different velocities.	
ii)	***The Filter pump*** The filter pump has a narrow section in the middle so that water from the tap flows faster here. This causes a drop in pressure near it and air therefore flows in from the side tube to which the vessel is connected. The air and water together are expelled through the bottom of the pump.	
4. a i)	***Limiting friction*** is the maximum friction that exist between two surfaces in contact just before relative motion starts	
ii)		
b i)	$F = mg\sin\theta + mg\cos\theta$ $= 2000 \times 9.81(\sin 20 + 0.2\cos 20) = \underline{10397.8N}$ $P = FV = 10397.8 \times 15 \quad = 1.56 \times 10^5 W$	
c	• The resultant force on the body is zero. • The sum of the clockwise moments about any point is equal to the sum of the anticlockwise moment about the same point	
d i)		

		
ii)	$h = 3\cos 3\,0 = 2.6m$ $x = 3\cos 60 = 1.5m$ $R_1 = mg = 5 \times 9.81$ Taking moment about P: $F \times 2.6 + 5 \times 9.8 \times 1 = R_1 \times 1.5$ $2.6F = 5 \times 9.81(1.5 - 1)$ $F = \underline{\underline{9.3N}}$ Reaction at the ground $R = (9.43^2 + (5 \times 9.81)^2)^{\frac{1}{2}} = \underline{\underline{49.95N}}$	
e i)	***A couple*** is a pair of equal parallel forces acting points on a body in opposite directions	
ii)	$W = F \times D$ $D = 10 \times 2\pi = 37.68m$ $W = 4 \times 37.68 = \underline{150.72J}$	
5. *a i)*	***Moment of inertia*** is the sum of the product of the masses of the particles of a rotating body and the square of their respective distances from the axis of rotation. $\sum mr^2$	
b i)	$I = (0.01 \times 0.25^2) + (0.01 \times 0.25^2) + (0 \cdot 01 \times 0 \cdot 5^2) + (0 \cdot 01 \times 0 \cdot 5^2)$ $= 6.25 \times 10^{-3} kgm^2$	
ii)	$8rev/s = 8 \times 2\pi rads^{-1}$ $\Rightarrow kE = \frac{1}{2}I\omega^2 = \frac{1}{2} \times 6 \cdot 25 \times 10^{-3} \times (8 \times 2\pi)^2 = 7.89J$	
c i)	 R_1 and R_2 are Normal Reactions F_1 and F_2 are Frictional Forces	

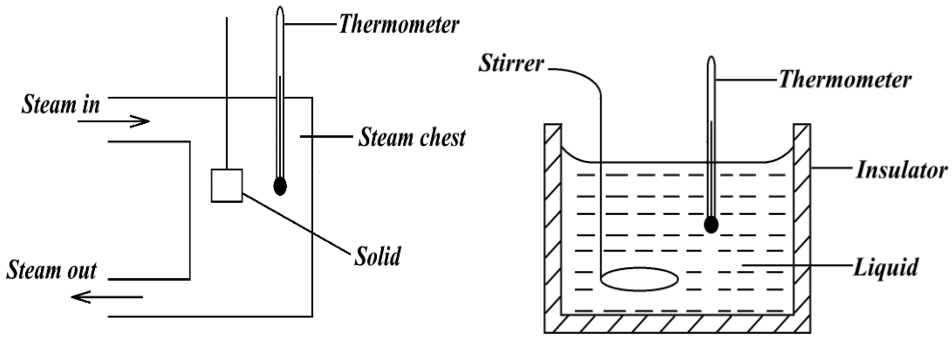
	Mg is the Weight of the Car	
ii)	$F_1 + F_2 = \frac{mV^2}{r} \ldots\ldots (i)$ $R_1 + R_2 = mg \ldots\ldots (ii)$ $F_1h + F_2h + R_1a = R_2a \quad \Rightarrow R_2 - R_1 = \frac{mV^2h}{ra} \cdots (iii)$ $(ii) - (iii),\ mg - \frac{mV^2h}{a} = 2R_1 = m\left(g - \frac{V^2h}{ra}\right)$ For safety of the car, $\frac{V^2h}{ra} \leq g \Rightarrow V_{\max} = \sqrt{\frac{gra}{h}}$ Where ***a***, is the distance half way between the tyres and ***h***, is the height of the centre of gravity above the ground.	
d.	Racing cars can move faster on banked circular tracks than on level tracks because there is a larger value of Centripetal force since it is provided by both the component of friction and the component of normal reaction.	
6. a i)	✓ Planets describe ellipses about the sun as one focus ✓ The line joining a planet to the sun sweeps out equal areas in equal time intervals ✓ The square of the period of revolution of the planet round the sun, is proportional to the cube of their mean distance of separation.	
ii)	For any two bodies in the universe, there is a force of attraction between them which is proportional to the product of their masses and inversely proportional to the square of their distance of separation.	
b i)		
ii)	$\frac{GMm}{r^2} = mg \Rightarrow g = \frac{GM}{r^2}$ Effective mass of the Earth $= \frac{4}{3}\pi(R_e - r)^3\rho$ $\Rightarrow g = G \times \frac{4}{3}\pi \frac{(R_e - r)^3\rho}{(R_e - r)^2}$ $g = \frac{4}{3}G\pi(R_e - r)\rho$	

c i)	If orbital radius of the Earth is R_e, then orbital radius of Mars $R_m = 1.53R_e$ $\frac{GMm}{{R_e}^2} = m\omega^2 R_e,\ \ but\ \omega = \frac{2\pi}{T_e} \Rightarrow GM = \frac{4\pi^2}{{T_e}^2}{R_e}^2$ Also, $GM = \frac{4\pi^2}{{T_m}^2}{R_m}^2 \quad \Rightarrow \frac{4\pi^2}{{T_e}^2}{R_e}^3 = \frac{4\pi^2}{{T_m}^2}(1.53R_e)^2$ $\Rightarrow T_m = \sqrt{(1.53^3 {T_e}^2)} = \sqrt{1.53^3 \times 365^2} = \underline{690.8\ days}$	
d i)	***Parking orbit*** is the path of a satellite about the Earth, whose period of revolution is the same as the period of rotation of the Earth about its axis i.e. $\boldsymbol{24 hours}$	
ii)	Artificial satellites are used for; Navigation, Global communication, Weather forecast, Study of the universe, Scientific research	
e i)	$M.E = \frac{GMm}{2R}$, but $R = 6\cdot4 \times 10^6 + 3\cdot59 \times 10^7$ $= 4\cdot23 \times 10^7 m$ $\Rightarrow M.E = \frac{6\cdot67\times10^7\times5\cdot97\times10^{24}\times100}{2\times4\cdot23\times10^7} = \underline{4\cdot71 \times 10^8 J}$	
ii)	Satellite will move to an orbit of smaller radius and its velocity or kinetic energy increases.	
7. a	***Specific heat capacity*** is the amount of heat required to raise the temperature of a ***1kg*** mass of a substance by ***1K.*** **Unit**: *JKg⁻¹K⁻¹*	
b	 • The liquid is allowed to flow through the apparatus at a constant rate. • The switch is closed and the current I and voltage V are recorded. • The experiment is left to run until a steady state is attained.	

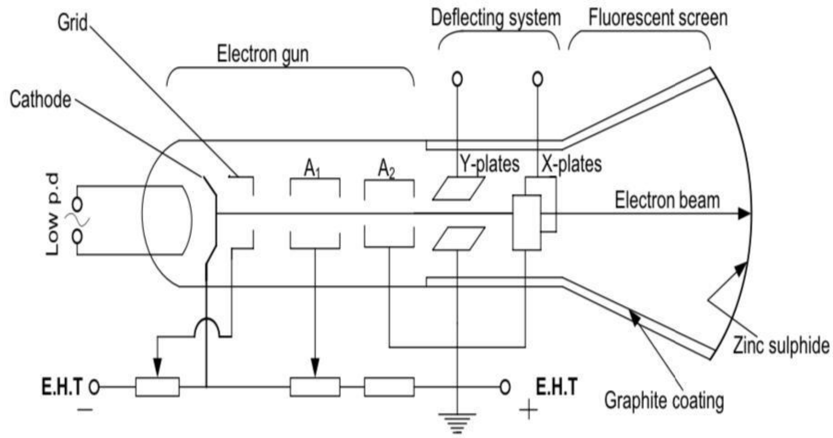
	• The steady state temperatures θ_1 and θ_2 are recorded from the thermometers T_1 and T_2 respectively. • The mass M, of the liquid collected in time t is recorded. • The rheostat is adjusted for new values of current I' and voltage V'. • The rate of flow is adjusted so as to have the same steady temperatures θ_1 and θ_2. The new mass M' collected in the same time t is recorded. • The specific heat capacity of the liquid; $C = \frac{(V'I' - VI)t}{(M' - M)(\theta_2 - \theta_1)}$	
c i)	$IV = mc(\theta_2 - \theta_1) + h$ $\Rightarrow 35 \times 2 = 4.07 \times 10^{-2} c(29 - 25) + h$ $h = 70 - 68.47 = 1.53\text{Js}^{-1}$	
ii)	From $C = \frac{(V'I' - VI)t}{(M' - M)(\theta_2 - \theta_1)}$ $C = \frac{(35 \times 2 - 26 \times 2)10}{(1.07 \times 10^{-2})(29 - 25)} = 4.206 \times 10^3 JKg^{-1}K^{-1}$	
iii)	$0.035Lv + 4263 = 79{,}968 + 3360$ $Lv = \frac{79065}{0.035} = 2.259 \times 10^6$ JKg^{-1}	
8. *a i)*	• ***Isobaric*** - compression or expansion at constant pressure • ***Isovolumetric*** – change in pressure and temperature at constant volume	
ii)	Isobaric: $\frac{V}{T} = \text{Constant}$ Isovolumetric: $\frac{P}{T} = Constant$	
b. i)	 	
ii)	$T_1 = 25^0C = 298K, V_1 = V, \quad P_1 = 1 \cdot 01 \times 10^5 Pa$ $T_2 = 596K, V_2 = 2V, P_2 = 1 \cdot 01 \times 10^5 Pa$ $T_3 = 200K, V_3 = 2V, P_3 = 3.39 \times 10^4 Pa$ $T_4 = 263.9K, V_4 = V, P_4 = ??$ $\frac{V}{298} = \frac{2V}{T_2} \Rightarrow T_2 = 2 \times 298 = 596K$	

	$\frac{P_2}{T_2} = \frac{P_3}{T_3}$, $\quad T_4V_4^{\gamma-1} = T_3V_3^{\gamma-1}$ *and* $P_4V_4^{\gamma} = P_3V_3^{\gamma}$ $\frac{1\cdot 01\times 10^5}{596} = \frac{P_3}{200} \Rightarrow P_3 = 3.39\times 10^4 Pa$ $T_4 = \frac{200\times 2^{0\cdot 4}\times V^{0.4}}{V^{0.4}} = 263\cdot 9K$ $P_4 = \frac{P_3V_3^{\gamma}}{V_4^{\gamma}} = \frac{3.39\times 10^4\times 2^{1\cdot 4}\times V^{1.4}}{V^{1.4}} = 8.95\times 10^4 Pa$	
d.i)	***Boyle's law*** states that the pressure of a fixed mass of a gas is inversely proportional to its volume at constant temperature	
ii)	 • Pressure of the dry air, $\boldsymbol{H+h}$ is measured and recorded • The volume **V** is obtained from the mm scale • The procedure is repeated by adding more mercury in the open limb • A graph of pressure against $\frac{1}{V}$ is plotted. • A straight line shows that $\boldsymbol{P \propto \frac{1}{V}}$	
9. a. i)	✓ Intermolecular forces of attraction are negligible ✓ The volume of the molecules is negligible compared to the volume of the gas ✓ Molecules are like perfect elastic spheres ✓ The duration of a collision is negligible compared to the time between collision	
ii)	***Dalton's law*** states that the pressure of a mixture of gases that do not chemically react is equal to the sum of the partial pressures of the individual gases.	
iii)	$P = \frac{1}{3}\rho\overline{c^2} \Rightarrow P = \frac{1}{3}\frac{Nm}{V}\overline{c^2} \Rightarrow N = \frac{3VP}{m\overline{c^2}}$ For a mixture of gases, $N = N_1 + N_2 + N_3$	

	$\Rightarrow N = \left(\frac{3VP_1}{m_1\overline{c_1^2}}\right) + \left(\frac{3VP_2}{m_2\overline{c_2^2}}\right) + \left(\frac{3VP_3}{m_3\overline{c_3^2}}\right)$ But at the same temperature, $m_1\overline{c_1^2} = m_1\overline{c_2^2} = m_1\overline{c_3^2} = m\overline{c^2}$ $\Rightarrow \frac{m\overline{C^2}N}{3v} = P_1 + P_2 + P_3$ but $\frac{m\overline{C^2}N}{3v} = P$ $\Rightarrow P = P_1 + P_2 + P_3$	
b. i)	When the temperature increases, the pressure will increase. This is because the kinetic energy of the gas molecules increases and they collide with the walls of the container with a higher velocity thus a higher rate of change in momentum. Since the volume is constant, the molecules will move to the walls in a shorter time and the number of collisions made per second will also increase hence a high pressure.	
ii)	Water boils when its S.V.P is equal to the atmospheric pressure. The atmospheric pressure at the top of a mountain is smaller than that at the bottom of the mountain. Therefore, water and the top of the mountain will boil at a lower S.V.P than at the bottom of the mountain. S.V.P increases with increase in temperature, this implies that lower S.V.P is attained at a lower temperature hence water boils at a lower temperature on top of a mountain than at the bottom.	
c. i)	For A $\frac{3 \times 10^5 \times 500}{283} = \frac{P_A \times 750}{283}, \qquad P_A = 2 \times 10^5 Pa$ For B $\frac{1 \times 10^5 \times 250}{373} = \frac{P_B \times 750}{373}, \qquad P_B = 3 \cdot 3 \times 10^4 Pa$ Total Pressure $\underline{\underline{= 2.33 \times 10^5 Pa}}$	
ii)	$PV = nRT \Rightarrow n = \frac{PV}{T}$ $n = n_A + n_B$ $\left(\frac{3 \times 10^5 \times 500}{8 \cdot 31 \times 283}\right) + \left(\frac{1 \times 10^5 \times 250 \times 10^{-6}}{8 \cdot 31 \times 373}\right)$ $= \frac{2.33 \times 10^{-6} \times 750 \times 10^{-6}}{8.31 \times T}$ $\Rightarrow T = \underline{292.7K}$	
10.a i)	***Cooling correction*** is a small temperature added to the observed maximum temperature during a heat experiment to account for the amount of heat lost to the surrounding during the experiment.	

ii)	***Newton's Law of Cooling*** states that the rate of heat loss of a body under forced convection, is proportional to the body's excess temperature above that of the surrounding	
b. i)	 **Procedure** ✓ The mass $\boldsymbol{m_s}$of the solid whose heat is required capacity is measured and recorded. ✓ The solid is heated in a stem chest to a temperature$\boldsymbol{\theta_3}$. ✓ It is then transferred into a calorimeter of mass $\boldsymbol{m_c}$ and specific heat capacity $\boldsymbol{c_c}$ containing a liquid of $\mathbf{m_L}$ and specific heat capacity $\boldsymbol{c_L}$ at initial temperature $\boldsymbol{\theta_1}$. ✓ The contents of the calorimeter are stirred and continuously and the observed temperature $\boldsymbol{\theta_2}$ is recorded. $Heat\ lost\ by\ the\ solid$ $= heat\ gained\ by\ liquid + calorimeter$ $m_s c_s(\theta_3 - \theta_2) = m_L c_L(\theta_2 - \theta_1) + m_c c_c(\theta_2 - \theta_1)$ $c_s = \dfrac{(m_L c_L + m_c c_c)(\theta_2 - \theta_1)}{m_s(\theta_3 - \theta_2)}$	
ii)	No heat lost to the surrounding	
c. i)	$mc\frac{\Delta\theta}{\Delta t} = \frac{m \times 1600 \times 10}{(160-0)} = 100m\ = rate\ of\ absorption$ $Heat\ absorbed\ during\ melting\ = 100m \times (400 - 160)$ $= mL$ $L = 100 \times 240 = 24{,}000 Jkg^{-1}$	
ii)	Let the specific heat capacity of liquid nitrogen be c. $Heat\ absorbed; mc \times 10\ = 100m \times (600 - 400)$ $= 2000\ Jkg^{-1}K^{-1}$	
d	During the day, the earth absorbs heat from the sun and at night when the temperature falls, it radiates heat to the atmosphere. On a cloudless night, the heat radiated is lost to the atmosphere and the earth cools. On a cloudy night, the radiated heat is reflected back to the earth and if feels warm.	

11.a i)



- ✓ The filament heats the cathode to emit electrons by thermionic emission.
- ✓ The anodes accelerate the electrons and focus them into a fine beam.
- ✓ X-plates deflect the electrons horizontally.
- ✓ Y-plates deflect the electrons vertically.
- ✓ The screen displays the beam formation.
- ✓ The grid controls the number of electrons striking the screen per second and hence controls the brightness of the spot formed on the screen.

ii)

$$\frac{V_0}{\sqrt{2}} = 7.072 \rightarrow V_0 = 10.001\,V$$

$$V_0 \propto \frac{L}{2} = 2cm \rightarrow Y - sensitivity = \frac{10}{2}$$

$$Y - sensitivity = 5.0Vcm^{-1}$$

b. i)

$$V_a = 3{,}000\,V$$

$$B = 0.6T$$

$$m = 6.64 \times 10^{-27}kg$$

$$qV = \frac{1}{2}mu^2, u = \sqrt{\frac{2qV}{m}} = \left(\frac{2\times(3.2\times10^{-19})\times3{,}000}{6.64\times10^{-27}}\right)^{\frac{1}{2}}$$

$$= 5.38 \times 10^5 ms^{-1}$$

ii)

$$Bqu = \frac{mu^2}{r} \Rightarrow r = \frac{mu}{Bq} = \frac{6.64\times10^{-27}\times5.38\times10^5}{0.6\times3.2\times10^{-19}}$$

$$= 1.82 \times 10^{-2}m$$

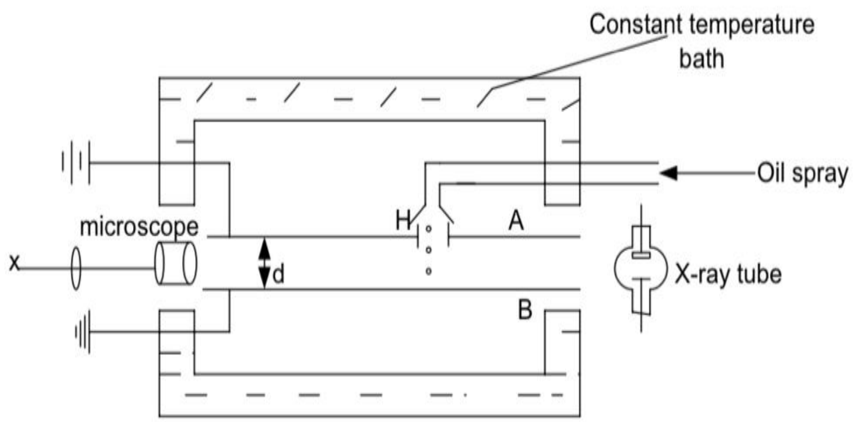
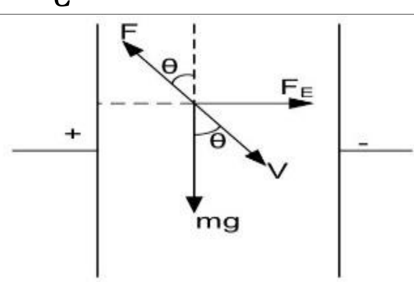
iii)

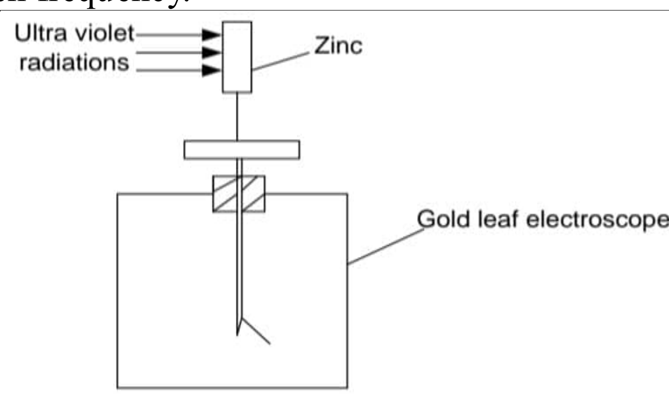
$$Eq = Bqu \Rightarrow E = Bu = 0.6 \times 5.38 \times 10^5$$

$$= 3.23 \times 10^5 Vcm^{-1}$$

e.

Cathode rays	***γ-rays***
✓ Carry a negative charge	✓ Have no charge
✓ Less penetrative	✓ Highly penetrative
✓ Fast moving electrons	✓ Electromagnetic radiations

	✓ Slower ✓ Faster	
12.a i)	***A mole*** is the amount of substance that contains 6.02×10^{23} elementary units	
ii)	***Faraday constant*** is the amount of charge required to liberate one mole of singly ionized ions in electrolysis	
iii)	***Avogadro's number*** is the number of particles in one mole	
b	 • Oil is sprayed and fine oil drops fall through a small hole in plate A. • A particular drop is observed and its terminal velocity V_0 measured by timing its fall through a measured distance using the microscope. Therefore, $\frac{4}{3}\pi r^3 \rho_{oil} g = \frac{4}{3}\pi r^3 \rho_{air} g + 6\pi\eta r V_o \ldots\ldots\ldots\ldots\ldots (i)$ • A pd is applied across the plates and adjusted until the drop remains stationary. Therefore, $\frac{4}{3}\pi r^3 \rho_{oil} g = \frac{4}{3}\pi r^3 \rho_{air} g + Eq \ldots\ldots\ldots\ldots (ii)$ $Eq = 6\pi\eta r V_o, \Rightarrow \quad q = \frac{6\pi\eta r V_o}{E}$ $from\ (i), \quad q = (\frac{9\eta V_o}{2g(\rho_{oil} - \rho_{air})})^{\frac{1}{2}}$ • Working with many oil drops, Millikan found that each value of charge obtained was an integral multiple of $1.6 \times 10^{-19} C$ and he concluded that the charge of an electron was $1.6 \times 10^{-19} C$	
c. i)	 $\theta = (31 + \frac{36}{60}) = 31.6^0$	

	$\frac{V_H}{1.066} = \tan 31.6^0 \quad \Rightarrow V_H = 1.066 \tan 31.6^0 = \underline{\underline{0.656cms^{-1}}}$	
ii)	$Eq = 6\pi\eta r V_o, \quad E = \dfrac{3000}{0.005} = 6 \times 10^5 Vm^{-1}$ $q = \frac{6\times3.14\times1.816\times10^{-5}\times1\times10^{-5}\times0.656\times10^{-2}}{6\times10^5} = \underline{\underline{3.741 \times 10^{-17}C}}$	
iii)	$\dfrac{4}{3}\pi r^3(\rho_{oil} - \rho_{air})g$ $= 6 \times 3.14 \times 1.816 \times 10^{-5} \times 1 \times 10^{-5} \times 1.066 \times 10^{-2}$ $\dfrac{4}{3} \times 3.14 \times (1 \times 10^{-5})^3 \times 9.81(880 - \rho_{air}) = 3.647 \times 10^{-11}$ $880 - \rho_{air} = 888$ $\rho_{air} = -8kgm^{-3}$	
d	$E_1 = 13.6eV, \quad E_3 = \dfrac{-13.6}{3^2} = -1.51eV$ $E_3 - E_1 = -1.51 + 13.6 = 12.09eV$ $hf = 12.09 \times 1.6 \times 10^{-19} = 1.9344 \times 10^{-18}$ $f = \frac{1.9344\times10^{-18}}{6.6\times10^{-34}} = 2.93 \times 10^{15}Hz$	
13.a	✓ For every metal surface, there is a minimum frequency of the incident radiation below which photoelectric emission will not take place. ✓ There is no detectable time lag between irradiation of the metal and emission of electrons. ✓ The kinetic energy of emitted electrons ranges from zero to a definite maximum value which is proportional to the frequency of the incident radiation. ✓ The number of electrons emitted per second (photo current) is proportional to the intensity of the incident radiation for a given frequency.	
b.	 • When U.V radiation is incident on the clean zinc plate, the negatively charged GLE collapses • The collapsing stops when Ultra Violet radiation is blocked.	

	• The leaf collapses because the zinc plate emits electrons and negative charge is lost from the GLE	
c. i)	$Work\ function\ \phi_0 = \frac{hC}{\lambda} = 4 \times 1.6 \times 10^{-19} J$ $\lambda = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{4 \times 1.6 \times 10^{-19}} = 3.094 \times 10^{-7} m$	
ii)	$hf = \phi + \frac{1}{2}mv^2 \Rightarrow \frac{1}{2}mv^2 = \frac{hC}{\lambda} - \phi$ $= \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{0.2 \times 10^{-6}} - 6.4 \times 10^{-19}$ $= 3.5 \times 10^{-19}$ $V = \sqrt{\frac{2 \times 3.5 \times 10^{-19}}{9.11 \times 10^{-31}}} = \underline{\underline{8.77 \times 10^5 ms^{-1}}}$	
d. i)	***Mass defect*** of the nucleus is the difference between the mass of the nucleus and the sum of the masses of its individual nucleons	
ii)	✓ Most of the alpha particles went through the gold foil undeflected because most of the space of an atom is empty space. ✓ Some alpha particles were deflected through angles less than 90°, implying that the positive charge of the atom was concentrated at the centre of the atom, in the nucleus ✓ Very few alpha particles were deflected through angles greater than 90° and did not go through the foil because the nucleus occupies a very small volume of the atom and the mass of the atom is concentrated at the nucleus.	
iii)	$Energy = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r} = \frac{1.6 \times 10^{-19} \times 79 \times 1.6 \times 10^{-19} \times 9 \times 10^9}{r}$ $= 5 \times 10^6 \times 1.6 \times 10^{-19} J$ $r = \frac{1.6 \times 10^{-19} \times 79 \times 1.6 \times 10^{-19} \times 9 \times 10^9}{5 \times 10^6 \times 1.6 \times 10^{-19}} = \underline{2.2752 \times 10^{-14} m}$	
14.a i)	***Binding Energy*** is the minimum energy released when individual nucleons combine to form a nucleus	

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<td>ii)</td>
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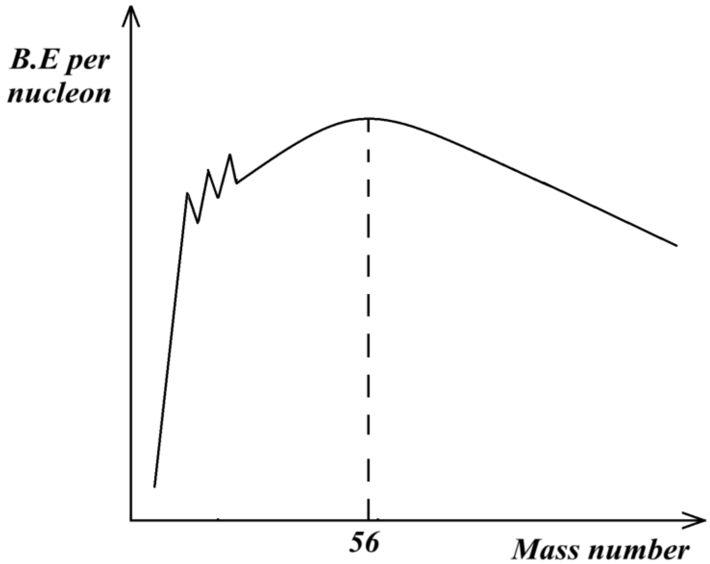

Binding energy increases sharply with mass number up to mass number ≈ 20
The peaks at ≈ 20 represent elements that are more stable compared to the neighbouring elements
B.E increases gently after 20 to a maximum value at mass number ≈ 60
After 60 (mass number) B.E decreases slowly with mass number

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<tr>
<td>c.</td>
<td>Nuclear fission is the splitting of a large unstable nucleus into two almost equal fragments that are more stable with release of energy while Nuclear fusion is the combining of two small unstable nuclei to form a bigger more stable nucleus with release of energy.</td>
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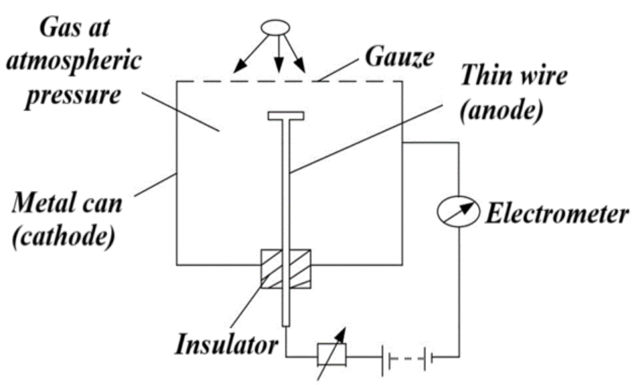
<td>d.</td>
<td>


✓ When radiation enters the chamber through the gauze, it causes ionization of the gas at atmospheric pressure.
✓ Electrons move towards the anode and the positive ions to the cathode.
✓ When they get to the respective electrodes, discharge occurs.
✓ Current flows and is detected by the electrometer
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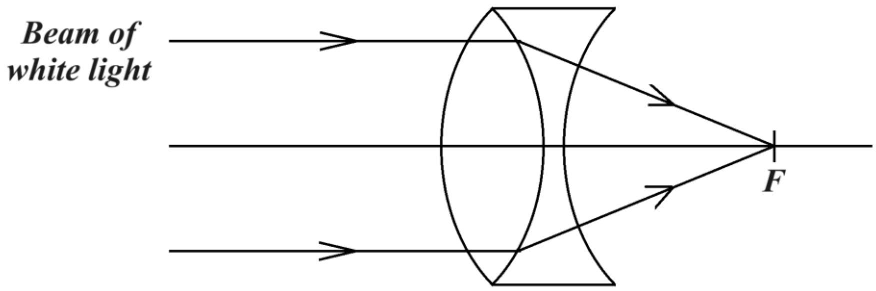
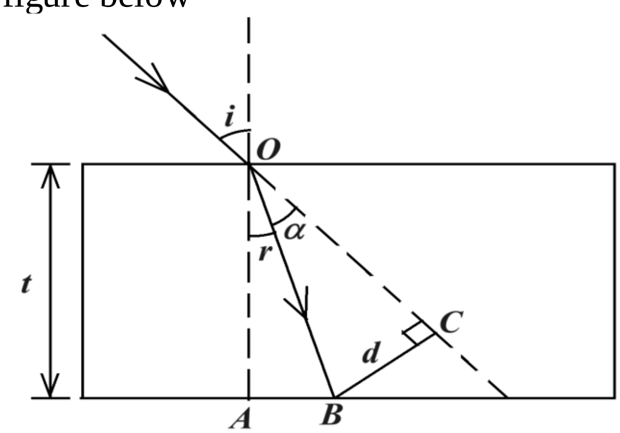
</table>

e. i)	***Half-life*** is the time taken for half the number of atoms (nuclei) in a radioactive sample to decay ***Decay constant*** is the ratio of number of nuclei disintegrating per second to the number of active nuclei in the sample.	
ii)	$N_0 = \frac{2}{222} \times 6.02 \times 10^{23} = 5 \cdot 42 \times 10^{21} atoms$ Spherical Area on which radiation falls $= 4 \times 3 \cdot 14 \times 20^2$ $= 5024 cm^2$ $\frac{A_0}{5024} = \frac{85}{10} \Rightarrow A_0 = 42704 Bq$ $A_0 = \lambda N_0 \Rightarrow \lambda = \frac{42704}{5 \cdot 42 \times 10^{21}} = \underline{\underline{7 \cdot 87 \times 10^{-18}}}$ $t_{\frac{1}{2}} = \frac{\ln 2}{\lambda} = \underline{\underline{8 \cdot 8 \times 10^{16} s}}$	

Qn.	Approach	Remarks
1(a)(i)	***Chromatic aberration*** is a defect in lenses which occurs when the constituent colours of white light are brought at different foci instead of one focus leading to the production of coloured images. This is so because different colours have different refractive indices with the red light being deviated least and violet the most.	
(ii)	Chromatic aberration is corrected by placing a suitable diverging lens besides a converging lens to form a combination called ***achromatic doublet.*** This recombines the colours of white light after refraction through the lens combination as illustrated in the diagram below; 	
(b) (i)	***Refractive index of a material*** is the ratio of sine of angle of incidence to the sine of the angle of refraction for a ray of light travelling from a vacuum/air to a material. ***OR*** it is the ratio of speed of light in air (vacuum) to speed of light in a material.	
(ii)	Consider a monochromatic ray of light incident on a glass block of refractive index, n at an angle of incidence, i. On striking the glass block, it undergoes refraction through an angle, r as shown in the figure below  *Consider triangle OAB*	

$$\cos r = \frac{t}{OB}$$

$$OB = \frac{t}{\cos r} ------(i)$$

Consider triangle OBC

$$\sin\alpha = \frac{d}{OB}$$

$$OB = \frac{d}{\sin\alpha} -----(ii)$$

Considering (i)and (ii)

$$d = \frac{t\sin\alpha}{\cos r} ------(*)$$

At point O

$$i = r + \alpha \Rightarrow \alpha = i - r$$

$$\sin\alpha = \sin(i-r) = \sin i\cos r - \cos i\sin r -------(iii)$$

But $\sin^2 r + \cos^2 r = 1$

$$\Rightarrow \cos r = \sqrt{1-\sin^2 r} ------(iv)$$

Substitute(iii) and (iv) in (*)

$$d = \frac{t(\sin i\cos r - \cos i\sin r)}{\sqrt{1-\sin^2 r}} ------(**)$$

Also, applying snell's law at O

$$n_a \sin i = n\sin r$$

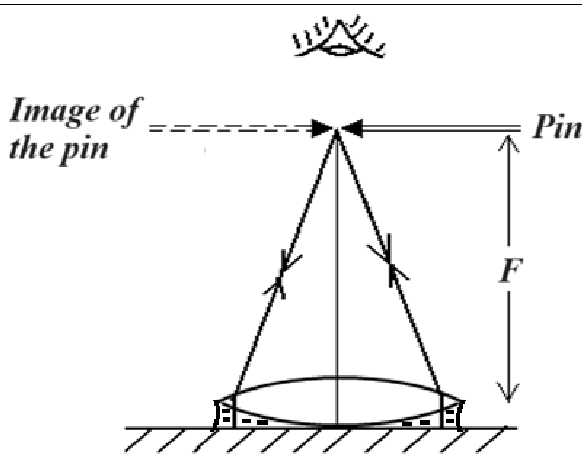
$$\Rightarrow \sin r = \frac{\sin i}{n} ------(v)$$

Substitute (iv) and (v) into (**)

$$d = \frac{t\left(\left(\sqrt{1-\left(\frac{\sin i}{n}\right)^2}\right)\sin i - \frac{\sin i}{n}\cos i\right)}{\sqrt{1-\left(\frac{\sin i}{n}\right)^2}}$$

$$d = \frac{t\sin i}{n}\left(\frac{\left(\sqrt{n^2-\sin^2 i} - \cos i\right)}{\frac{1}{n}\sqrt{n^2-\sin^2 i}}\right)$$

$$d = t\left(1 - \frac{\cos i}{\sqrt{n^2-\sin^2 i}}\right)\sin i$$

(c)	*For red* $\frac{1}{f_R} = (n_R - 1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$ $\frac{1}{f_R} = (1 \cdot 514 - 1)\left(\frac{1}{30} + \frac{1}{20}\right)$ $\frac{1}{f_R} = 0 \cdot 514\left(\frac{1}{30} + \frac{1}{20}\right)$ $f_R = 23.35cm$ *For blue* $\frac{1}{f_B} = (n_B - 1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$ $\frac{1}{f_B} = (1 \cdot 524 - 1)\left(\frac{1}{30} + \frac{1}{20}\right)$ $\frac{1}{f_B} = 0 \cdot 524\left(\frac{1}{30} + \frac{1}{20}\right)$ $f_B = 22.9cm$ *The separation, f between the foci of red and blue is;* $f = f_R - f_B$ $f = 23 \cdot 35 - 22 \cdot 9$ $= 0 \cdot 45cm$	
(d)	 • An object pin is clamped horizontally with its tip along the axis and moved up and down until it coincides with its own image. • The distance PC is measured and recorded. • The measured and recorded distance is the focal length f_l of the convex lens. • A small amount of a liquid whose refractive index, n_L is to be determined is poured on the plane mirror. • A convex lens is then placed on top of the liquid. • An object pin is again clamped horizontally and moved up and down until it coincides with its own image. • The distance P^l C^l is measured and recorded.	

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- The measured and recorded distance is the focal length, F of the combination of the lens.
- The refractive index of the liquid n_L is then obtained from $n_L = 1 + \frac{r}{f_2}$, where r is the radius of curvature of the biconvex liquid surface and f_2 is the focal length of the lens.
  $\boldsymbol{f_2}$ is obtained from the expression $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$

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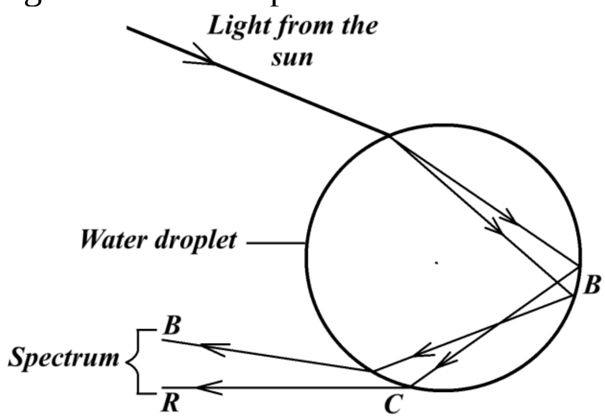
<tr><td>(e)</td><td>

When white light is incident on a rain drop, it is refracted and dispersed. The refracted light is reflected at B and emerges at C. The light viewed is a spectrum of colours.



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<tr><td>2(a) (i)</td><td>

Principal focus of a convex mirror is a point on the principal axis where rays parallel and close to the principal axis appear to diverge from after reflection by the mirror.

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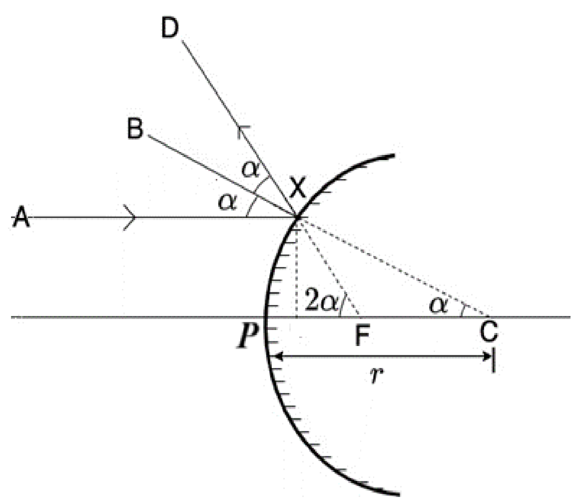
<tr><td>(ii)</td><td>

Consider a ray *AX* parallel and close to the principal axis incident onto the mirror.



FP = Focal length (f)
If C is the Centre of curvature, then CP is the radius of curvature of the mirror.
From the diagram;
$<AXB = <BXD = \alpha$ (Law of reflection)

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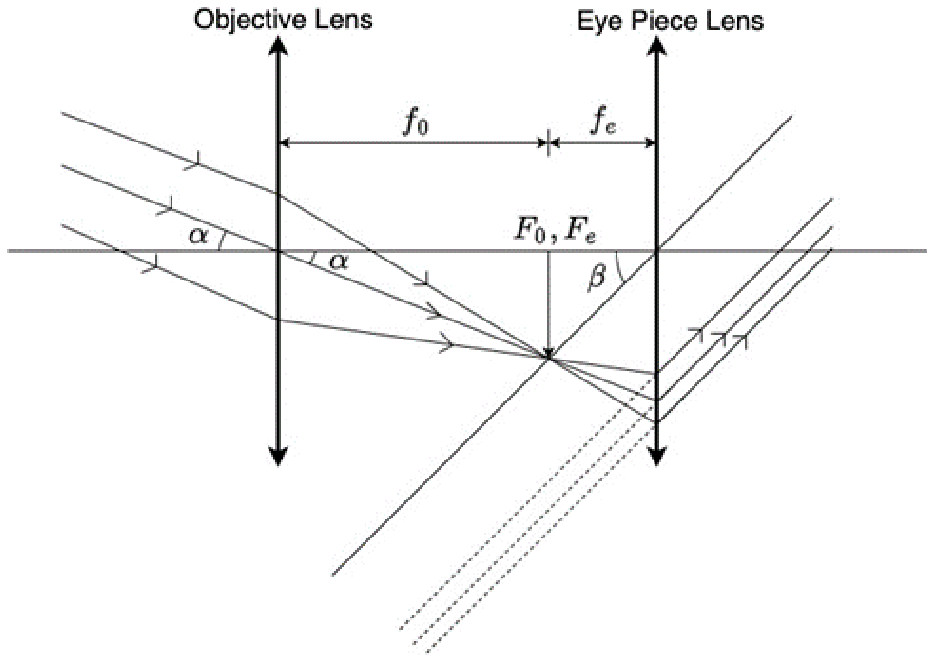
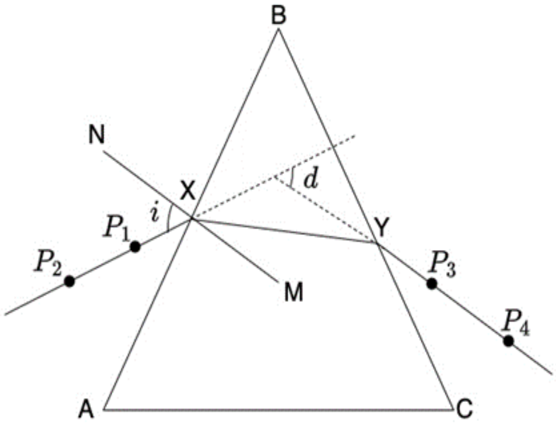
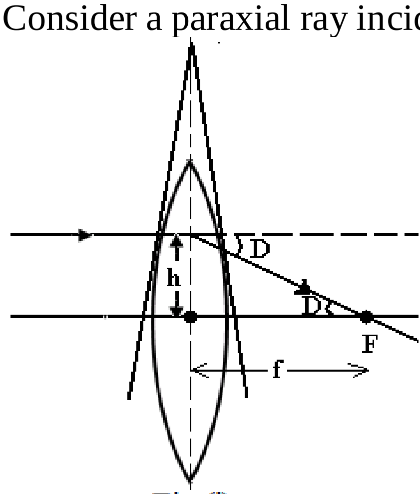
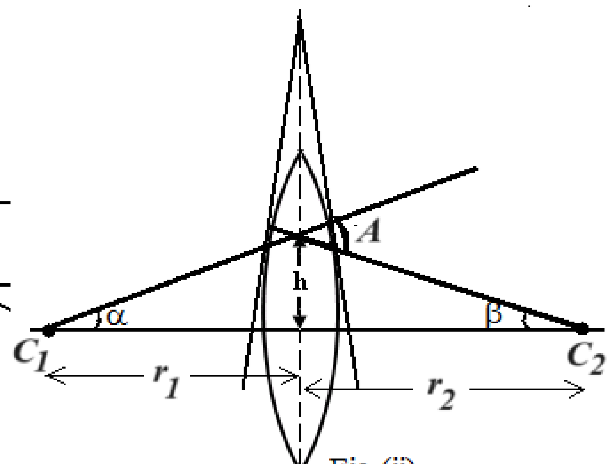
	$\angle AXB = \angle XCP = \alpha$ (alternate angles) $FC = FX$ (isosceles triangle FXC) For X very close to P, $FX \approx FP$ Therefore, $CF = FP$ $2FP = CP = r$ $r = 2f$	
(b)	When a lamp is placed at the principal focus of a parabolic mirror, all rays from this lamp that strike the mirror at points close to and far from the principle axis will be reflected parallel to the principle axis and the intensity of the reflected beam remains practically undiminished as the distance from the mirror increases unlike for a concave mirror where rays from a lamp at its focus is reflected at different directions therefore the intensity of the reflected beam diminishes as the distance from the mirror increases. Therefore, parabolic mirrors instead of concave mirrors are used as reflectors in search lights.	
(c)	***Magnifying Power*** is the ratio of the angle subtended by the final image at the eye when using an optical instrument to the angle subtended by the object at the eye when the object is at the near point. ***Resolving Power*** is the ability of an optical instrument to produce separate images of close objects.	
(d) (i)	$Given\ f_o = 20mm\ ,\ f_e = 50mm$ Lens separation, d = 220cm $d = V_0 + f_e$ $220 = V_0 + 50$ $V_0 = 170mm$ Action of the objective $\frac{1}{f_0} = \frac{1}{U_0} + \frac{1}{V_0}$ $\frac{1}{20} = \frac{1}{U_0} + \frac{1}{170}$ $\frac{1}{U_0} = \frac{1}{20} - \frac{1}{170}$ $U_0 = 22.67mm$	
(ii)	$M = \frac{D}{f_e}\left(\frac{V_0}{f_0} - 1\right)$ $M = \frac{250}{50}\left(\frac{170}{20} - 1\right)$ $M = 37.5$	

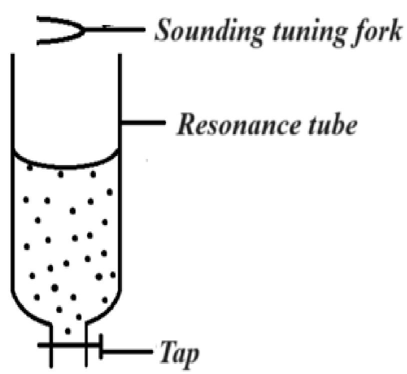
(e) (i)	 *Angular Magnification,* $M = \frac{\beta}{\alpha}$ …………(1) From the diagram; $\tan\beta = \frac{h}{f_e}$ and $\tan\alpha = \frac{h}{f_0}$ *But for small angles measured in radians;* $\alpha \approx \tan\alpha$ and $\beta \approx \tan\beta$ $\Rightarrow \alpha = \frac{h}{f_0}$ and $\beta = \frac{h}{f_e}$ *Substitute* α *and* β *in (1)* $M = \frac{h}{f_e} / \frac{h}{f_0}$ $M = \frac{f_0}{f_e}$	
(ii)	This is done by introducing an erecting lens of focal length, *f* between the objective and the eye piece lenses. The erecting lens has no effect on the magnitude of angular magnification produced and it is placed a distance *2f* after the principal focus of the objective lens and a distance *2f* before the principal axis of the eye piece lens. The objective lens forms a real inverted image of a distant object at its focal point, F_0 and this image acts as a real object of the erecting lens which forms a real erect image of the same size as the image formed by the objective. The final image formed is also erect.	
3 (a)(i)	***Deviation of light*** by a prism is the change in direction of light due to refraction at the prism's two non - parallel faces.	

(ii)	 • The prism is placed on a plane sheet of paper on a soft board and its outline ABC is traced out as shown above. • A normal NM is drawn through point X on side AB of the prism and a line PX is drawn making an angle *i* . • Two optical pins $P_1$and P_2 are placed along the lines that make different angles of incidence *i*. • Pins P3 and P4 are placed such that they appear to be in line with the images of P1 and P2 as seen through the prism. • The angles of deviation d are measured for different angles of incidence. • A graph of d against i is plotted to give a curve whose angle of deviation at its turning point is the angle of minimum deviation d_{min} of the prism.	
(b)	***Principal focus*** of a convex lens is a point on the principal axis where rays originally parallel and close to the principal axis converge after refraction by the lens. ***Radii of curvature*** of a convex lens are radii of the spheres of which the convex lens surfaces form part.	
(c)(i)	Consider a paraxial ray incident on a convex lens as shown below  Fig (i)  Fig (ii)	

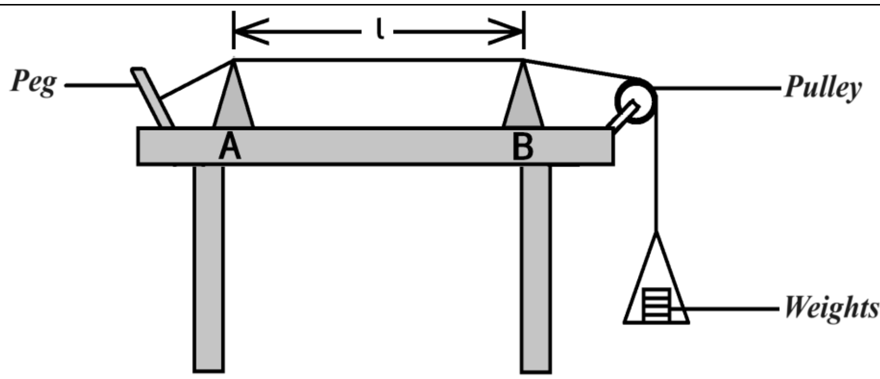
	From the ***Fig. (i)*** above; $\tan D = \frac{h}{f}$ But for small angles in radians; $\tan D \approx D$ $\Rightarrow D = \frac{h}{f} \dots\dots\dots\dots\dots\dots\dots\dots (1)$ Consider normals at points Q and R going through centres of curvature C_1 and C_2 respectively as shown ***Fig.(ii).*** The normal meet the tangents to the lens surfaces at points P and Q respectively. From the diagram; $\alpha + \beta = A \dots\dots\dots\dots\dots\dots. (2)$ Also $\tan \alpha = \frac{h}{r_1}$ and $\tan \beta = \frac{h}{r_2}$ But for small angles in radians; $\tan \alpha \approx \alpha$ and $\tan \beta \approx \beta$ $\Rightarrow \alpha = \frac{h}{r_1}$ *and* $\beta = \frac{h}{r_2} \dots\dots\dots\dots\dots\dots (*)$ Substituting $(*)$ in 2 gives; $\frac{h}{r_1} + \frac{h}{r_2} = A \dots\dots\dots\dots\dots\dots\dots\dots (3)$ *For a prism of small refracting angle, A.* $d = (n-1)A$ From (1) $\Rightarrow \frac{h}{f} = (n-1)A \dots\dots\dots\dots\dots\dots\dots\dots (**)$ *Equation 3 and* $(**)$ *give;* $\frac{h}{f} = (n-1)\left(\frac{h}{r_1} + \frac{h}{r_2}\right)$ $\frac{1}{f} = (n-1)\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$	
(ii)	*Consider the liquid lens* $\frac{1}{f_l} = (n_l - 1)\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$ $\frac{1}{f_l} = (1.4-1)\left(-\frac{1}{23} + \frac{1}{\infty}\right)$ $f_1 = -57.5cm$ *For the combination*	

	$\frac{1}{f} = \frac{1}{f_l} + \frac{1}{f_g}$ $\frac{1}{37.3} = \frac{1}{-57.5} + \frac{1}{f_g}$ $\frac{1}{f_g} = \frac{1}{37.3} + \frac{1}{57.5}$ $f_g = 22.62cm$ *Consider the glass lens* $\frac{1}{f_g} = (n_g - 1)\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$ $\frac{1}{22.62} = (n_g - 1)\left(\frac{1}{23} + \frac{1}{23}\right)$ $n_g - 1 = 0.51$ $n_g = 1.51$	
(d)(i)	***Spherical aberration*** is a defect produced in both lenses and spherical mirrors. It occurs when rays which are parallel and far from the principal axis fail to converge a single focal point but instead converge at different focal points which results into a blurred and distorted final image.	
(ii)	• Prisms don't tarnish or deteriorate as plane mirrors do because plane mirrors lose the silvering surface with time. • Prisms form brighter images than plane mirrors. This is because mirrors absorb more of the incident light and produce fainter images. • Prisms produce clear images than plane mirrors. This is because plane mirrors produce blurred images due to the formation of multiple images.	
4 (a)(i)	(see table below)	

Progressive waves	***Stationary waves***
Transfer energy from one end to another along the medium.	Doesn't transfer energy along the medium.
The amplitude of vibration of the particles is constant.	The amplitude of vibration of particles varies from place to place.
They consist of crests and troughs/ consist of compressions and rarefactions.	Consist of nodes and antinodes.

	The phase of vibration varies from point to point along the wave profile. / The phase of vibration of particles is constant between nodes.	
(ii)	• They have constant amplitude • They move with constant speed • They have constant frequency • They transfer energy along the profile The transfer of sound energy is possible when vibrating molecules hit the next layer of molecules in the atmosphere in a direction parallel to that of propagation of the sound wave. Thus, a longitudinal wave motion.	
(b)	 • The resonance tube is filled with water and a sounding tuning fork of known frequency, *f* is held over the open end of the tube. • The tap is opened and water is allowed to flow gradually until a loud sound is heard. • The tap is immediately closed and the length, *l* of the air column is measured and recorded. • The experiment is repeated with different tuning forks of known frequencies. The results are tabulated including values of $\frac{1}{f}$. • A graph of *l* against $\frac{1}{f}$ is plotted and the intercept, C on the *l* axis is obtained. • The end correction of the tube, $e = -C$.	
(c)	Given: $l = 0 \cdot 4m$, $f_n = 960Hz$, $v = 330ms^{-1}$ $f_n = \frac{nv}{4l}$ $960 = \frac{n \times 330}{4 \times 0.4}$ $n = 4.65$ $n \approx 5$ *The air column is vibrating producing the 2nd overtone.*	

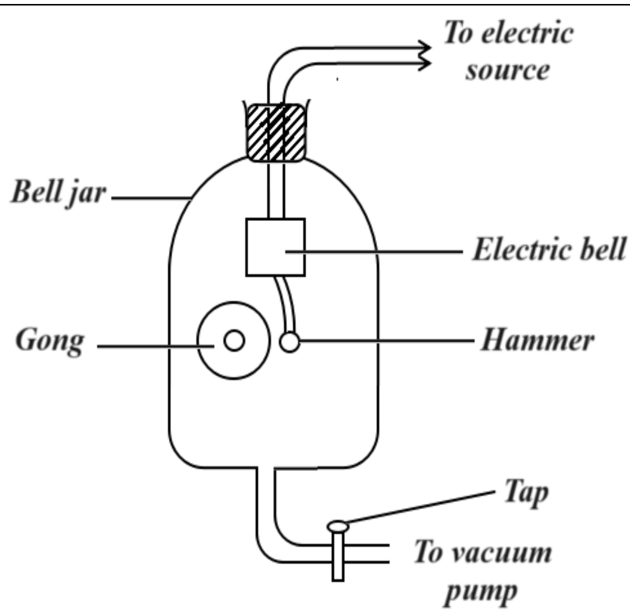
(d) (i)	***Doppler effect*** is the apparent change in the frequency of a wave due to relative motion between the source and the observer. ***Beats*** are a periodic rise and fall in the intensity of sound heard when two notes of nearly equal frequencies but similar amplitudes are sounded together.	
(ii)	• A spectral photograph of an arc or spark of light from an element known to be in the star is taken in a laboratory and its wavelength, λ is recorded. • A spectral photograph of the star is taken and the corresponding wavelength, λ^1 is noted. • Velocity of the star is calculated from $u_s = \frac{c\lvert\lambda^1-\lambda\rvert}{\lambda}$. Where c is the speed of light in air/vacuum	
(e)	*Given*: $\frac{f_1'}{f_2^1} = \frac{5}{4}$ *Case 1* $f_1^1 = \left(\frac{v}{v-u_s}\right)f$ $f_1^1 = \left(\frac{340}{340-u_s}\right)f ------(i)$ *Case 2* $f_2' = \left(\frac{v}{v+u_s}\right)f$ $f_2' = \left(\frac{340}{340+u}\right)f ------(ii)$ $\frac{f_1'}{f_2^1} = \frac{5}{4} = \frac{\left(\frac{340}{340-u_s}\right)}{\left(\frac{340}{340+u}\right)}$ $(340+u_s) = \frac{5}{4}(340-u_s)$ $\frac{9u_s}{4} = \frac{340}{4}$ $U_s = 37\cdot 8ms^{-1}$	
5 *(a)(i)*	A tone is a sound with a regular frequency produced by a musical instrument	
(ii)	A harmonic is a note whose frequency is an integral multiple of the fundamental frequency.	
(iii)	An overtone is a note with a frequency higher than the fundamental frequency produced along with the fundamental note.	

(b) (i)	 • A tuning fork of low frequency is sounded and brought near the wire. • The wire is plucked and the bridge *B* is moved towards *A* until a loud sound is heard. • The frequency *f* of the fork is recorded. • Keeping the length, *l* and mass of the pan constant, a tuning fork of frequency *2f* is sounded and brought near the wire and plucked. A loud sound is heard. • Therefore a stretched wire plucked in the middle vibrates in more than one mode simultaneously.	
(ii)	Given: $l = 0 \cdot 3m, m = 5g = 5 \times 10^{-3}kg, T = 170\ N$ For a stretched string vibrating at its third harmonic $f_3 = 3f_1 = \frac{3}{2l}\sqrt{\frac{T}{\mu}} - - - - - - - - - - - -(i)$ For an open piper vibrating at it fundamental note; $f_1 = \frac{v}{2L} - - - - - - - - - - - -(ii)$ *But (i)* $= (ii)$ $\frac{3}{2l}\sqrt{\frac{T}{\mu}} = \frac{v}{2L}$ $\frac{3}{2 \times 0.3}\sqrt{\frac{170 \times 0.3}{5 \times 10^{-3}}} = \frac{340}{2L}$ $L = 0.3367m$	
(c) (i)	When two notes of nearly equal frequencies but similar amplitudes are sounded together, they superpose. When they meet while in phase, reinforcement takes place and a loud sound is heard. When they meet while completely out of phase, cancelation occurs and a soft sound or no sound is heard. That happens alternately causing a periodic rise and fall in the intensity of sound heard, which leads to formation of beats.	

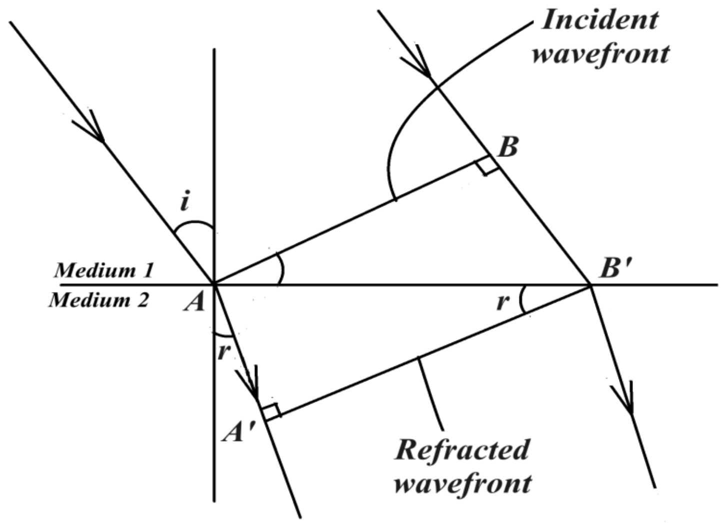
(ii)	*Case 1* $f_1^1 = \left(\frac{v - u_o}{v}\right) f ----(i)$ *Case 2* $f_2' = \left(\frac{v + u_o}{v}\right) f ----(ii)$ $f_2' - f_1^1 = 5$ $\left(\left(\frac{v + u_o}{v}\right) - \left(\frac{v - u_o}{v}\right)\right) f = 5$ $\frac{2fu_o}{v} = 5$ $\frac{2 \times 425 u_o}{340} = 5$ $u_o = 2\ ms^{-1}$	
(d) (i)	see table below	

Sound waves	***Light waves***
They are longitudinal in nature	They are transverse in nature
They are mechanical waves	They are electromagnetic waves
They travel at relatively low speed	They travel at very high speed
They have relatively longer wavelength	They have very short wavelength

(ii)



- When an electric bell inside a bell jar is switched on, a loud sound is heard.

	• The air inside the bell jar is gradually removed by means of a vacuum pump, and the loudness is observed to fade out. • When all the air is completely removed from the bell jar, no sound is heard even though the hammer is seen hitting the gong. • When air is again allowed in the bell jar, sound is heard again. • This shows that sound requires a material medium for its transmission, thus a mechanical wave.	
6(a)(i)	***Huygen's principle*** states that every point on a wave front may be regarded as a source of secondary spherical wavelets which spread out with the wave velocity. The new wave front is the envelope of the secondary wavelets	
(ii)	Consider a plane wave front of light AB which is about to cross form one medium into another  Let v_1 and v_2 be the velocities of light in air and the medium respectively. If the wave particle at B takes time t to move to B^1, then the distance $BB^1 = v_1t$. In the same time interval wave particle at A moves to A^1, distance $AA^1 = v_2t$ From triangle ABB^1 and AA^1B^1 $\frac{\sin i}{\sin r} = \frac{\left(\frac{BB^1}{AB^1}\right)}{\left(\frac{AA^1}{AB^1}\right)} = \frac{BB^1}{AA^1} = \frac{v_1 t}{v_2 t} = \frac{v_1}{v_2}$	
(b)	***Diffraction*** is the spreading of light into the geometrical shadow leading to interference ***Polarization*** is a process by which vibration of electric vector is restricted to take place in only one plane.	

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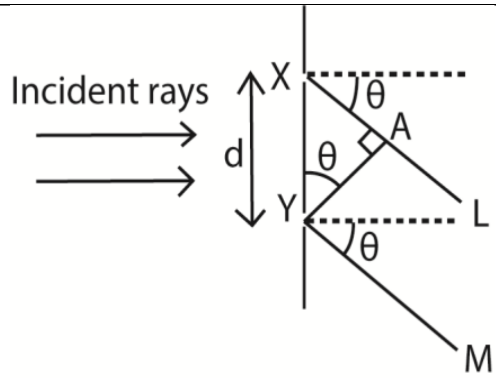

The path difference $XA = d\sin\theta$
For constructive interference, diffraction maxima occurs when the path difference is an integral multiple of wavelength, λ.
i.e. path difference = nλ
Thus $d\sin\theta = n\lambda$
where n = 0, 1, 2, 3, ……….
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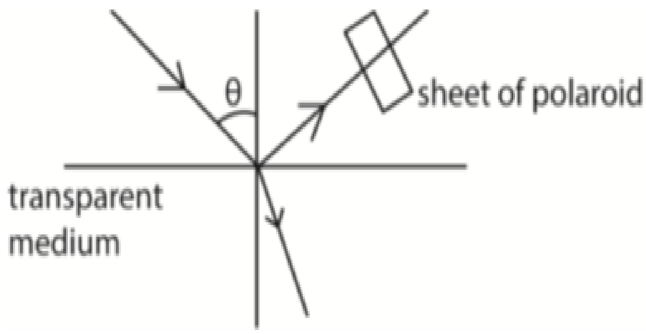

Unpolarized light is made incident on a transparent medium at an angle θ.
The reflected light is viewed through a sheet of polaroid while turning the sheet about an axis perpendicular to its plane until light is just cut off from the observer as the polaroid is being rotated.
The procedure is repeated for various angles of incidence until the reflected ray is cut off from object.
At this particular angle θ, the reflected light is completely polarized

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Sound interference effects can be observed using two sources because sound waves are typically coherent and have a consistent phase relationship when emitted from similar sources.
This coherence allows constructive and destructive interference patterns to form which can be detected by our ears.
On the other hand, light emitted from two lamps is generally incoherent, this means the light waves do not maintain a consistent phase relationship, making it impossible to observe clear interference patterns.
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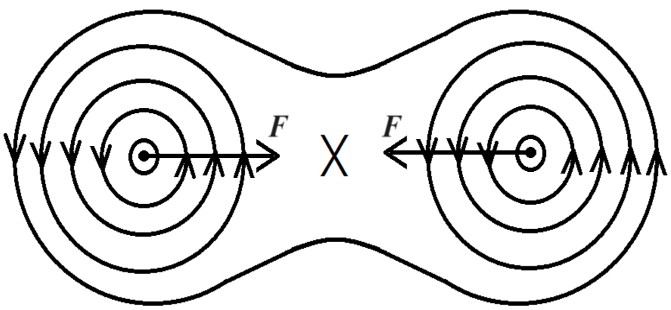
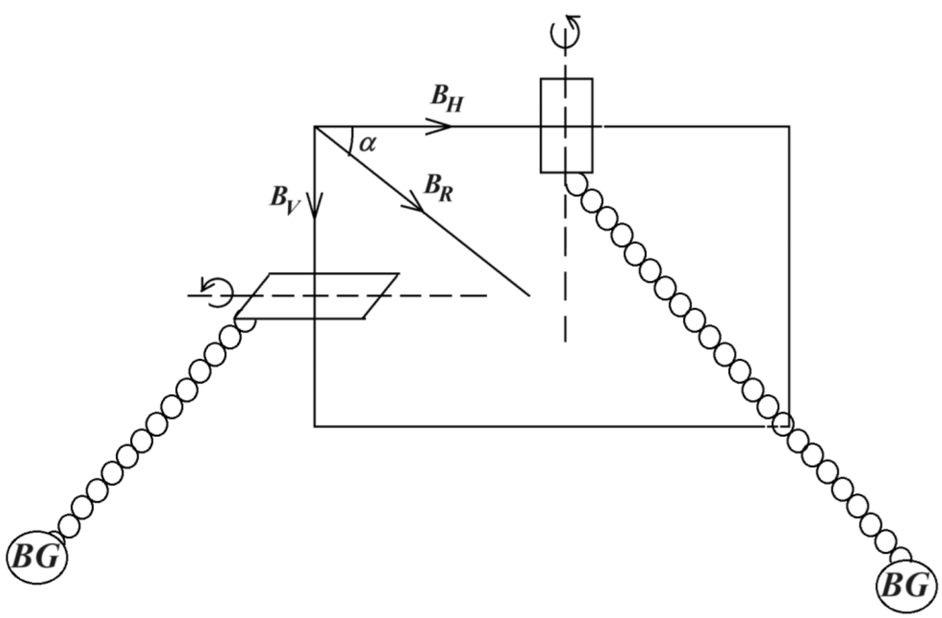
(f)	Fringe separation $y = \frac{3.9\times10^{-3}}{23}$ $y = 1.70 \times 10^{-4}m$ $a = \frac{\lambda d}{y}$ where d is the distance from the slits, a is the slit separation $a = \frac{5.5\times10^{-7}\times0.31}{1.70\times10^{-4}}$ $a = 1.003 \times 10^{-3}m$	
7(a)(i)	***Magnetic field strength*** is the force experienced by a straight conductor of length 1m carrying a current of *1A* when it is placed perpendicular to a uniform magnetic field.	
(ii)	***Magnetic flux*** is the product of the magnetic flux density and the area element perpendicular to the field at that point.	
(b) (i)		
(ii)	Magnetic field strength at P From $B_x = \frac{\mu_0 I_x}{2\pi r_{px}}$ $B_x = \frac{\mu_0 I_x}{2\pi r_{px}} = \frac{4\pi\times10^{-7}\times5}{2\pi\times0.019} = 5\cdot2632\times10^{-5}T$ $B_y = \frac{\mu_0 I_y}{2\pi r_{py}} = \frac{4\pi\times10^{-7}\times9}{2\pi\times0.009} = 2\times10^{-4}T$ $B_p = B_y - B_x$ $= 2\times10^{-4} - 5\cdot2632\times10^{-5}$ $= 1\cdot4737\times10^{-4}T$	
(iii)	$F_{Px} = BxI_PL_p = \frac{\mu_0 I_x I_p L_p}{2\pi r_{px}}$ $= \frac{4\pi\times10^{-7}\times5\times3\times5}{2\pi\times1\cdot9\times10^{-2}}$ $= 7\cdot8947\times10^{-4}N$ *Attractive* $F_{Px} = B_X I_P L_P = \frac{\mu_0 I_y I_p L_p}{2\pi r_{py}}$ $= \frac{4\pi\times10^{-7}\times9\times3\times5}{2\pi\times9\times10^{-3}}$ $= 3\times10^{-3}N$ *Attractive* $F_p = F_{py} - F_{px} = 3x10^{-3} - 7\cdot8947\times10^{-4}$	

	$= 2.21053 \times 10^{-3}\text{N}$ towards X	
(iv)	• If a current carrying conductor, P is placed in the field of wires X and Y due to currents I_X and I_Y, also a wire P sets a field around it due to current. • The setup field due to current through P interacts with the field of X and Y which results into a greater magnetic flux density on one side of the conductor P than the other. • The resultant force is created from the side with a stronger field to the side with a weaker field and it is this force that tends to move the conductor P.	
(c)(i)	***Angle of dip*** is the angle between the magnetic axis of a freely suspended magnet at rest and the horizontal.	
(ii)	***Magnetic meridian*** is the vertical plane containing the magnetic axis of a freely suspended magnet under the action of the earth's magnetic field. ***OR*** It is a vertical plane in which a freely suspended magnet sets itself. ***OR*** It is a vertical plane containing the magnetic poles of the earth.	
(d)	 • The coil of the earth inductor of negligible resistance is connected to a B.G of known sensitivity, k and resistance, R. • The coil is placed with its plane horizontal and perpendicular to B_V as well as the magnetic meridian using a plotting compass needle. • The coil is then rotated through 180^0 along the horizontal axis and the deflection, Θ_v of the B.G is noted. • The B_v of the earth's magnetic field is then obtained from the expression, $B_v = \frac{K\theta_V R}{2AN}$.	

	• The coil is again placed with its plane vertical and perpendicular to B_H as well as the magnetic meridian using a plotting compass needle. • The coil is then rotated through 180^0 along the vertical axis and the deflection, Θ_H of the B.G is noted. • The B_H of the earth's magnetic field is then obtained from $B_H = \frac{K\theta_H R}{2AN}$ • The angle of dip is then obtained from $\tan\theta = \frac{B_V}{B_H} = \frac{\theta_V}{\theta_H}$ $$\theta = \tan^{-1}\left(\frac{\theta_v}{\theta_H}\right)$$	
8 (a)(i)	***Faraday's law*** states that the magnitude of emf in a coil is directly proportional to the rate of change of magnetic flux linking it. ***Lenz's law*** states that the induced current flows always in such a direction to oppose the change causing it.	
(ii)	• When the field is on, as the block oscillates it cuts the magnetic field lines which results into changing magnetic flux and an emf is induced in it creating eddy current to circulate with in the metal • The eddy current generates the magnetic field which opposes the original field that causes the opposition to the motion of the metal hence coming to rest in a short time • When the field is off, there is no eddy currents generated which results into the electromagnetic damping of the oscillation of the metal. Its motion is only opposed by weaker mechanical friction and air resistance with less impact hence oscillating for a longer time.	

(b) When the coil is rotated, the flux linkage starts to change and an emf induced is given by; $E = -N\frac{d\emptyset}{dt}$……………………(1)

And current that flows , $I = \frac{E}{R} = -\frac{N}{R}\frac{d\emptyset}{dt}$……….(2)

Since time is changing, $I = \frac{dQ}{dt}$…………(3)

Equating (2) and (3), $\frac{dQ}{dt} = -\frac{N}{R}\frac{d\emptyset}{dt}$

$$dQ = -\frac{N}{R}\,d\emptyset$$

$$\int_0^Q dQ = \int_{\emptyset I}^{\emptyset f} -\frac{N}{R}\,d\emptyset$$

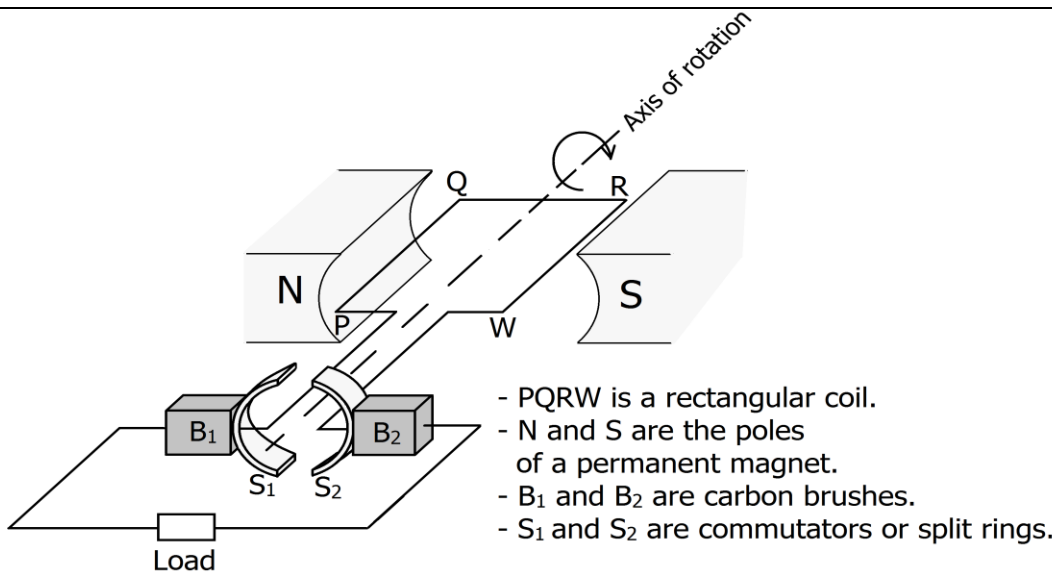
$$Q = -\frac{N}{R}(\emptyset_f - \emptyset_i)$$

But $\emptyset_f = BA\cos180$ and $\emptyset_I = BA\cos0$

$$Q = -\frac{N}{R}(BA\cos180^\circ - BA\cos0^\circ)$$

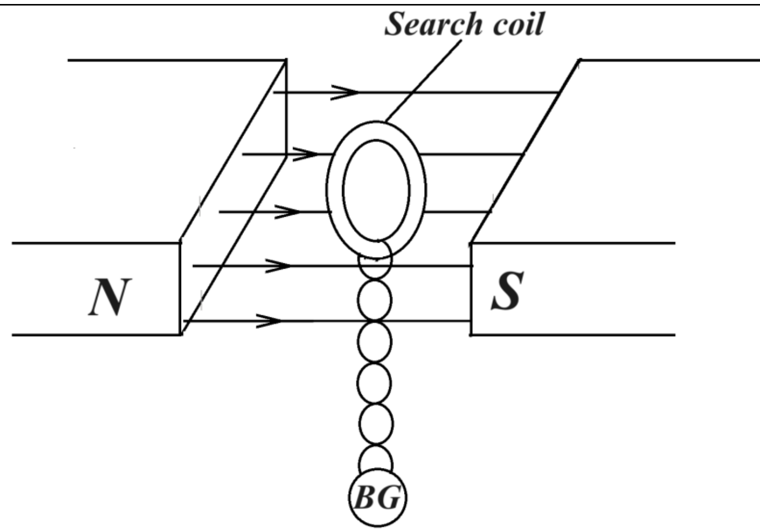
$$Q = \frac{2NBA}{R}$$

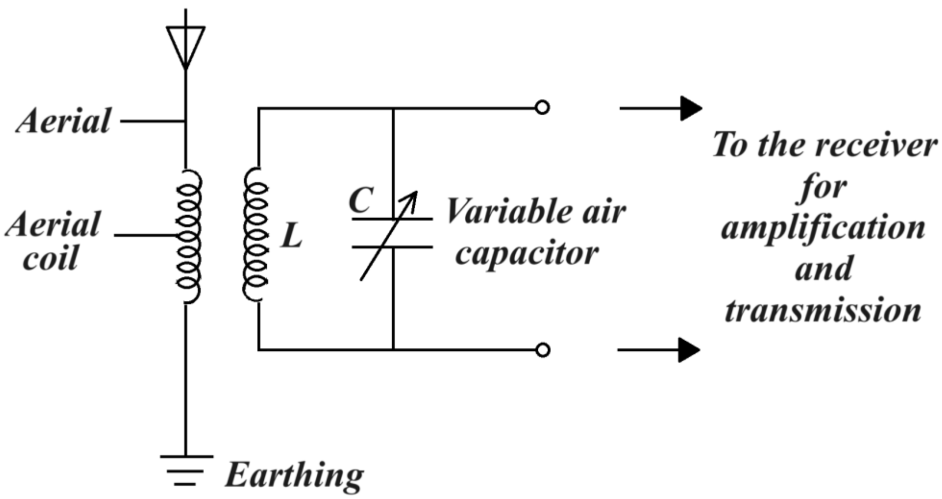
(c)

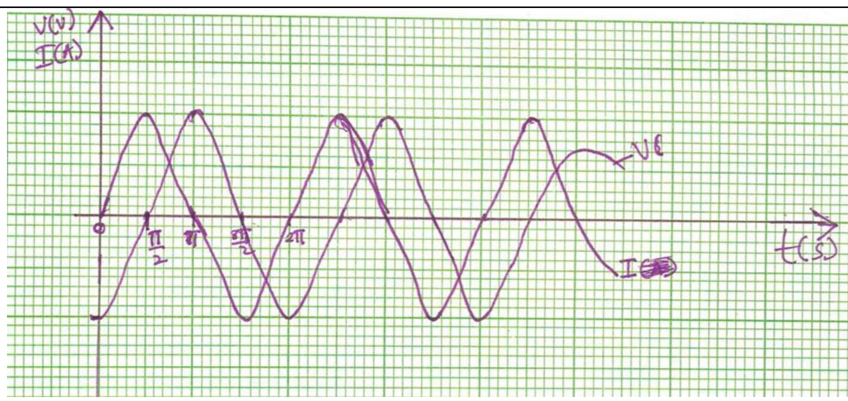


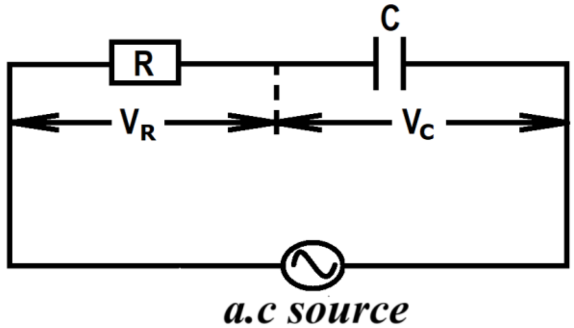
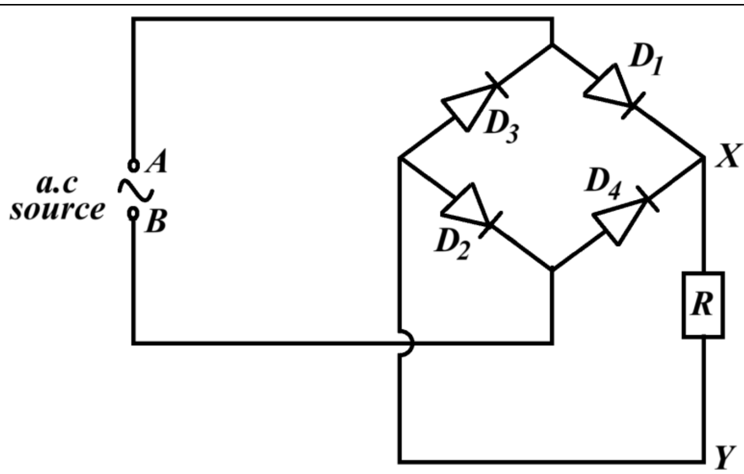
- When the coil is rotated with uniform angular speed and emf is induced in it. The resulting current is tapped through the carbon brushes B_1 and B_2

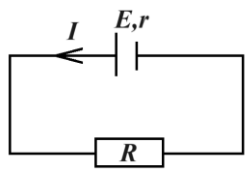
	• As side PQ moves up and RW down, an emf is induced in the coil in the direction PQRW. In the vertical position, emf induced is zero. • As PQ begins to move down and RW up, emf is induced in the direction WRQP, so current reverses in the coil. But at the same time commutators change contacts with the carbon brushes S_1 to B_2 and S_2 to B_1. • Hence current continues flowing in the same direction in the load.	
(d)(i)	***Back emf*** is an induced emf which opposes the applied voltage in the circuit.	
(ii)	Using $Va = E_b + Ir_a$ $220 = E_b + 1.5 \times 3$ $E_b = 215.5V$ But $E_b = BAN\omega$ $\omega = \frac{215.5}{0.74 \times 12 \times 10^{-4} \times 100} = 2426.8\ rads^{-1}$	
9(a)(i)	***Self induction*** is the process of generating an emf in the coil due to changing current in the same coil ***Mutual induction*** is the process of generating an emf in the coil due to changing current in the nearby coil.	
(ii)	When the switch is closed, current flows in the coil and a magnetic field is established. When it is opened, magnetic flux in the coil collapses creating an emf which appears as a large p.d between the contact points of the switch. Since the contacts are very close, a high electric field intensity is created which ionizes the air between the contacts producing negative and positive ions that collide and neutralize violently causing a spark	

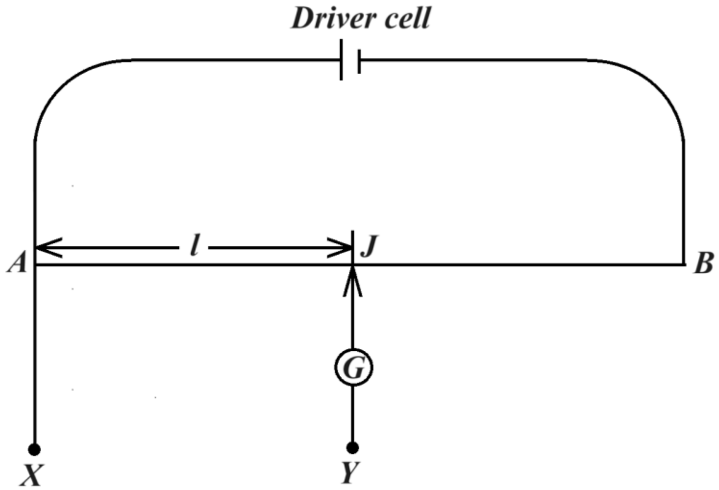
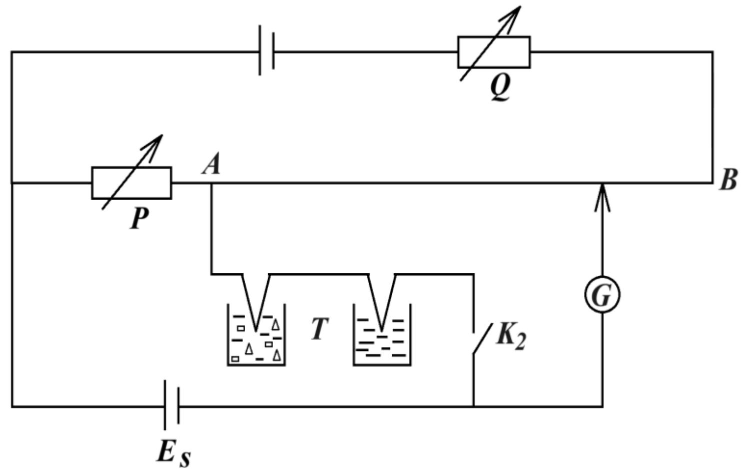
(b)	 • A search coil of N turns and cross-section area A is connected in series with a ballistic galvanometer of known charge sensitivity k and resistance R • A search coil is positioned at right angles to the field to be measured such that it enters the coil normally. The coil is then pulled completely out of the field and the first throw θ of the galvanometer is noted. • The charge that passes round the circuit is proportional to θ i.e $Q = k\theta$ and the magnetic flux density B is obtained from; $B = \frac{K\theta R}{AN}$.	
(c)(i)	When a piece of metal moves in a magnetic field, a magnetic force acts on the delocalized electrons thereby displacing them in a particular direction in accordance to Fleming's Right Hand Grip rule. The electron deficient atoms (positive charges) attract electrons from other atoms. The movement of these electrons causes current loops that are called eddy currents.	
(ii)	Used in melting metal scrap. Thick copper wire is wound round the furnace and alternating current is passed through the wire. A changing magnetic field is established in the furnace which links the scrap, producing eddy currents in it. The eddy currents dissipate heat that is adequate to melt the scrap.	
(d)	$E = BAN\omega = 0.7 \times 3\times10^{-2}\times 500 \times 2\pi \times \frac{400}{60} = 439.823V$ But $E = IR$	

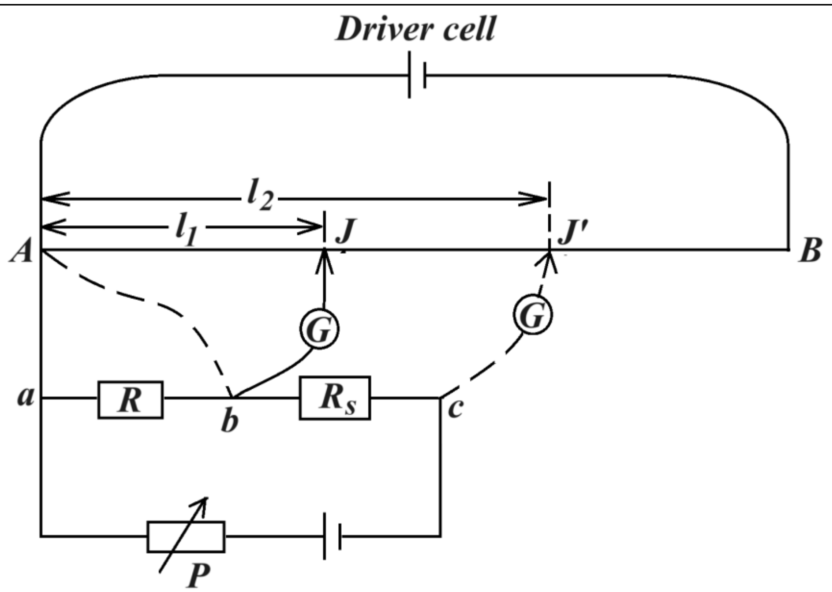
	$439.823 = I \times 1.5$ $I = 293.22\text{A}$	
10 (a)	***Impedance*** is the total opposition to the flow of a.c through a circuit containing resistive and reactive components ***Root mean square value of an alternating current*** is the value of direct (steady) current that dissipates energy (heat) in a given resistor at the same rate as the A.C.	
(b)(i)	***Resonance*** is a condition when the total opposition to the flow of alternating current flowing through a circuit containing resistive and reactive components is minimum. ***OR*** It is the condition when the alternating current flowing through a circuit containing resistive and reactive components is maximum.	
(ii)	 • Radio waves from the different transmitting radio or T.V stations induce e.m.fs of different frequencies at the aerial coil, which in turn induce currents of the same frequency in the inductor, L by mutual induction and connected in series with the variable air capacitor, C. • By altering or tuning the variable air capacitor, C, the circuit is tuned to resonate with the frequency of the desired signal. • At a particular frequency, it responds and stores a large amount of energy that passes on to and fro between the electric field and magnetic fields of the inductor. • The currents due to unwanted signals are negligibly small in comparison to the desired values. At resonance, the impedance whose value Z = R is very small	

	in comparison to X_L and X_C, thus making the circuit highly selective and clear signals are obtained.	
(c)(i)	$I = I_0 \sin \omega t$ $I = \frac{dQ}{dt} = \frac{dCV}{dt} = C\frac{dV}{dt}$ $dV = \frac{I}{C}dt$ $dV = \frac{I_0}{C}\sin \omega t dt$ $\int dV = \frac{I_0}{C}\int \sin \omega t dt$ $V = -\frac{I_0}{\omega C}\cos \omega t = -V_0 \cos \omega t$ $V = -V_0 \sin\left(\omega t + \frac{\pi}{2}\right)$	
(ii)	 • The current and voltage are out phase by a phase angle $\frac{\pi}{2}$, i.e the current leads voltage by $\frac{\pi}{2}$. • When the P.d between the plates is minimum the current flowing is maximum because there is no charge on the plates to oppose the arrival of electrons. • As the P.d increases the current flowing decreases because the already existing electrons oppose the arrival of more charges hence rate of flow of charge decreases.	

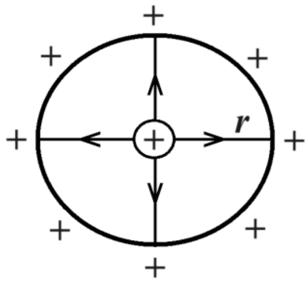
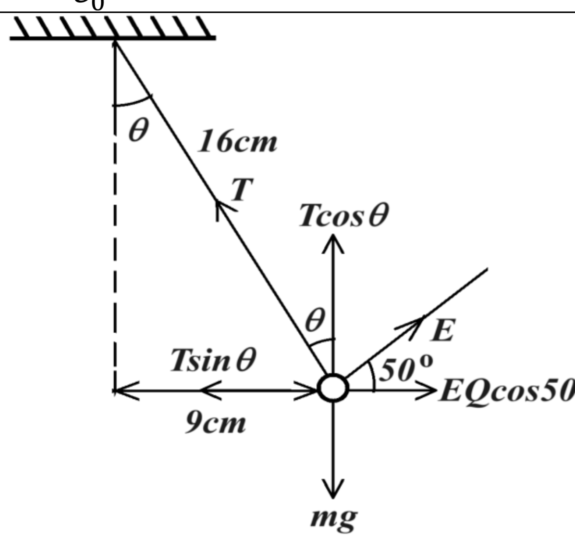
	• When the capacitor is fully charged, the P.d is maximum, the rate of flow of charge is zero hence current is zero. Thus the current reads the voltage by $\frac{\pi}{2}$.	
(d)	 $C = 100\mu F, V_R = 2.5V, I = 0.3A, f = 50Hz$ *For the lamp* $V_R = IR \Rightarrow 2.5 = 0.3R$ $R = 8.33\Omega$ $Z = \sqrt{R^2 + X_C^2} = \sqrt{8.33^2 + \left(\frac{1}{2\pi \times 50 \times 100 \times 10^{-6}}\right)^2}$ $Z = 32.902\Omega$ $V_{rms} = IZ$ *Since in series I is the same,* $V_{rms} = 0.3 \times 32.902 = 9.87V$	
(e)		

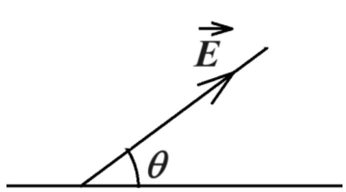
	• In the first half cycle when A is positive relative to B diodes D_1 and D_2 are in forward bias and current flows through R in the direction XY ,while D_3 and D_4 are reverse biased. • In the next half cycle when B is positive relative to A, diodes D_3 and D_4 are forward biased and current flows through R in the direction XY again while D_1 and D_2 are reverse biased. • During both cycles current is passed through the ammeter in one direction.	
11 (a)	***Resistivity*** is the resistance between the opposite faces of a *1m*^{3} of a material. From $\rho = \frac{RA}{l} = \frac{\Omega m^2}{m} = \Omega m$. Thus its *S.I unit* is the Ωm	
(b)	Consider a resistor, *R* connected in series with a cell of *emf*, *E* and internal resistance, *r*  $E = I(R+r)-------(1)$ *Power output,* $P_{out} = I^2R$ *Power input,* $P_{out} = IE$ *Efficiency,* $\eta = \frac{P_{out}}{P_{in}} \times 100\% = \frac{I^2R}{IE} \times 100\%$ $\eta = \frac{IR}{E} \times 100\% = \frac{IR}{I(R+r)} \times 100\%$ $\eta = \frac{R}{(R+r)} \times 100\%$	

(c) (i)	 ✓ The driver cell maintains a steady current through slide wire. ✓ The slide wire has uniform resistance, hence the *p.d per cm* is uniform and any test p.d can be balanced across an appropriate length along the slide wire.	
(ii)	By connecting a large resistance boxes in the driver circuit as shown below.  ***P*** and ***Q*** are connected to reduce current through the wire ***AB*** to a suitable small emf of the thermocouple to be balanced. ***Q*** also helps raise the p.d in this section to enable a balance point to be found for E_S.	

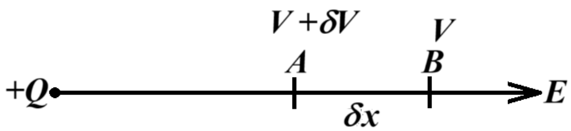
(d)	 ✓ The test resistor, ***R*** and a standard resistor, ***R_s*** are connected in series so that the same current passes through them as shown in the circuit above. ✓ With contacts at ***a*** and ***b*** the jockey J is tapped at different points along the slide wire ***AB*** until a point is reached when the galvanometer shows no deflection. The balance length, ***l_1*** is measured and recorded. ✓ The galvanometer is then disconnected from ***b*** to ***c*** and ***b*** is connected directly to ***A*** as shown by the dotted lines in the diagram above. ✓ The jockey is again tapped along ***AB*** until a balance point is obtained. The new balance length, ***l_2*** is measured and recorded. ✓ The unknown resistance, *R* is then calculated from $R = \left(\frac{l_1}{l_2}\right)R_s$	

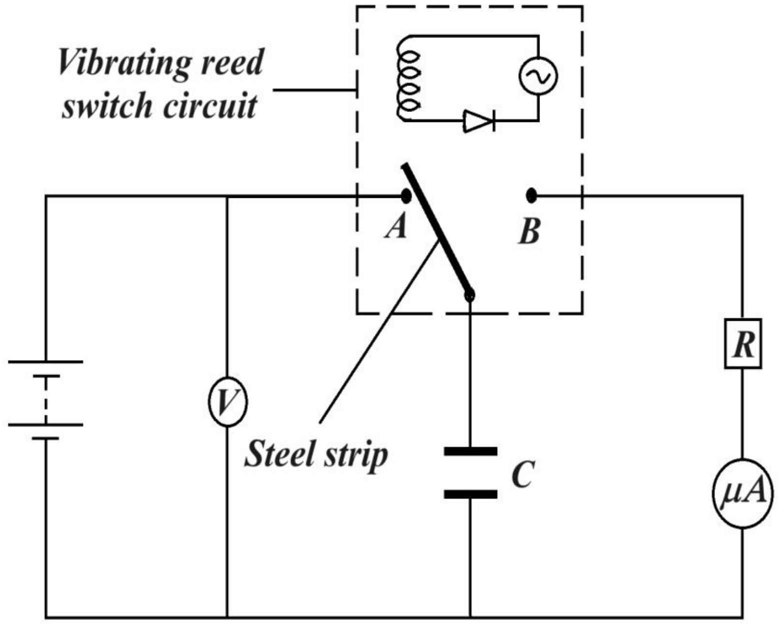
(e) (i)	$R_s = 10\Omega$ *At 0°C,* $l_1 = 40cm, l_2 = 60cm$ *At balance point,* $\frac{R_0}{R_s} = \frac{l_1}{l_2} \Rightarrow R_0 = \frac{40}{60} \times 10 = \frac{20}{3}\Omega$ *At 100°C,* $l_1 = 50cm, l_2 = 50cm$ $\frac{R_{100}}{R_s} = \frac{l_1}{l_2} \Rightarrow R_{100} = \frac{50}{50} \times 10 = 10\Omega$ *At* $\theta^{\circ}C$, $l_1 = 42cm, l_2 = 58cm$ $\frac{R_\theta}{R_s} = \frac{l_1}{l_2} \Rightarrow R_\theta = \frac{42}{58} \times 10 = \frac{210}{29}\Omega$ *From* $R_\theta = R_0(1+\theta\alpha)$ $R_\theta = R_0(1+\theta\alpha) \Rightarrow \frac{210}{29} = \frac{20}{3}(1+\theta\alpha) ----(1)$ $R_{100} = R_0(1+100\alpha)$ $10 = \frac{20}{3}(1+100\alpha) \Rightarrow \alpha = 5\times10^{-3}K^{-1}$ *From (1),* $\theta = \frac{\left(\frac{210\times3}{29\times20} - 1\right)}{5\times10^{-3}}$ $\theta = 17.24°C$	
(ii)	$\rho_\theta = \frac{R_\theta A}{l} = \frac{210}{29} \times \frac{2.5\times10^{-4}\times10^{-4}}{1.5} = 1.207\times10^{-7}\Omega m$	
(f)	*Positive temperature coefficient of resistance*. This will result into increase in resistance of the heating element due to increase in its temperature when current flows through it.	
12(a)(i)	***Action at a point*** is the apparent loss of charge at the sharp points of a charged conductor. The high charge density at sharp points causes high electric field intensity that ionizes surrounding air molecules. Ions of similar charge are repelled and ions of opposite charge are attracted hence neutralizing the charge on the conductor.	
(ii)	When a negatively charged metal rod is placed on a neutral gold leaf, the leaf diverges because the electroscope gets charged by contact. When a sharp pin is placed on its cap with it's the sharp end facing away, the divergence of the leaf decreases with time. At the sharp point of the pin , there is a high charge density that causes a high electric field intensity that ionizes surrounding air molecules, the	

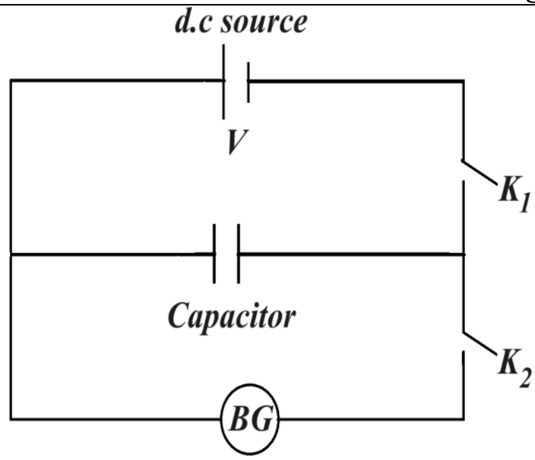
	positive ions are attracted to neutralize the negative charge on the electroscope hence the leaf falls	
(b)(i)	***Gauss' law*** states that the total flux passing normally through an area is equal to the relation of the charge enclosed to the permittivity of the medium.	
(ii)	Assuming we consider a radius, r, concentric with a positive charge Q in free space.  Electric field intensity on the surface of the sphere is given by $E = \frac{Q}{4\pi\varepsilon_0 r^2} \ldots\ldots\ldots\ldots.(i)$ But $\phi = EA \ldots\ldots\ldots\ldots\ldots (ii)$ Substituting (i) into (ii) $\phi = \frac{Q}{4\pi\varepsilon_0 r^2}A$ For a sphere, $A = 4\pi r^2$ $\phi = (\frac{Q}{4\pi\varepsilon_0 r^2})4\pi r^2$ $\phi = \frac{Q}{\varepsilon_0}$	
(c) *(i)*	 Let the tension in the thread be T, θ be the angle the string makes with the vertical. Resolving vertically, $T\cos\theta + EQsin50 = mg$ $Tcos\theta = mg - EQsin50 - - - - (i)$	

	$But\ \theta = \sin^{-1}\left(\frac{9}{16}\right) = 34.24^0$ Resolving horizontally, $T\sin\theta = EQ\ cos50 - - - -(ii)$ $(ii) \div (i)$ $\frac{T\sin\theta}{Tcos\theta} = \frac{EQcos50}{mg - EQsin50}$ $\frac{EQcos50}{mg - EQsin50} = tan34.24$ $EQcos50 = mgtan34.24 - EQsin50tan34.24$ $EQ(cos50 + sin50tan34.24) = mgtan34.24$ $Q = \frac{mgtan34.24}{E(cos50 + sin50tan34.24)}$ $Q = \frac{60 \times 10^{-3} \times 9.81tan34.24}{1.24 \times 10^5(cos50 + sin50tan34.24)}$ $Q = 2.77 \times 10^{-6}C$	
(ii)	From (i) $T\sin\theta = EQ\ cos50$ $T = \frac{1.24 \times 10^5 \times 2.77 \times 10^{-6}cos50}{sin34.24}$ $T = 0.3924N$	
(d)(i)	***Equipotential surface*** is surfaces is one in which the potential is the same at all points. *Examples include;* Any spherical shell concentric with a point charge. The surface a charged conductor.	
(ii)	Suppose $\vec{E}$ due to the charged surface makes an angle θ with the equipotential surface.  *The work done to move 1C of a positive charge through a distance, x along the surface is;* $Work = Force \times distance$ $W = Fx$	

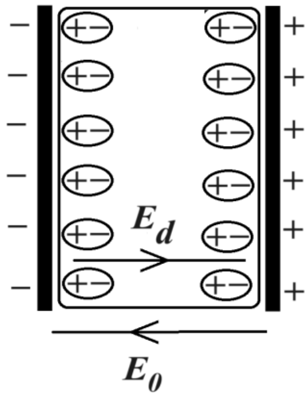
	But $\vec{F} = \vec{E} \times 1 = \vec{E}$ *where* $Q = +1C$ *Along the surface,* $\vec{E} = E\cos\theta$ $\Rightarrow W = (E\cos\theta)x$ *For an equipotential surface, Work, W=0* $\Rightarrow Ex\cos\theta = 0$ *If* $E \neq 0$ *and* $x \neq 0$*, then,* $\cos\theta = 0$ $\Rightarrow \theta = \cos^{-1}(0)$ $\therefore \theta = 90^\circ$ *Hence* $\vec{E}$ *is perpendicular to the equipotential surface*	
13 (a)	***Capacitance*** of a capacitor is the ratio of magnitude of charge on either plate of the capacitor to the potential difference between the plates. ***A farad*** is the capacitance of a capacitor when the magnitude of charge of *1C* is stored on either plate and the p.d between the plates is *1V*.	
(b)(i)	Consider a battery with pd V, if it charges the capacitor to charge Q, then $Energy\ supplied\ by\ the\ battery\ E = VQ$ $Heat\ disspated\ in\ the\ circuit$ $= energy\ supplied\ by\ the\ battery$ $-\ energy\ stored\ in\ the\ capacitor$ The small work δw done to move a small charge δq from one plate to another is given by $\delta w = V\delta q$ The total work W done to charge the capacitor to Q from zero is given by. $W = \int_o^Q V dq = \int_o^Q \frac{Q}{c} dq$ $W = \frac{Q^2}{2C}$ $But\ C = \frac{Q}{V}$ $W = QV$ The work done is stored as energy. $Thus\ E = QV$ $Energy\ stored\ in\ the\ capacitor\ E_1 = \frac{QV}{2}$ $Heat\ dissipated = E - E_1$ $Energy\ lost = QV - \frac{QV}{2} = \frac{QV}{2}$	

	$Heat\ dissipated = energy\ stored = \frac{QV}{2}$	
(b)(ii)	Consider a charge $+Q$ at a distance x from A in an electric field where electric field strength is E.  Suppose the points A and B are so close a small distance δx apart such that the electric field intensity is constant. Work done to move a charge of $+1C$ from B to A is $W = (V + \delta V) - V = \delta V$ $Also\ Work, W = E \times 1 \times (-\delta x) = -E\delta x$ $\Rightarrow W = -E\delta x$ $-E\delta x = \delta V$ $E = -\frac{\delta V}{\delta x}$ Electric field intensity at any point is equal to the potential gradient at and near the point	
(c)(i)	$A_1 = \frac{\pi d^2}{4} = \frac{\pi \times (0.1)^2}{4} = 7.854 \times 10^{-3} m^2$ $A_2 = \frac{\pi d^2}{4} = \frac{\pi \times (0.12)^2}{4} = 1.131 \times 10^{-2} m^2$ $C_1 = \frac{A\varepsilon_0}{d} = \frac{7.854 \times 10^{-3} 8.85 \times 10^{-12}}{2.0 \times 10^{-3}} = 3.477 \times 10^{-11} F$ $C_2 = \frac{A\varepsilon_0}{d} = \frac{1.131 \times 10^{-2} 8.85 \times 10^{-12}}{3.0 \times 10^{-3}} = 3.338 \times 10^{-11} F$ $Effective\ capacitance\quad C = \frac{C_1 C_2}{c_1 + C_2} = \frac{3.477 \times 10^{-11} \times 3.338 \times 10^{-11}}{3.477 \times 10^{-11} + 3.338 \times 10^{-11}} = 1.705 \times 10^{-11} F$ $C = 1.705 \times 10^{-11} F$	
(ii)	Energy stored in the system , $E = \frac{CV^2}{2} = \frac{120^2 1.705 \times 10^{-11}}{2}$ $E = 1.227 \times 10^{-7} J$	

(d)	 • The apparatus is set up as shown above. • A capacitor with free space between its plates is connected at position C. • The reed switch is then activated so that the capacitor alternately charges and discharges through a sensitive microammeter at a known frequency *f* of the low a.c supply energizing the reed switch. • The voltmeter reading V and microammeter reading I_0 are noted. • The dielectric whose relative permittivity is required is then inserted between the plates of the capacitor. • Keeping the plate separation and area of overlap constant, the procedure is repeated and new microammeter reading I_1 is recorded. • The relative permittivity ε_r is determined from $\varepsilon_r = \frac{I_1}{I_0}$	
(e) (i)	At equilibrium, $The\ sum\ of\ clockwise\ moments$ $= sum\ of\ anticlockwise\ moments$ $EQx = mgx$ $\frac{V}{d}CV = mg$ $\frac{CV^2}{d} = mg$ $\frac{A\varepsilon_0}{d^2}V^2 = mg$ $\frac{120^{-4} \times 8.85 \times 10^{-12}}{0.4^2}V^2 = 2.66 \times 10^{-6} \times 9.81$ $V = 6.27kV$	

(ii)	Charge density, $\delta = \frac{Q}{A}$ $\delta = \frac{CV}{A}$ $= \frac{A\varepsilon_0 V}{Ad} = \frac{\varepsilon_0 V}{d}$ $= \frac{8.85 \times 10^{-12} \times 6.27 \times 10^3}{0.4}$ $\delta = 1.387 \times 10^{-7} Cm^{-2}$	
14 (a)	***Dielectric strength*** is the maximum potential gradient a dielectric can withstand before it starts conducting.	
(b)	 • The circuit is connected as shown above • A capacitor is connected to position C. • With switch K_2 open, K_1 is closed and the capacitor charges fully to the p.d V of the source. • Switch K_1 is opened and K_2 is closed and the capacitor discharges through the ballistic galvanometer. • The maximum deflection θ_0 of the ballistic galvanometer is recorded. • Keeping the plate separation constant, one of the plates is slightly displaced to reduce the effective area of overlap. • The procedure is repeated and the new deflection θ_1 of the ballistic galvanometer is recorded. • It is observed that $\theta_1 < \theta_0$ thus the capacitance of the capacitor reduces when the area of overlap is reduced. Hence $C \propto A$.	

(c) (i)	Consider a capacitor connected to a battery and charged to a p.d V The small work δw done to move a small charge δq from one plate to another is given by $\delta w = V\delta q$ The total work W done to charge the capacitor to Q from zero is given by. $W = \int_{o}^{Q} V dq$ $W = \int_{o}^{Q} \frac{Q}{c} dq$ $W = \frac{Q^2}{2C}$ The work done is stored as electrostatic energy between the plates of the capacitor. $Energy\ stored\ in\ the\ capacitor\ E = \frac{Q^2}{2C}$ $But\ C = \frac{Q}{V}$ $E = \frac{Q^2}{2\left(\frac{Q}{V}\right)}$ $E = \frac{1}{2}QV$	
(ii)	From $C_2 = \frac{A\varepsilon_0}{d}$, when the separation d is reduced, the capacitance C of the capacitor increases. Also $Energy\ E = \frac{CV^2}{2}\ thus\ E \propto C$. Therefore, the energy reduces when the distance of separation reduces. This is because, when the capacitor is connected to the battery, the decrease in capacitance results in a decrease in the amount of charge stored by the capacitor since $Q = CV$ and V is constant. This charge is returned to the battery thus a decrease in energy is as a result of the capacitor discharging.	

(iii)	 • When a dielectric is inserted between the plates of the capacitor, the molecules of the capacitor get polarized forming positive charge near the negative plate and negative charge near the positive plate. These charges are bound charges so they can't be neutralized. This creates an electric field intensity E_d in a direction opposite to that of the applied electric field intensity E_0. • This reduces the electric field intensity $E = E_0 - E_d$ between the plates of the capacitor. • Since $E = \frac{V}{d}$, a reduction in E reduces the P.d, V between the plates. • From $C = \frac{Q}{V}$, a decrease in V increases the capacitance of the capacitor. Hence presence of a dielectric increases capacitance of a capacitor.	
(d)	*For C_2 and C_3 with a dielectric* $C' = \frac{C_2 \varepsilon_r C_3}{C_2 + \varepsilon_r C_3} = \frac{3 \times 2.3 \times 3}{3 + 2.3 \times 3} = 2.091\mu F$ *For C' and C_1* *Total capacitance,* $C = C' + C_1$ $C = 3 + 2.091$ $C = 5.091\mu F$ *Total charge,* $Q = CV$ $Q = 5.091 \times 60$ $Q = 305.46\mu C$ *But* $Q = k\theta$ $305.46 = 4\theta$ $\theta = 76.365\ divisions$	

END