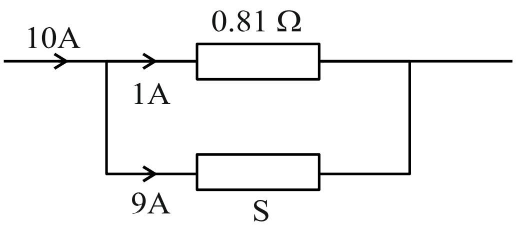
BK BIRLA CENTRE FOR EDUCATION

SARALA BIRLA GROUP OF SCHOOLS
SENIOR SECONDARY CO-ED DAY CUM BOYS' RESIDENTIAL SCHOOL

MID-TERM EXAMINATION 2023-24

Class : XII — Duration: **3 Hrs**
Date : 21/10/2023 — **MARKING SCHEME** — Max. Marks: **70**

1. (a) Charge, which is a fraction of charge on an electron, is not possible **1**
2. (a) Zero **1**
3. (c) 2 mC **1**
4. (c) Electric current **1**
5. (b) Parallel currents attract and anti-parallel currents repel. **1**
6. (b) **1**



$9 \times S = 1 \times 0.81\ \Omega$

$S = \frac{0.81}{9} = 0.09\ \Omega$

7. (a) decreases 1
8. (a) reduction of current 1
9. (b) increase 1
10. (c)2 1
11. (a) perpendicular to E and B and out of the plane of the paper 1
12. (d) Both electric and magnetic field vectors are parallel to each other 1
13. (b) 1
14. (c) 1
15. (c) 1
16. (b) 1

17. The charge of the 1st and 2nd spheres is $2X10^{-7}$ C and $3X10^{-7}$C
The distance r is = 30 cm = 0.3m
The electrostatic force that exists between the spheres can be denoted as 1
$F= Kq_1q_2/r^2 = 6X10^{-3}$ N.
A repulsive force will exist between the charges as they are of similar nature. 1

18. (a) As

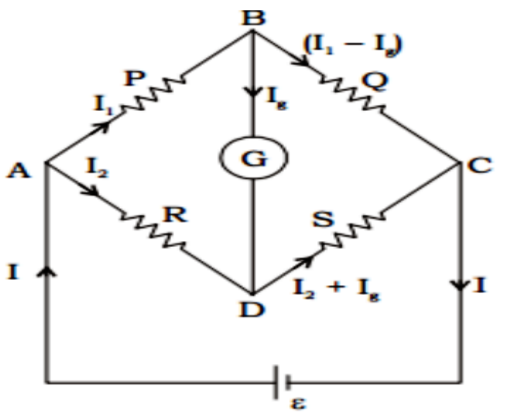
$$E = -\frac{\Delta V}{\Delta r}$$

If E =0, at a given point, then

$\frac{\Delta V}{\Delta r} = 0$ i.e., V = 0 or constant at that point. **[1 mark for correct explanation]**

(b) At mid-point P in Fig I, E is zero, but V is non-zero.
At mid-point P in Fig II, E is non-zero, but V adds up to zero. **[0.5 mark for each point]**

19.



Using Kirchoff's seconds law to the loop ABDA,
we get I1P - IgG - I2R = 0: G is the galvanometer resistance.
Applying Kirchoff's law to the loop ABDA, we get (I1 - Ig)Q - (I2 - Ig)S - GIg = 0 1
When the bridge is balanced Ig = 0 Then, the equations can be written as, I_1 P - I_2R = 0 or $I_1P = I_2R$ ....(1) $I_1Q - I_2S = 0$ or $I_1Q = I_2S$ ....(2) On dividing equation (1) by (2), we get P/Q = R/S, which is the balanced condition of a Wheatstone bridge. 1

20.

(a) As $\chi_m = \frac{I}{H}$

Slope of the line gives magnetic susceptibilities. 1
For magnetic material B, it is giving higher +ve value.
So material is 'ferromagnetic'.
For magnetic material A, it is giving lesser +ve value than 'B'.
So material is 'paramagnetic'.
(b) Larger susceptibility is due to characteristic 'domain structure'. More number of mag¬netic moments get aligned in the direction of magnetising field in comparision to that for paramagnetic materials for the same value of magnetising field. 1

OR

A - diamagnetic ½
B- paramagnetic ½
The magnetic susceptibility of A is small negative and that of B is small positive. ½+½

21. (a) Infrared (b) Ultraviolet **(½ + ½)**
Any one method of the production of each one **(½ + ½)**

22.

Consider an electric dipole consisting of charges + q and – q and of length 2a placed in a uniform electric field E→ making an angle θ with it. It has a dipole moment of magnitude,

$p = q \times 2a$

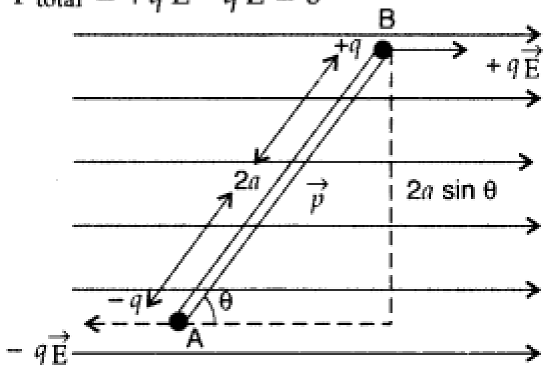
Force exerted on charge $+q$ by field,

$\vec{E} = q\vec{E}$ (along $\vec{E}$)

Force exerted on charge $-q$ by field,

$\vec{E} = q\vec{E}$ (opposite to $\vec{E}$)

$\therefore \quad \vec{F}_{total} = +q\vec{E} - q\vec{E} = 0$



1

Hence the net translating force on a dipole in a uniform electric field is zero. But the two equal and opposite forces act at different points of the dipole. They form a couple which exerts a torque.

Torque = Either force × Perpendicular distance between the two forces

x = qE × 2a sin θ 1

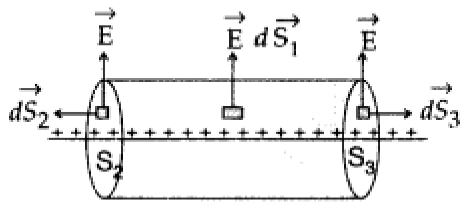
X = pE sin θ [∵ p = q × 2a; p is dipole moment]

As the direction of torque $\vec{\tau}$ is perpendicular to $\vec{p}$ and $\vec{E}$, so we can write $\vec{\tau} = \vec{p} \times E$ 1

OR

Gauss's law in electrostatics : It states that "the total electric flux over the surface S in vaccum is 1ε0 times the total charge (q)."

Contained in side S $\quad \therefore \phi_E = \oint_S \vec{E}.d\vec{S} = \frac{q}{\varepsilon_0}$



1

Electric field due to an infinitely long straight wire : Consider an infinitely long straight line charge having linear charge density X to determine its electric field at distance r. Consider a cylindrical Gaussian surface of radius r and length l coaxial with the charge. By symmetry, the electric field E has same magnitude at each point of the curved surface S_1 and is directed radially outward. Total flux through the cylindrical surface,

$$\oint \vec{E}.d\vec{S} = \oint_{s_1} \vec{E}.d\vec{S_1} + \oint_{s_2} \vec{E}.d\vec{S_2} + \oint_{s_3} \vec{E}.d\vec{S_3}$$

$$= \oint_{s_1} EdS_1 \cos 0° + \oint_{s_2} EdS_2 \cos 90° + \oint_{s_3} EdS_3 \cos 90°$$

$$= E\oint dS_1 = E \times 2\pi rl$$

As λ is the charge per unit length and l is the length of the wire, so charge enclosed is,

$q = \lambda l$

By Gauss's theorem :

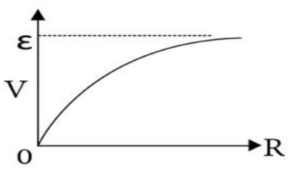
$$\oint \vec{E}.d\vec{S_1} = \frac{q}{\varepsilon_0} \qquad \Rightarrow E \times 2\pi rl = \frac{\lambda l}{\varepsilon_0}$$

$$\therefore \quad E = \frac{\lambda}{2\pi\varepsilon_0 r}$$

2

23.

Circuit diagram 1+1



Maximum current drawn will be at R=0 1

24. (a) downwards in the plane of the paper (or) perpendicular to B and v, downwards

(b) (i) proton moving with a velocity v. No deviation **(0.5 marks)**

qE = qvB

does not depend on mass and the charge cancels out. So the proton will also pass undeviated. **(0.5 marks for correct explanation)**

(i) electron moving with a velocity v/2 The electron will deviate upwards. **(0.5 marks)**

Since velocity is halved, electric force > magnetic force **(0.5 marks for correct explanation)**

25. This is done by placing a small compass needle of known magnetic moment m and moment of inertia I and allowing it to oscillate in the magnetic field $\vec{B}$.

The torque on the needle is, $\vec{\tau} = \vec{M} \times \vec{B}$

In magnitude $\tau = mB \sin\theta$. Here τ is restoring torque and θ is the angle between m and B.

$\therefore$ In equilibrium, $I\alpha = -mB\sin\theta$ $[\tau = I\alpha]$

where [α is angular acceleration]

$$I\frac{d^2\theta}{dt^2} = -mB\sin\theta \Rightarrow I\frac{d^2\theta}{dt^2} = -mB\,\theta$$

$$\left[\alpha = \frac{d^2\theta}{dt^2}\right]$$

or $\frac{d^2\theta}{dt^2} = \frac{-mB}{I}\theta$

This represents a simple harmonic motion. The square of the angular frequency is $\omega^2 = \frac{mB}{I}$ and the time period is

$$\boxed{T = 2\pi\sqrt{\frac{I}{mB}}}$$

3

26.

$= 3.14 \times (0.12)^2 \text{ m}^2 = 4.5 \times 10^{-2} \text{ m}^2$

$E = -\frac{d\varphi}{dt} = -\frac{d}{dt}(BA) = -A\frac{dB}{dt} = -A \cdot \frac{B_2 - B_1}{t_2 - t_1}$

For $0 < t < 2s$

$E_1 = -4.5 \times 10^{-2} \times \left\{\frac{1-0}{2-0}\right\} = -2.25 \times 10^{-2}$ V

$\therefore I_1 = \frac{E_1}{R} = \frac{-2.25 \times 10^{-2}}{8.5}$ A $= -2.6 \times 10^{-3}$ A $= -2.6$ mA

For $2s < t < 4s$,

$E_2 = -4.5 \times 10^{-2} \times \left\{\frac{1-1}{4-2}\right\} = 0$

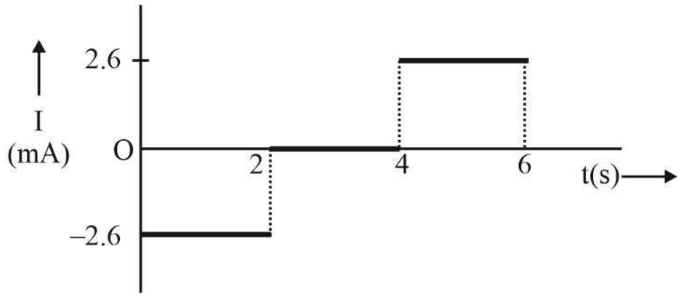
$\therefore I_2 = \frac{E_2}{R} = 0$

For $4s < t < 6s$,

$I_3 = -\frac{4.5 \times 10^{-2}}{8.5} \times \left\{\frac{0-1}{6-4}\right\}$A $= 2.6$ mA

2

	0<t<2s	2<t<4s	4<t<6s
E(V)	-0.023	0	+0.023
I(mA)	-2.6	0	+2.6



1

27. (a) $X_L = 2\pi f L$ ***(0.5 marks)***

$L = X_L / 2\pi f$

$L = 20/(2 \times 3.14 \times 100) = 0.032$ H ***(0.5 marks)***

(b) A battery is a source of direct current and thus f = 0 Hz. ***(0.5 marks)***

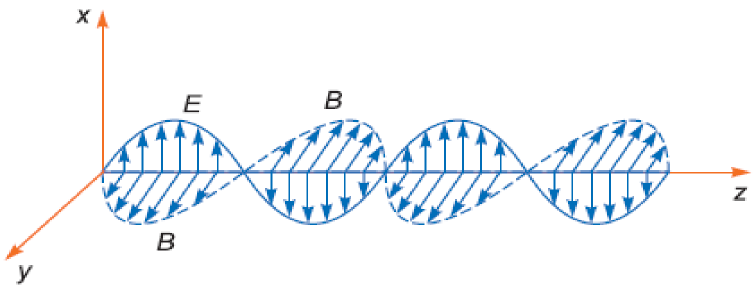
As $X_L = 2\pi fL$, the inductive reactance of the inductor becomes zero. ***(0.5 marks)***

(c)$P_{avg} = V_{rms}I_{rms}\cos\phi$ where ϕ is the phase difference between current and voltage in the circuit. Phase difference is 90° for pure inductive circuit. ***(0.5 marks)***

$\therefore P_{avg} = 0$ ***(0.5 marks)***

28. (a) An oscillating charge produces an oscillating electric field in space, which produces an oscillating magnetic field. The oscillating electric and magnetic fields regenerate each other, and this results in the production of em waves in space. 1

(b) Electric field is along x-axis and magnetic field is along y-axis. 2



29. (i) (d) (ii) (d) (iii) (b) (iv) (d) OR (iv) (b) **(1+1+1+1)**

30. (i) (a) (ii) (b) (iii) (c) (iv) (c) OR (iv) (b) **(1+1+1+1)**

31.

(a) V = 300 V C = 100 μF Energy = 1/2 CV^2 ***(0.5 marks)***

= 1/2 × 100 × 10^{-6} $(300)^2$ = 4.5 J ***(0.5 marks)***

(b) q = CV ***(0.5 marks)***

q = 100 × 10^{-6} × 300 = 0.03 C ***(0.5 marks)***

(c) Capacitance of a parallel plate capacitor C = $(\in_0 A)/d$ ***(0.5 marks)***

C = 100 μF d' = 2d ,

C' = (∈0 A)/d'

C' = $(\in_0 A)/2d$ = 100/2 = 50 μF

Hence, if the distance between the plates of the capacitor is increased two times the capacitance of the capacitor decreases by 1/2 ie becomes 50 μF. ***(0.5 marks)***

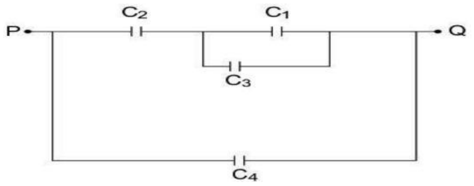
(d) The slope of the q vs V graph gives the capacitance of a parallel plate capacitor. When the space between the plates of a capacitor is filled with a substance of dielectric constant K, its capacitance increases K times. ***(0.5 marks)***

Greater the slope of the q vs V graph, the higher the capacitance. ***(0.5 marks)***

As line A has a greater slope it represents greater capacitance and corresponds to scenario ***(1 mark)***

OR

(a) The arrangement of capacitors is equivalent to:



C_1 and C_3 are in parallel. C_p = 6 + 6 = 12 μF

C_p and C_2 are in series ***(0.5 marks)***

$1/C_s$ = 1/12 + 1/6 = 1/12 + 2/12 = 3/12 C_s = 4 μF ***(0.5 marks)***

C_s and C_4 are in parallel C_{net} = 4 + 6 = 10 μF ***(1 mark)***

(b) We know that C = Q/V Charge on C_4 Q_4 = 10 x 6 = 60 μC ***(0.5 marks)***

Net capacitance of C_1 and C_3 = 6 + 6 = 12 μF Net capacitance of C_1, C_3 ,and C_2 is :

1/C = 1/12 + 1/6 = 3/12 = 1/4 C = 4 μF Net charge across C_1, and C_3 ,and C_2

Q = C V = 4 x 10 = 40 μC ***(0.5 marks)***

Since the charge in the series combination is the same,

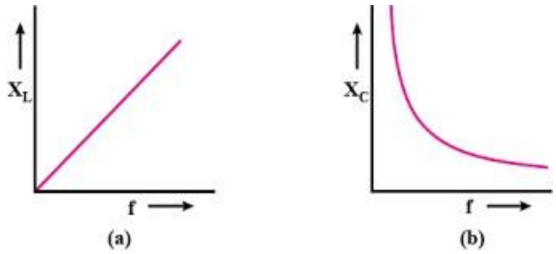
Net charge across C_1 and C_3 = 40 μC ***(0.5 marks)***

Potential across C_1 and C_3 = Q/C = 40/12 = 10/3 V Charge across C_1

$Q_1 = C_1$ × V = 6 x 10/3 = 20 μC ***(0.5 marks)***

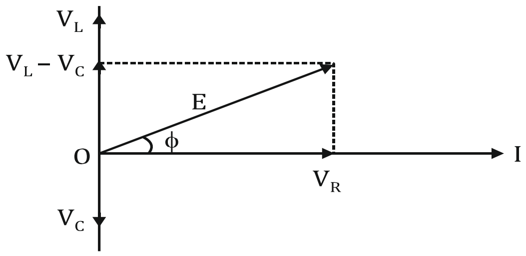
Ratio of charges across C_1 and C_4 Q_1/Q_4 = 20/60 = 1:3 ***(1 mark)***

32. (a)



(½ + ½)

(b)



1

(c)(i) In device X, Current lags behind the voltage by π /2, X is an inductor

In device Y, Current in phase with the applied voltage, Y is resistor **(½ + ½)**

(ii) We are given that

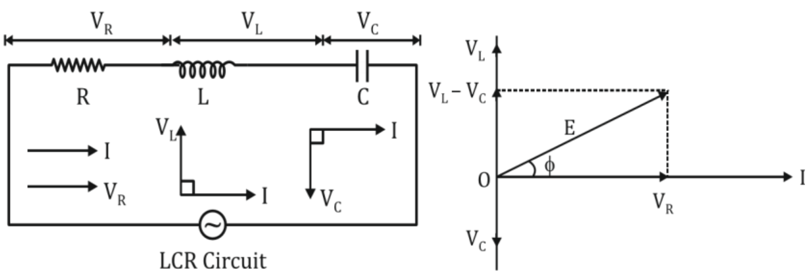
0.25=220/X_L, X_L =880Ω, Also 0.25=220/R, R = 880Ω **1**

For the series combination of X and Y,

Equivalent impedance Z = 880 √2 Ω , I= 0.177 A **1**

OR

a.



1

E = E_0 sinωt is applied to a series LCR circuit. Since all three of them are connected in series the current through them is same. But the voltage across each element has a different phase relation with current. The potential difference V_L, V_C and V_R across L, C and R at any instant is given by $V_L = IX_L$, $V_C = IX_C$ and $V_R = IR$, where I is the current at that instant.

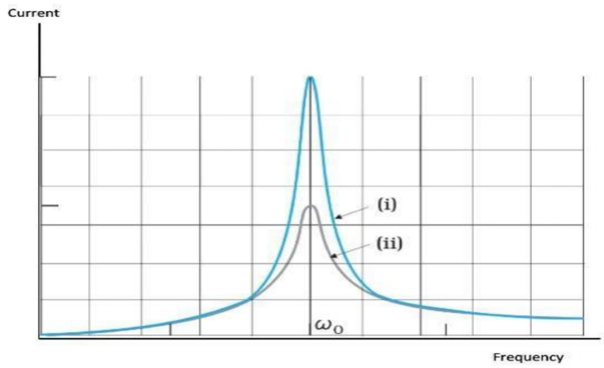
V_R is in phase with I. V_L leads I by 90° and V_C lags behind I by 90° so the phasor diagram will be as shown .Assuming $V_L > V_C$, the applied emf E which is equal to resultant of potential drop across R, L & C is given as

$$E^2 = I^2 [R^2 + (X_L - X_C)^2]$$

Or $I = \frac{E}{\sqrt{[R^2 + (X_L - X_C)2]}} = \frac{E}{Z}$, where Z is Impedance. **3**

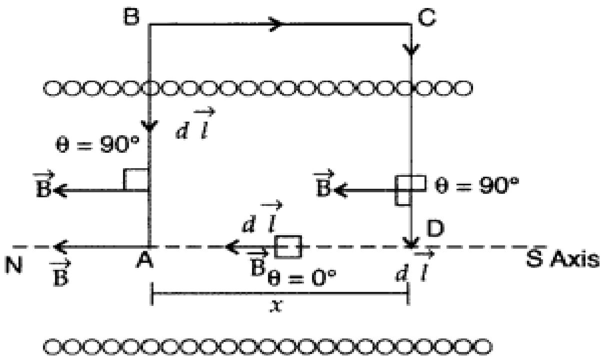
Emf leads current by a phase angle ϕ as $\tan\phi = \frac{VL - VC}{R} = \frac{XL - XC}{R}$

b. The curve (i) is for R_1 and the curve (ii) is for R_2 **1**



33.

(a) Magnetic field due to Solenoid Let length of solenoid = L
Total number of turns in solenoid = N
No. of turns per unit length = NL = n
ABCD is an Ampere's loop AB, DC are very large BC is in a region of B→ = 0
AD is a long axis Length of AD = x
Current in one turn = I0 2



Applying Ampere's circuital loop — | B .dl = μ_o I '

$$\oint \vec{B}.d\vec{l} = \mu_0 I$$

L.H.S.

$$= \int_A^B \vec{B}.d\vec{l} + \int_B^C \vec{B}.d\vec{l} + \int_C^D \vec{B}.d\vec{l} + \int_D^A \vec{B}.d\vec{l}$$

$$= 0 + 0 + 0 + \int_D^A \vec{B}.d\vec{l}$$

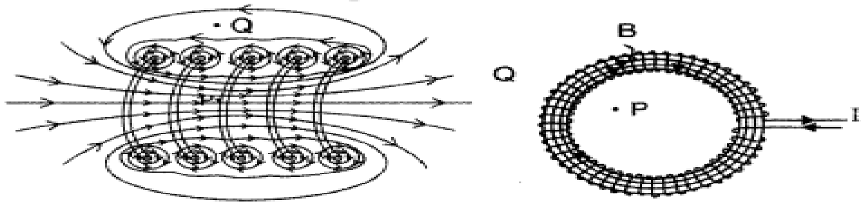
$$(\because \theta = 90°) \quad (\because \vec{B} = 0) \quad (\because \theta = 90°) \quad (\because \theta = 0°)$$

$$= \int_D^A \vec{B}.\, d\vec{l} = B\int_D^A dl \cos\theta \qquad ...[\because \cos\theta = 1$$

$$= B\int_D^A dl = B[l]_0^x = Bx$$

No. of turns in x length = nx,
Current in turns nx, I = nx I_0
According to Ampere's circuital law
Bx = μ_0 I => Bx = μ_0 nx I_0
∴ B = $\mu_0 n I_0$

(b) Magnetic field inside a given solenoid is made strong by putting a soft iron core inside it. It is strengthened by increasing the amount of current through it. 2



(a) Solenoid (b) Toroid

(c) Solenoid consists of a long wire wound in the form of a helix where the neighbouring turns are closely spaced, whereas, the toroid is a hollow circular ring on which a large number of turns of a wire is closely wound. 1

OR

Radius of circular coil = *R*
Number of turns on the coil = *N*
Current in the coil = *I*
Magnetic field at a point on its axis at distance *x* is given by the relation,

$$B = \frac{\mu_0 I R^2 N}{2\left(x^2 + R^2\right)^{\frac{3}{2}}}$$

Where,
μ_0 = Permeability of free space
(a) If the magnetic field at the centre of the coil is considered, then $x = 0$. 2

$$\therefore B = \frac{\mu_0 I R^2 N}{2R^3} = \frac{\mu_0 I N}{2R}$$

This is the familiar result for magnetic field at the centre of the coil.
(b) Radii of two parallel co-axial circular coils = *R* 3
Number of turns on each coil = *N*
Current in both coils = *I*
Distance between both the coils = *R*
Let us consider point Q at distance *d* from the centre.

Then, one coil is at a distance of $\frac{R}{2} + d$ from point Q.
∴ Magnetic field at point Q is given as:

$$B_1 = \frac{\mu_0 N I R^2}{2\left[\left(\frac{R}{2} + d\right)^2 + R^2\right]^{\frac{3}{2}}}$$

Also, the other coil is at a distance of $\frac{R}{2} - d$ from point Q.
∴ Magnetic field due to this coil is given as:

$$B_1 = \frac{\mu_0 N I R^2}{2\left[\left(\frac{R}{2} - d\right)^2 + R^2\right]^{\frac{3}{2}}}$$

Total magnetic field, $B = B_1 + B_2$

$$= \frac{\mu_0 I R^2}{2}\left[\left\{\left(\frac{R}{2}-d\right)^2 + R^2\right\}^{-\frac{3}{2}} + \left\{\left(\frac{R}{2}+d\right)^2 + R^2\right\}^{-\frac{3}{2}}\right]$$

$$= \frac{\mu_0 I R^2}{2}\left[\left\{\frac{5R^2}{4} + d^2 - Rd\right\}^{-\frac{3}{2}} + \left\{\frac{5R^2}{4} + d^2 + Rd\right\}^{-\frac{3}{2}}\right]$$

$$= \frac{\mu_0 I R^2}{2} \times \left(\frac{5R^2}{4}\right)^{-\frac{3}{2}}\left[\left(1 + \frac{4}{5}\frac{d^2}{R^2} - \frac{4}{5}\frac{d}{R}\right)^{-\frac{3}{2}} + \left(1 + \frac{4}{5}\frac{d^2}{R^2} + \frac{4}{5}\frac{d}{R}\right)^{-\frac{3}{2}}\right]$$

For d << R, neglecting the factor $\frac{d^2}{R^2}$, we get:

$$\approx \frac{\mu_0 I R^2}{2} \times \left(\frac{5R^2}{4}\right)^{-\frac{3}{2}} \times \left[\left(1 - \frac{4d}{5R}\right)^{-\frac{3}{2}} + \left(1 + \frac{4d}{5R}\right)^{-\frac{3}{2}}\right]$$

$$\approx \frac{\mu_0 I R^2 N}{2R^3} \times \left(\frac{4}{5}\right)^{-\frac{3}{2}} \times \left[1 - \frac{6d}{5R} + 1\frac{6d}{5R}\right]$$

$$B = \left(\frac{4}{5}\right)^{\frac{3}{2}} \frac{\mu_0 I N}{R} = 0.72\left(\frac{\mu_0 I N}{R}\right)$$

Hence, it is proved that the field on the axis around the mid-point between the coils is uniform.

--------------------------BEST OF LUCK------------------------------