SAMPLE QUESTION PAPER

BLUE PRINT

Time Allowed : 3 hours **Maximum Marks :** 70

S. No.	Chapter	VSA/ AR/ Case Based (1 mark)	SA-I (2 marks)	SA-II (3 marks)	LA (5 marks)	Total
1.	Electrostatics	2(2)	1(2)	–	1(5)	**6(16)**
2.	Current Electricity	1(4)	–	1(3)	–	
3.	Magnetic Effects of Current and Magnetism	2(2)	2(4)	–	–	**8(17)**
4.	Electromagnetic Induction and Alternating Current	1(1)	1(2)	1(3)	1(5)	
5.	Electromagnetic Waves	2(2)	1(2)	–	–	**8(18)**
6.	Optics	2(5)	2(4)	–	1(5)	
7.	Dual Nature of Radiation and Matter	1(1)	–	1(3)	–	**6(12)**
8.	Atoms and Nuclei	2(2)	–	2(6)	–	
9.	Electronic Devices	3(3)	2(4)	–	–	**5(7)**
	Total	**16(22)**	**9(18)**	**5(15)**	**3(15)**	**33(70)**

Subject Code : **042**

PHYSICS

Time allowed : 3 hours ***Maximum marks : 70***

(i) All questions are compulsory. There are 33 questions in all.
(ii) This question paper has five sections: Section A, Section B, Section C, Section D and Section E.
(iii) Section A contains ten very short answer questions and four assertion reasoning MCQs of 1 mark each. Section B has two case based questions of 4 marks each, Section C contains nine short answer questions of 2 marks each, Section D contains five short answer questions of 3 marks each and Section E contains three long answer questions of 5 marks each.
(iv) There is no overall choice. However internal choice is provided. You have to attempt only one of the choices in such questions.

SECTION - A

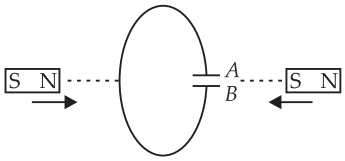
All questions are compulsory. In case of internal choices, attempt any one of them.

1. What is the forbidden energy gap (in joule) for a germanium crystal ?

2. Plot a graph showing variation of induced e.m.f. with the rate of change of current flowing through a coil.

OR

Predict the polarity of the capacitor in the situation described below.



3. An electron is moving along +ve x – axis in the presence of uniform magnetic field along +ve y – axis. What is the direction of the force acting on it?

4. Long distance radio broadcasts use short-wave bands. Why?

OR

Optical and radio telescopes are built on the ground but X-ray astronomy is possible only from satellites orbiting the earth. Why?

5. What is the effect on the velocity of the emitted photoelectrons if the wavelength of the incident light is decreased?

6. In a half wave rectifier circuit operating from 50 Hz mains frequency, what would be the fundamental frequency in the ripple ?

7. What is the purpose of heavy water in nuclear reactors?

OR

Compare the radii of two nuclei with mass numbers 1 and 27 respectively.

8. The total energy of an electron in the first excited state of the hydrogen atom is about –3.4 eV.
   (i) What is the kinetic energy of electron in this state ?
   (ii) What is the potential energy of electron in this state ?

9. A potential barrier of 0.3 V exists across a *p-n* junction. If the depletion region is 1 μm wide, what is the intensity of electric field in this region?

OR

When the voltage drop across a *p-n* junction diode is increased from 0.65 V to 0.70 V, the change in the diode current is 5 mA. Find the value of the dynamic resistance of the diode.

10. Depict the direction of the magnetic field lines due to a circular current carrying loop.

For question numbers 11, 12, 13 and 14, two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false and R is also false

11. **Assertion (A) :** If a dielectric is placed in external field then field inside dielectric will be less than applied field.
    Reason (R) : Electric field will induce dipole moment opposite to field direction.

12. **Assertion (A) :** If a convex lens is kept in water its convergent power decreases.
    Reason (R) : Focal length of convex lens in water increases.

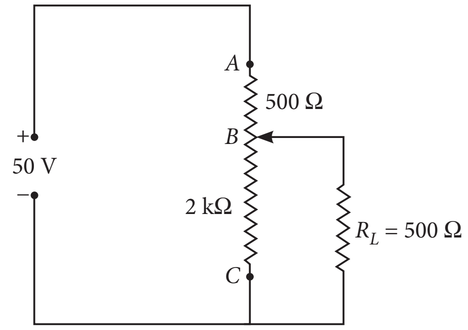
13. **Assertion (A) :** In a cavity within a conductor, the electric field is zero.
    Reason (R) : Charges in a conductor reside only at its surface.

14. **Assertion (A) :** When a charged particle moves in a circular path. It produces electromagnetic wave.
    Reason (R) : Charged particle has acceleration.

SECTION - B

Questions 15 and 16 are Case Study based questions and are compulsory. Attempt any 4 sub parts from each question. Each question carries 1 mark.

15. A Rheostat is used in applications that requires the adjustment of current or varying of resistance in an electric circuit. As shown in figure, a variable rheostat of 2 kΩ is used to control the potential difference across a 500 Ω load. Here, the source emf is 50 V and resistance *AB* is 500 Ω.



(i) The total resistance of the circuit is
(a) 500 Ω (b) 375 Ω (c) 875 Ω (d) 1500 Ω

(ii) The value of total current flowing through the circuit is
(a) 2.87 A (b) 0.057 A (c) 0.87 A (d) 0.677 A

(iii) The potential difference across the load is
(a) 21.43 V (b) 32.45 V (c) 17.62 V (d) 19.83 V

(iv) If the load is removed, the current across the rheostat is,
(a) 1/4 A (b) 1/20 A (c) 1/40 A (d) 40 A

(v) If the load is removed, what should be the resistance at BC to get 40 V between B and C ?
(a) 500 Ω (b) 375 Ω (c) 1600 Ω (d) 1500 Ω

16. Image of a white object is coloured and blurred because μ (hence f) of lens is different for different colours. This defect is called chromatic aberration. As $\mu_0 > \mu_r$, therefore, $f_r > f_v$. The difference $(f_r - f_v)$ is a measure of longitudinal chromatic aberration of the lens. Focal length for mean colour is $f = \sqrt{f_r \times f_v}$. Using lens maker formula, for mean colour of light, we have $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ where f is focal length of mean colour and μ is the refractive index of mean colour.

(i) Focal length of a equiconvex lens of glass μ = 3/2 in air is 20 cm. The radius of curvature of each surface is
(a) 10 cm (b) –10 cm (c) 20 cm (d) –20 cm

(ii) Focal length of the lens in water would be
(a) 20 cm (b) 80 cm (c) –20 cm (d) –80 cm

(iii) If $\mu_v = 1.6$, $\mu_r = 1.5$, $R_1 = 20$ cm and $R_2 = -20$ cm, then the chromatic aberration of the lens would be
(a) 3 cm (b) 3.3 cm (c) –3 cm (d) –3.3 cm

(iv) A given convex lens of glass (μ = 3/2) can behave as concave when it is held in a medium of μ equal to
(a) 1 (b) 3/2 (c) 2/3 (d) 7/4

(v) Chromatic aberration of a lens can be corrected by
(a) providing different suitable curvature to its two surfaces
(b) proper polishing of its two surfaces
(c) Suitably combining it with another lens
(d) reducing its aperture.

SECTION - C

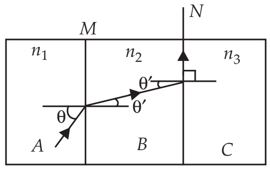
All questions are compulsory. In case of internal choices, attempt anyone.

17. Interstellar space has an extremely weak magnetic field of the order of 10^{-12} T. Can such a weak field be of any significant consequence? Explain.

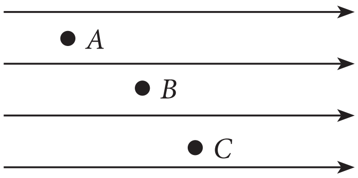
OR

Consider the plane S formed by the dipole axis and the axis of earth. Let P be point on the magnetic equator and in S. Let Q be the point of intersection of the geographical and magnetic equators. Obtain the declination and dip angles at P and Q.

18. *A*, *B* and *C* are the parallel sided transparent media of refractive index n_1, n_2 and n_3 respectively. They are arranged as shown in the figure. A ray is incident at an angle θ on the surface of separation of *A* and *B* is as shown in the figure. After the refraction into the medium *B*, the ray grazes the surface of separation of the media *B* and *C*. Find the value of sinθ.



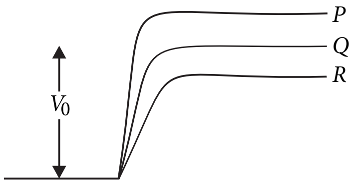
19. Figure shows three points *A*, *B* and *C* in an uniform electric field. At which of the points the electric potential is maximum?



OR

Is it possible to transfer all the charge from a conductor to another insulated conductor?

20. In figure, V_0 is the potential barrier across a *p*-*n* junction, when no battery is connected across the junction.



Which of *P*, *Q* and *R* corresponds to forward and reverse bias of junction ?

21. A charged particle *q* is moving in the presence of a magnetic field *B* which is inclined to an angle 30° with the direction of the motion of the particle. Draw the trajectory followed by the particle in the presence of the field and explain how the particle describes this path.

22. When an electric field is applied across a semiconductor what happens to electrons and holes ?

23. Starting from the expression for the energy $W = \frac{1}{2}LI^2$, stored in a solenoid of self-inductance *L* to build up the current *I*, obtain the expression for the magnetic energy in terms of the magnetic field *B*, area *A* and length *l* of the solenoid having *n* number of turns per unit length. Hence, show that the energy density is given by $B^2/2\mu_0$.

24. Show, by giving a simple example, how *e.m.* waves carry energy and momentum.

OR

An *e.m.* wave is travelling in a medium with a velocity $\vec{v} = v\hat{i}$. Draw a sketch showing the propagation of the *e.m.* wave, indicating the direction of the oscillating electric and magnetic fields.

25. For a single slit of width '*a*', the first minimum of the interference pattern of a monochromatic light of wavelength λ occurs at an angle of $\frac{\lambda}{a}$. At the same angle of $\frac{\lambda}{a}$, we get a maximum for two narrow slits separated by a distance '*a*'. Explain.

SECTION - D

All questions are compulsory. In case of internal choices, attempt any one.

26. Define resistivity of a conductor. Plot a graph showing the variation of resistivity with temperature for a metallic conductor. How does one explain such a behaviour, using the mathematical expression of the resistivity of a material.

OR

Derive an expression for the drift speed of electrons in a good conductor in terms of the relaxation time of electrons.

27. ${}_{86}Rn^{222}$ is converted into ${}_{84}Po^{218}$ and ${}_{93}Np^{239}$ is converted into ${}_{94}Pu^{239}$. Name the particles emitted in each case and write down the corresponding equations.

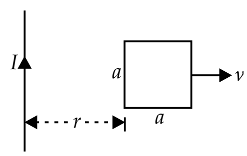
28. The work function for the following metals is given :
Na : 2.75 eV; K: 2.30 eV; Mo : 4.17 eV; Ni : 5.15 eV. Which of these metals will not give photoelectric emission for a radiation of wavelength 3300 Å from a He-Cd laser placed 1 m away from the photocell? What happens if the laser is brought nearer and placed 50 cm away?

OR

Why should gases be insulators at ordinary pressures and start conducting at very low pressure?

29. Using the relevant Bohr's postulates, derive the expression for the speed of the electron in the n^{th} orbit.

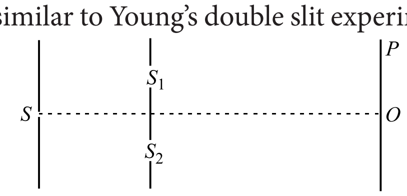
30. Obtain an expression for the mutual inductance between a long straight wire and a square loop of side a as shown in figure.



SECTION - E

All questions are compulsory. In case of internal choices, attempt any one.

31. Figure shows an experiment setup similar to Young's double slit experiment to observe interference of light.



Here $SS_2 - SS_1 = \lambda/4$

Write the condition of (i) constructive, (ii) destructive interference at any point P in terms of path difference, $\Delta = S_2P - S_1P$

Does the central fringe observed in the above setup lie above or below O? Give reason in support of your answer. Yellow light of wavelength 6000Å produces fringes of width 0.8 mm in Young's double slit experiment. What will be the fringe width if the light source is replaced by another monochromatic source of wavelength 7500Å and separation between the slits is doubled?

OR

(a) What are coherent sources of light? State two conditions for two light sources to be coherent.

(b) Derive a mathematical expression for the width of interference fringes obtained in Young's double slit experiment with the help of a suitable diagram.

32. (a) An alternating voltage $V = V_m \sin \omega t$ applied to a series LCR circuit drives a current given by $i = i_m \sin(\omega t + \phi)$. Deduce an expression for the average power dissipated over a cycle.

(b) Determine the current and quality factor at resonance for a series LCR circuit with L = 1.00 mH, C = 1.00 nF and R = 100 Ω connected to an ac source having peak voltage of 100 V.

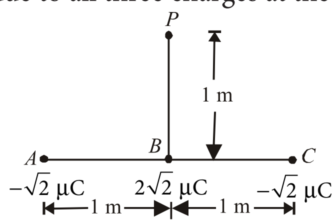
OR

(a) Draw the diagram of a device which is used to decrease high ac voltage into a low ac voltage and state its working principle. Write four sources of energy loss in this device.

(b) A small town with a demand of 1200 kW of electric power at 220 V is situated 20 km away from an electric plant generating power at 440 V. The resistance of the two wire line carrying power is 0.5 Ω per km. The town gets the power from the line through a 4000-220 V step-down transformer at a sub-station in the town. Estimate the line power loss in the form of heat.

33. (a) Obtain the formula for the electric field due to a long thin wire of uniform linear charge density λ without using Gauss's law.

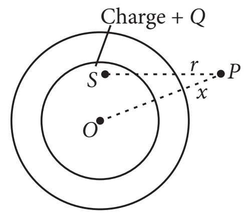
(b) Three charges $-\sqrt{2}\,\mu C$, $2\sqrt{2}\,\mu C$ and $-\sqrt{2}\,\mu C$ are arranged along a straight line as shown in the figure. Calculate the total field intensity due to all three charges at the point P.



OR

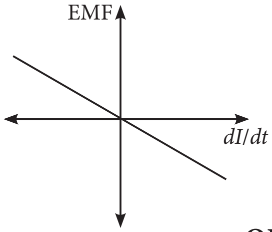
(a) A hollow charged conductor has a tiny hole cut into its surface. Show that the electric field in the hole is $\left(\frac{\sigma}{2\varepsilon_0}\right)\hat{n}$, where $\hat{n}$ is the unit vector in the outward normal direction, and σ is the surface charge density near the hole.

(b) The figure shows a charge + Q held on an insulating support S and enclosed by a hollow spherical conductor. O represents the centre of the spherical conductor and P is a point such that $OP = x$ and $SP = r$. Find the electric field at point P.



SOLUTIONS

1. $E_g = 0.7 \text{ eV} = 0.7 \times 1.6 \times 10^{-19} \text{ J} = 1.12 \times 10^{-19} \text{ J}$

2. 

OR

Polarity of plate *A* will be positive with respect to plate *B* in the capacitor, as induced current is in clockwise direction

3. Using Fleming's right hand rule, the direction of force will be along –ve *z*-axis.

4. Electromagnetic waves in frequency range of short-wave band reflect from ionosphere where lower frequency radio waves *i.e.*, medium waves are absorbed. So, short-waves are suitable for long distance radio broadcast.

OR

Atmosphere absorb X-rays, while visible and radiowaves can penetrate through it. Hence optical telescope can work on ground but X-ray astronomical telescopes only work above atmosphere, hence installed on the satellite orbiting around earth.

5. $\frac{1}{2}mv^2 = h\upsilon - W_0 = \frac{hc}{\lambda} - W_0$

So, if λ of incident light is decreased, energy $h\upsilon$ of photon increases and hence K.E. and velocity of emitted photoelectron also increases.

6. As the output voltage obtained in a half wave rectifier circuit has a single variation in one cycle of ac voltage, hence the fundamental frequency in the ripple of output voltage would be = 50 Hz.

7. Heavy water is used as a moderator in some reactors to slow down the fast moving neutrons.

OR

As $\frac{R_1}{R_2} = \left(\frac{A_1}{A_2}\right)^{1/3} = \left(\frac{1}{27}\right)^{1/3} = \frac{1}{3}$

8. (i) $E_K = -E = -(-3.4) = +3.4$ eV
(ii) $E_P = 2E = 2 \times (-3.4) = -6.8$ eV

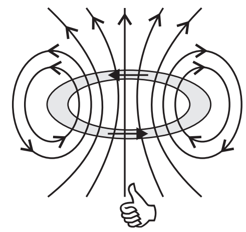
9. Electric field $E = \frac{V}{d} = \frac{0.3}{1 \times 10^{-6}} = 3 \times 10^5 \text{ V m}^{-1}$

OR

Dynamic resistance, $r_d = \frac{\Delta V}{\Delta I}$

$$r_d = \frac{0.70 \text{ V} - 0.65 \text{ V}}{5 \times 10^{-3} \text{ A}} = \frac{0.05 \times 1000}{5} \Omega = 10\ \Omega$$

10. Magnetic field lines due to a circular wire carrying current *I* :



11. **(c) :** Dipole moment will be in the same direction as the external field. The collective effect of dipole moments produces a field that opposes the external field and hence, the net electric field inside the dielectric is less than the external electric field.

12. **(a) :** The focal length of a lens in a medium of refractive index μ_m is given by

$$\frac{1}{f_m} = \left(\frac{\mu - \mu_m}{\mu_m}\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

where μ is the refractive index of glass.

In air $\frac{1}{f_a} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

From these two expressions it is clear that $f_m > f_a$.
That is the focal length of the convex lens in water increases thereby reducing its convergent power.

13. **(a) :** Both the assertion and reason are true and the reason is the correct explanation. It is because the charges are only at the surface of a conductor, the charge enclosed in the Gaussian surface in the cavity is zero. The field is therefore zero.

14. **(a) :** Accelerated charges radiate electromagnetic waves.

15. **(i) (b) :** Here, load resistance, $R_L = 500\ \Omega$;
and e.m.f. of the source, $E = 50$ V
Total resistance of the rheostat between points *A* and *C*,
$R_{AC} = 2\text{k}\Omega = 2000\ \Omega$
The resistance of the rheostat between points *A* and *B*,
$R_{AB} = 500\ \Omega$
Therefore, resistance between points *B* and *C*,
$R_{BC} = R_{AC} - R_{AB} = 2000 - 500 = 1500\ \Omega$

Now, R_{BC} and R_L are connected in parallel. If R' is resistance of their combination, then

$$\frac{1}{R'} = \frac{1}{R_{BC}} + \frac{1}{R_L} = \frac{1}{1500} + \frac{1}{500} = \frac{4}{1500}$$

or $R' = 375\ \Omega$

(ii) (b) : Further, R_{AB} and R are in series. If I is the current in the circuit, then

$$I = \frac{E}{R_{AB} + R'} = \frac{50}{500 + 375} = \frac{2}{35}\text{ A} = 0.057\text{ A}$$

(iii) (a): Potential drop across R_L is same as the potential drop across the parallel combination of R_{BC} and R_L.

$$\therefore\ V_L = \frac{50 \times 375}{500 + 375} = 21.43\text{ V}$$

(iv) (c) : When the load is removed, the source of e.m.f. will send current through the rheostat wire AB having a total resistance of 2000 Ω. Therefore, current through the rheostat,

$$I' = \frac{50}{2{,}000} = \frac{1}{40}\text{A}$$

(v) (c) : If R'_{BC} is the value of the resistance of the rheostat between points B and C, which will give a potential difference of 40 V across these two points, then

$I'R'_{BC} = 40$

or $R'_{BC} = \frac{40}{I'} = \frac{40}{1/40} = 1600\,\Omega$

16. (i) (c) : $\frac{1}{f} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

For equiconvex lens, $R_1 = R$, $R_2 = -R$

$$\frac{1}{20} = \left(\frac{3}{2} - 1\right)\left(\frac{2}{R}\right) = \frac{1}{R}$$

$\therefore\ R = 20$ cm

(ii) (b) : $\frac{1}{f_w} = \left(\frac{\mu_g}{\mu_w} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$$= \left(\frac{3/2}{4/3} - 1\right)\left(\frac{1}{20} + \frac{1}{20}\right) = \frac{1}{8} \times \frac{1}{10} = \frac{1}{80}$$

$\therefore\ f_w = 80$ cm

(iii) (b): $\frac{1}{f_v} = (\mu_v - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

$$= (1.6 - 1)\left(\frac{2}{20}\right) = \frac{6}{100}$$

$$\therefore\ f_v = \frac{100}{6} = 16{\cdot}7\text{ cm}$$

$$\frac{1}{f_r} = (\mu_r - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right) = (1{\cdot}5 - 1)\left(\frac{2}{20}\right) = \frac{1}{20}$$

$f_r = 20$ cm

Chromatic aberration $= f_r - f_v$

$= 20 - 16.7 = 3.3$ cm

(iv) (d) : $\frac{1}{f_m} = \left(\frac{\mu_g}{\mu_m} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$

The given lens would behave as concave when f_m becomes negative, for which $\mu_m > \mu_g$.

(v) (c)

17. A weak field of the order of 10^{-12} T can cause the charged particles to move along circular paths of very large radii. Over a small distance, we may not be able to notice the deflection in the path of the charged particles but over large interstellar distance the distance is quite noticeable.

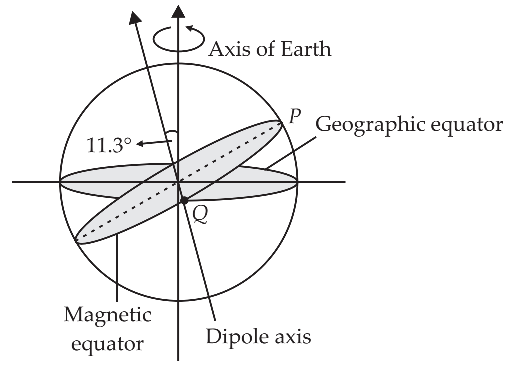
OR

From figure,

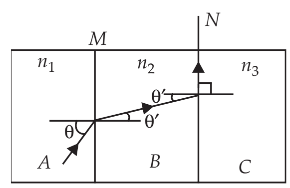
For point P : Since point P lies in plane S formed by the dipole axis and the axis of the Earth, declination, $D = 0°$.

For point Q : Since point Q lies on the magnetic equator, dip, $\delta = 0°$

Declination, $D = 11.3°$



18.



Applying Snell's law

$n_1\sin\theta = n_2\sin\theta' = n_3\sin 90° = n_3$

$$\therefore\ \sin\theta = \frac{n_3}{n_1}$$

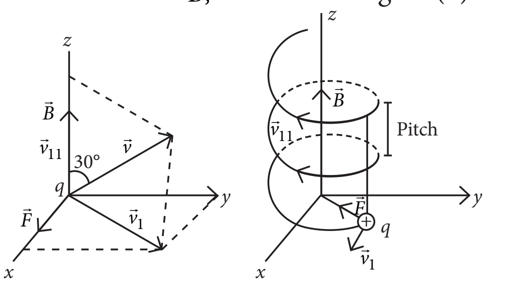
19. $V_A > V_B > V_C$, direction of electric field is from higher to lower potential.

OR

'Yes'. By enclosing uncharged conductor inside charged conductor and then by connecting them with wire.

20. Height of potential barrier decreases when *p-n* junction is forward biased and it increases when junction is reverse biased. So, curve *R* corresponds to forward biasing and *P* corresponds to reverse biasing.

21. When a charged particle moving in a uniform magnetic field has two concurrent motions.
A linear motion in the direction of $\vec{B}$ (along *z*-axis) as shown in figure (a) and a circular motion in a plane perpendicular to $\vec{B}$ (in *xy*-plane). Hence the resultant path of the charged particle will be a helix, with its axis along the direction of $\vec{B}$, as shown in figure (b).



(a) (b)

22. Electrons in conduction band get accelerated and acquire energy by the application of electric field and move from lower energy level to higher energy level.
While holes in valence band move from higher energy level to lower energy level.

23. The magnetic energy is,

$$U_B = \frac{1}{2}LI^2$$

$$= \frac{1}{2}L\left(\frac{B}{\mu_0 n}\right)^2 \qquad (\because\ B = \mu_0 nI, \text{ for a solenoid})$$

$$= \frac{1}{2}(\mu_0 n^2 Al)\left(\frac{B}{\mu_0 n}\right)^2$$

$$= \frac{1}{2\mu_0}B^2 Al$$

The magnetic energy per unit volume is,

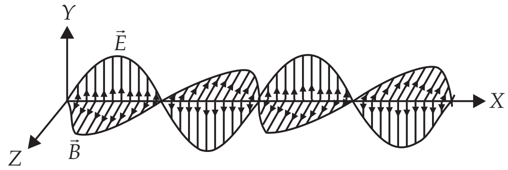
$$u_B = \frac{U_B}{V} \quad \text{(where } V \text{ is volume that contains flux)}$$

$$= \frac{U_B}{Al} = \frac{B^2}{2\mu_0}$$

24. Consider a plane perpendicular to the direction of propagation of the wave. An electric charge, on the plane will be set in motion by the electric and magnetic fields of *e.m.* wave, incident on this plane. This illustrates that *e.m.* waves carry energy and momentum.

OR

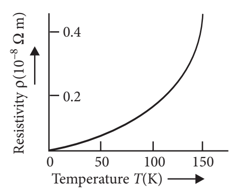
In figure, the velocity of propagation of *e.m.* wave is along *X*-axis $\vec{v} = v\hat{i}$ and electric field $\vec{E}$ along *Y*-axis and magnetic field $\vec{B}$ along *Z*-axis.



25. For a single slit of width "*a*" the first minima of the interference pattern of a monochromatic light of wavelength λ occurs at an angle of (λ/*a*) because the light from centre of the slit differs by a half of a wavelength.
Whereas a double slit experiment at the same angle of (λ/*a*) and slits separation "*a*" produces maxima because one wavelength difference in path length from these two slits is produced.

26. $R = \rho\frac{l}{A}$

If $l = 1$, $A = 1 \Rightarrow \rho = R$
Thus, resistivity of a material is numerically equal to the resistance of the conductor having unit length and unit cross-sectional area.



Resistivity ρ of metallic conductor as a function of temperature *T*

The resistivity of a material is found to be dependent on the temperature. Different materials do not exhibit the same dependence on temperature. Over a limited range of temperatures, that is not too large, the resistivity of a metallic conductor is approximately given by,

$$\rho_T = \rho_0\,[1 + \alpha(T - T_0)] \qquad ...(i)$$

where ρ_T is the resistivity at a temperature *T* and ρ_0 is the same at a reference temperature T_0. α is called the temperature coefficient of resistivity.
The relation in eqn. (i) implies that a graph of ρ_T plotted against *T* would be a straight line. At temperatures much lower than 0°C, the graph, however, deviates considerably from a straight line.

OR

In the absence of an external field, the free electrons in a metal are moving randomly in all directions due to thermal agitation. There is no overall drift and the average velocity is zero.
In the presence of an external electric field *E*, each electron experience an acceleration

$$a = \frac{eE}{m}$$

opposite to the field direction. However, this acceleration is momentary, since the electrons are continuously colliding with vibrating ions and other electrons. After each collision, the electron makes a fresh start and accelerates only to be deflected randomly again. If τ is the relaxation time, *i.e.*, the average time between two successive collisions, then the drift velocity of the electrons is given by

$$v_d = a\tau = \frac{eE\tau}{m}$$

In vector notation, $\vec{v}_d = \frac{e\vec{E}\tau}{m}$

27. Let the particle emitted in each case be represented as ${}_ZX_A$. Therefore,

(i) ${}_{86}Rn^{222} \rightarrow {}_{84}Po^{218} + {}_ZX_A$

Using the law of conservation of mass number and charge number, we get

$222 = 218 + A$

$\therefore\ A = 222 - 218 = 4$

$86 = 84 + Z$

$\therefore\ Z = 86 - 84 = 2$

Now, $A = 4$ and $Z = 2$ correspond to an alpha particle ${}_2He^4$. Therefore, emitted particle is an alpha particle, and the equation is

$${}_{86}Rn^{222} \rightarrow {}_{84}Po^{218} + {}_2He^4$$

(ii) ${}_{93}Np^{239} \rightarrow {}_{94}Pu^{239} + {}_ZX_A$

Using the law of conservation of mass number and charge number, we get

$239 = 239 + A, \quad \therefore \quad A = 239 - 239 = 0$

$93 = 94 + Z, \quad \therefore \quad Z = 93 - 94 = -1.$

Now, $A = 0$ and $Z = -1$ correspond to electron $({}_{-1}e^0)$. Therefore, emitted particle is a beta particle, and the equation is

$${}_{93}Np^{239} \rightarrow {}_{94}Pu^{239} + {}_{-1}e^0 + \bar{\nu}$$

28. The distance between laser source and receiver does not affect the energy of each photon incident, hence does not affect the energy of emitted photoelectrons.

But the reduction in distance will increase the intensity of incident light and hence number of photons. This will increase the photoelectric current.

Given that, wavelength of incident radiation is

$\lambda = 3300$ Å

So, energy of incident radiation is

$$E = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{3300 \times 10^{-10} \times 1.6 \times 10^{-19}} = 3.75 \text{ eV}$$

Now, work function of Mo : 4.17 eV, Ni : 5.15 eV is more than energy of incident photon, hence these two metals will not give photoelectric emission.

OR

At ordinary pressures a few positive ions and electrons produced by the ionisation of the gas molecules by energetic rays (like X-rays, γ-rays, cosmic rays etc., coming from outer space and entering the earth's atmosphere) are not able to reach their respective electrodes, even at high voltages, due to their frequent collisions with gas molecules and recombinations. That is why the gases at ordinary pressures are insulators.

At low pressures, the density of the gas decreases, the mean free path of the gas molecules become large. Now under the effect of external high voltage, the ions acquire sufficient energy before they collide with molecules causing further ionisation. Due to it, the number of ions in the gas increases and it becomes a conductor.

29. Speed of the electron in the n^{th} orbit : The centripetal force required for revolution is provided by the electrostatic force of attraction between the electron and the nucleus.

$$\therefore\ \frac{mv^2}{r} = \frac{KZe^2}{r^2} \qquad \left[\text{where, } K = \frac{1}{4\pi\varepsilon_0}\right]$$

$$\Rightarrow r = \frac{KZe^2}{mv^2} \qquad \text{...(i)}$$

The angular momentum for any permitted (stationary) orbit is

$$mvr = \frac{nh}{2\pi}$$

where n is any positive integer.

$$r = \frac{nh}{2\pi mv} \qquad \text{...(ii)}$$

From (i) and (ii), we get

$$\frac{KZe^2}{mv^2} = \frac{nh}{2\pi mv} \quad \therefore\ v = \frac{2\pi KZe^2}{nh}$$

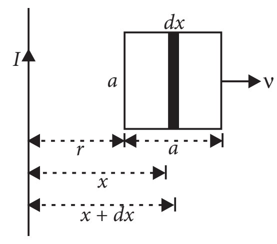
For hydrogen atom, $Z = 1$

$$\therefore\ v = \frac{2\pi Ke^2}{nh}$$

30. Consider a rectangular strip of small width dx of the square loop at a distance x from the wire as shown in figure.

Magnetic field due to current carrying wire at a distance x from the wire is

$$B = \frac{\mu_0 I}{2\pi x}$$



Area of the strip, $dA = adx$

$\therefore$ Magnetic flux linked with the strip is

$$d\phi = BdA = \frac{\mu_0 I}{2\pi x}(adx)$$

Total magnetic flux linked with the square loop is

$$\phi = \int_{x=r}^{x=r+a} d\phi = \int_{x=r}^{x=r+a} \frac{\mu_0 I}{2\pi x}(adx) = \frac{\mu_0 Ia}{2\pi}\int_{x=r}^{x=r+a} \frac{dx}{x}$$

$$= \frac{\mu_0 I a}{2\pi} |\ln x|_{x=r}^{x=r+a} = \frac{\mu_0 I a}{2\pi} \ln\left(\frac{r+a}{r}\right)$$

$$\phi = \frac{\mu_0 I a}{2\pi} \ln\left(\frac{a}{r}+1\right)$$

If M is the mutual inductance between the straight wire and the square loop, then, $MI = \phi$

or $MI = \frac{\mu_0 I a}{2\pi} \ln\left(\frac{a}{r}+1\right)$ $\therefore$ $M = \frac{\mu_0 a}{2\pi} \ln\left(\frac{a}{r}+1\right)$

31. Given $SS_2 - SS_1 = \frac{\lambda}{4}$

Now path difference between the two waves from slits S_1 and S_2 on reaching point P on screen is

$\Delta x = (SS_2 + S_2P) - (SS_1 + S_1P)$

or $\Delta x = (SS_2 - SS_1) + (S_2P - S_1P)$ or $\Delta x = \frac{\lambda}{4} + \frac{yd}{D}$

(i) For constructive interference at point P, path difference

$$\Delta x = n\lambda \quad \text{or} \quad \frac{\lambda}{4} + \frac{yd}{D} = n\lambda$$

or $\frac{yd}{D} = \left(n - \frac{1}{4}\right)\lambda$ ...(i)

where $n = 0, 1, 2, 3, ...$

(ii) For destructive interference at point P, path difference

$$\Delta x = (2n-1)\frac{\lambda}{2} \quad \text{or} \quad \frac{\lambda}{4} + \frac{yd}{D} = (2n-1)\frac{\lambda}{2}$$

or $\frac{yd}{D} = \left(2n - 1 - \frac{1}{2}\right)\frac{\lambda}{2} = (4n-3)\frac{\lambda}{4}$ ...(ii)

where $n = 1, 2, 3, 4, ...$

For central bright fringe, putting $n = 0$ in equation (i), we get

$$\frac{yd}{D} = -\frac{\lambda}{4} \quad \text{or} \quad y = \frac{-\lambda D}{4d}$$

The –ve sign indicates that central bright fringe will be observed below centre O of screen, at distance $\frac{\lambda d}{4d}$ below it.

Given for $\lambda_1 = 6000$ Å, fringe width $\beta_1 = 0.8$ mm, then for $\lambda_2 = 7500$Å, fring width $\beta_2 = ?$

Also, $d_2 = 2d_1$

So, $\frac{\beta_2}{\beta_1} = \frac{\lambda_2 D/d_2}{\lambda_1 D/d_1} = \frac{\lambda_2}{\lambda_1} \times \frac{d_1}{d_2}$

or $\beta_2 = \frac{7500}{6000} \times \frac{d_1}{2d_1} \times 0.8$ or $\beta_2 = 0.5$ mm

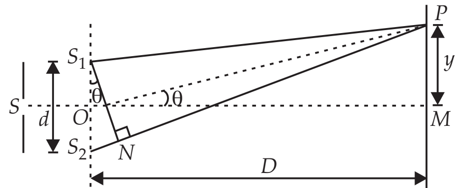
OR

(a) Coherent sources are those which have exactly the same frequency and are in the same phase or have a constant difference in phase.

Conditions : (i) The sources should be monochromatic and originating from common single source.

(ii) The amplitudes of the waves should be equal.

(b) Expression for fringe width : Let S_1 and S_2 be two coherent sources separated by a distance d. Let the distance of the screen from the coherent sources be D. Let M be the foot of the perpendicular drawn from O, the midpoint of S_1 and S_2 on the screen. Obviously point M is equidistant from S_1 and S_2. Therefore the path difference between the two waves at point M is zero. Thus the point M has the maximum intensity. Consider a point P on the screen at a distance y from M. Draw S_1N perpendicular from S_1 on S_2P.



The path difference between two waves reaching at P from S_1 and S_2 is $\Delta = S_2P - S_1P \approx S_2N$

As $D >> d$, therefore $\angle S_2S_1N = \theta$ is very small

$\therefore$ $\angle S_2S_1N = \angle MOP = \theta$

In ΔS_1S_2N, $\sin\theta = \frac{S_2N}{S_1S_2}$

In ΔMOP, $\tan\theta = \frac{MP}{OM}$

As θ is very small

$\therefore$ $\sin\theta = \theta = \tan\theta$

$\therefore$ $\frac{S_2N}{S_1S_2} = \frac{MP}{OM}$ $\therefore$ $S_2N = S_1S_2\frac{MP}{OM} = d \cdot \frac{y}{D}$

$\therefore$ Path difference $\Delta = S_2P - S_1P = S_2N = \frac{yd}{D}$

(i) Positions of bright fringes (or maxima) : For bright fringe or maximum intensity at P, the path difference must be an integral multiple of wavelength (λ) of light used. *i.e.*, $\Delta = n\lambda$

$\therefore$ $\frac{yd}{D} = n\lambda, n = 0, 1, 2, 3, ...$

$\therefore$ $y = \frac{nD\lambda}{d}$

This equation gives the distance of n^{th} bright fringe from the point M. Therefore writing y_n for y, we get

$$y_n = \frac{nD\lambda}{d}$$

(ii) Position of dark fringes (or minima) : For dark fringe or minimum intensity at P, the path difference must be an odd number multiple of half wavelength

i.e. $\Delta = (2n-1)\frac{\lambda}{2}$

$\therefore \quad \frac{y \cdot d}{D} = (2n-1)\frac{\lambda}{2}$ where $n = 1, 2, 3, ...$

or $\quad y = \frac{(2n-1)\lambda D}{2d} = \left(n - \frac{1}{2}\right)\frac{\Delta\lambda}{d}$

This equation gives the distance of n^{th} dark fringe from point M. Therefore writing y_n for y, we get

$$y_n = \left(n - \frac{1}{2}\right)\frac{D\lambda}{d}$$

(iii) Fringe width : The distance between any two consecutive bright fringes or any two consecutive dark fringes is called the fringe width. It is denoted by β.

For bright fringes : If y_{n+1} and y_n denote the distances of two consecutive bright fringes from M, then we have

$$y_{n+1} = (n+1)\frac{D\lambda}{d} \text{ and } y_n = \frac{nD\lambda}{d}$$

$\therefore \quad$ Fringe width,

$$\beta = y_{n+1} - y_n = (n+1)\frac{D\lambda}{d} - \frac{nD\lambda}{d} = \frac{D\lambda}{d}$$

For dark fringes : If y_{n+1} and y_n are the distances of two consecutive dark fringes from M, then we have

$$y_{n+1} = \left(n + \frac{1}{2}\right)\frac{D\lambda}{d}, \quad y_n = \left(n - \frac{1}{2}\right)\frac{D\lambda}{d}$$

$\therefore \quad$ Fringe width,

$$\beta = y_{n+1} - y_n = \left(n + \frac{1}{2}\right)\frac{D\lambda}{d} - \left(n - \frac{1}{2}\right)\frac{D\lambda}{d}$$

$$= \frac{D\lambda}{d}\left(n + \frac{1}{2} - n + \frac{1}{2}\right) = \frac{D\lambda}{d}$$

Thus, fringe width is the same for bright and dark fringes and is equal to

$$\beta = \frac{D\lambda}{d}$$

32. (a) $V = V_m \sin \omega t$, $i = i_m \sin(\omega t + \phi)$

and instantaneous power, $P = Vi$

$= V_m \sin \omega t . i_0 \sin(\omega t + \phi) = V_m i_m \sin \omega t \sin(\omega t + \phi)$

$= \frac{1}{2} V_m i_m 2 \sin \omega t . \sin(\omega t + \phi)$

From trignometric formula,

$2 \sin A \sin B = \cos(A - B) - \cos(A + B)$

$\therefore$ Instantaneous power, $P = \frac{1}{2} V_m i_m [\cos(\omega t + \phi - \omega t) - \cos(\omega t + \phi + \omega t)]$

$P = \frac{1}{2} V_m i_m [\cos\phi - \cos(2\omega t + \phi)] \quad ...(i)$

Average power for complete cycle

$$\bar{P} = \frac{1}{2} V_m i_m [\cos\phi - \overline{\cos(2\omega t + \phi)}]$$

For a complete cycle, $\overline{\cos(2\omega t + \phi)} = 0$

$\therefore \quad$ Average power,

$$\bar{P} = \frac{1}{2} V_m i_m \cos\phi = \frac{V_0}{\sqrt{2}} \frac{i_0}{\sqrt{2}} \cos\phi = V_{rms} i_{rms} \cos\phi$$

(b) Given, $L = 1.00 \text{ mH} = 1 \times 10^{-3}$ H,

$C = 1.00 \text{ nF} = 1 \times 10^{-9}$ F

$R = 100\ \Omega$, $E_0 = 100$ V

$$I_0 = \frac{E_0}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}} = \frac{E_0}{Z} \quad \left\{\begin{array}{l}\text{At resonance } \omega L = \frac{1}{\omega C} \\ \text{Hence } \quad Z = R\end{array}\right\}$$

$$\therefore \ I_0 = \frac{V}{R} = \frac{100}{100}, I_0 = 1 \text{ A}$$

$$I_v = \frac{I_0}{\sqrt{2}} = \frac{1}{\sqrt{2}} = \frac{\sqrt{2}}{2} = \frac{1.414}{2} = 0.707 \text{ A}$$

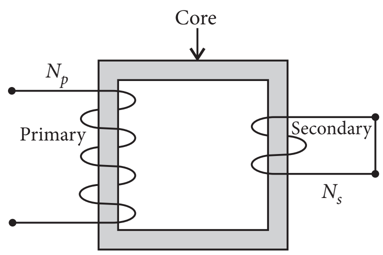
$I_v = 0.707$ A

$$Q = \frac{1}{R}\sqrt{\frac{L}{C}} = \frac{1}{100}\sqrt{\frac{1.0 \times 10^{-3}}{1.0 \times 10^{-9}}} = \frac{1}{100} \times 10^3 = 10$$

$Q = 10$

OR

(a) Step down transformer (or transformer) :



Principle : When the current flowing through the primary coil changes, an emf is induced in the secondary coil due to the change in magnetic flux linked with it *i.e.*, it works on the principle of mutual induction.

There are number of energy losses in a transformer.

(i) Copper losses due to Joule's heating produced across the resistances of primary and secondary coils. It can be reduced by using copper wires.

(ii) Hysteresis losses due to repeated magnetization and demagnetization of the core of transformer. It is minimized by using soft iron core, as area of hysteresis loop for soft iron is small and hence energy loss also becomes small.

(iii) Iron losses due to eddy currents produced in soft iron core. It is minimized by using laminated iron core.

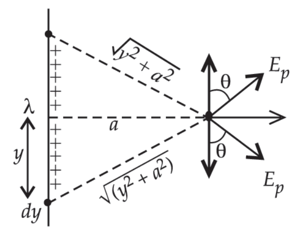
(iv) Flux losses due to flux leakage or incomplete flux linkage and can be minimised by proper coupling of primary and secondary coils.

(b) Power required, $P = 1200\text{ kW} = 1200 \times 10^3\text{ W}$
Total resistance of two wire lines, $R = 2 \times 20 \times 0.5 = 20\ \Omega$
$E_v = 4000$ volt
As, $P = E_v I_v$ $\therefore$ $1200 \times 10^3 = 4000 \times I_v$

$$\Rightarrow \ I_v = \frac{1200 \times 10^3}{4000} = 300\text{ A}$$

where I_v is the rms value of current.
Line power loss in the form of heat is,
$= (I_p)^2 \times$ Resistance of line wire
$= (300)^2 \times 20 = 1800$ kW

33. (a) Consider a point P, a unit away from the long charged wire.



Electric field due to element dy,

$$dE_p = \frac{Q}{4\pi\varepsilon_0 r^2}$$

$Q = \lambda dy$
$r^2 = y^2 + a^2$

$$\Rightarrow dE_p = \frac{\lambda dy}{4\pi\varepsilon_0 (y^2 + a^2)} \quad \Rightarrow \ E_p = \int_{-\infty}^{\infty} dE_p$$

Vertical components cancel out and horizontal components are added due to symmetry.

$$\Rightarrow \ E_p = \int_0^{\infty} \frac{2\lambda dy}{4\pi\varepsilon_0 (y^2 + a^2)} \times (\cos\theta)$$

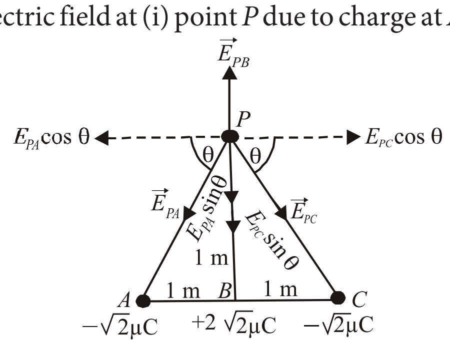
$$= \frac{2}{4\pi\varepsilon_0} \int_0^{\infty} \frac{\lambda dy}{y^2 + a^2} \times \frac{y}{\sqrt{y^2 + a^2}}$$

$$= \frac{2}{4\pi\varepsilon_0} \int_0^{\infty} \frac{\lambda y dy}{(y^2 + a^2)^{3/2}}$$

Take $y^2 + a^2 = x$ $\quad \Rightarrow \quad 2ydy = dx$
Taking proper limits

$$E_p = \frac{\lambda}{4\pi\varepsilon_0} \int_{a^2}^{\infty} \frac{dx}{x^{3/2}} \Rightarrow \left[\frac{-2\lambda}{4\pi\varepsilon_0} \frac{1}{\sqrt{x}}\right]_{a^2}^{\infty} = \frac{\lambda}{2\pi\varepsilon_0 a}$$

(b) Electric field at (i) point P due to charge at A or C is



$$E_{PA} = E_{PC} = 9 \times 10^9 \times \frac{\sqrt{2} \times 10^{-6}}{(\sqrt{2})^2} = \frac{9\sqrt{2}}{2} \times 10^3\text{ N/C}$$

(ii) Point P due to charge at B is

$$E_{PB} = 9 \times 10^9 \times \frac{2\sqrt{2} \times 10^{-6}}{1^2} = 18\sqrt{2} \times 10^3\text{ N/C}$$

Horizontal component of net electric field at point P is
$E_X = E_{PC}\cos\theta - E_{PA}\cos\theta = 0$
Vertical component of net electric field at point P is
$E_Y = E_{PB} - E_{PA}\sin\theta - E_{PC}\sin\theta$

$$= \left(18\sqrt{2} - \frac{9\sqrt{2}}{2} \times \frac{1}{\sqrt{2}} - \frac{9\sqrt{2}}{2} \times \frac{1}{\sqrt{2}}\right) \times 10^{-3}\text{ N/C}$$

(as, $\theta = 45°$)

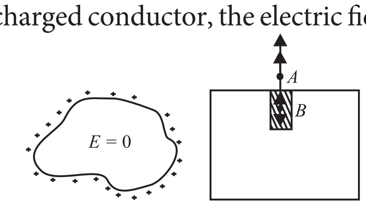
$= (18\sqrt{2} - 4.5 - 4.5) \times 10^{-3}$ N/C
$= 16.45 \times 10^{-3} = 1.645 \times 10^{-2}$ N/C
So resultant electric field at point P is

$$E = \sqrt{E_X^2 + E_Y^2} = E_Y \ \text{ or } E = 1.645 \times 10^{-2}\text{ N/C}$$

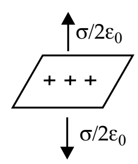
directed along vertical, *i.e.*, along PB.

OR

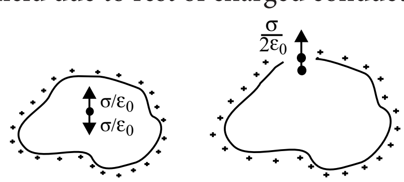
(a) Inside a charged conductor, the electric field is zero.



But a uniformly charged flat surface provide an electric field $\dfrac{\sigma}{2\varepsilon_0}$ normal to its plane.



If we consider a small flat part on the surface of charged conductor, it certainly provides an electric field $\dfrac{\sigma}{2\varepsilon_0}$ inside the conductor, which is nullified by an equal field due to rest of charged conductor.



Now if a hole is made in charged conductor, the field due to small flat part is absent but the field due to rest of charged conductor is present, *i.e.*, equal to $\dfrac{\sigma}{2\varepsilon_0}\hat{n}$.

(b) According to Gauss's theorem,

$$\Rightarrow \ \oint E.dS = \frac{Q_{in}}{\varepsilon_0} \ \Rightarrow \ E.4\pi x^2 = \frac{Q}{\varepsilon_0} \quad \text{or} \ E = \frac{Q}{4\pi\varepsilon_0 x^2}$$

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