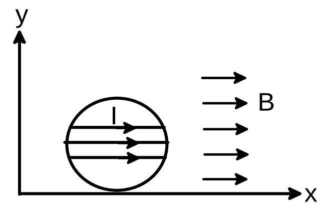
PART III: PARAGRAPH TYPE

This section contains **3 multiple choice questions** relating to ONE paragraph. Each question has four choices (A), (B), (C) and (D) out of which **ONLY ONE is correct.** **(+4, –1)**

PARAGRAPH – I

A person wants to roll a solid non-conducting spherical ball of mass m and radius r on a surface whose coefficient of static friction is μ. He placed the ball on the surface wrapped with n turns of closely packed conducting coils of negligible mass at the diameter. By some arrangement he makes a current I to pass through the coils either in the clockwise direction or in the anti-clockwise direction. A constant horizontal magnetic field $\vec{B}$ is present throughout the space as shown in the figure. Assume μ is sufficient enough to ensure pure rolling motion. Based on the facts provided, answer the following questions.



13. The maximum torque in the coil is

(a) $-\left(\pi n I r^2 B\right)\hat{k}$ (b) $\left(\pi n I r^2 B\right)\hat{j}$ (c) $-\left(\pi n I r^2 B\right)\hat{j}$ (d) $\left(\pi n I r^2 B\right)\hat{k}$

14. Angular acceleration of the ball after it has rotated through an angle $\theta\left(\theta < 180^\circ\right)$, is

(a) $\frac{5}{7}\left(\frac{\pi n I B}{m}\right)\cos\theta$ (b) $\frac{2}{5}\left(\frac{\pi n I B}{m}\right)\cos\theta$ (c) $\frac{7}{5}\left(\frac{\pi n I B}{m}\right)\cos\theta$ (d) $\frac{5}{2}\left(\frac{\pi n I B}{m}\right)\cos\theta$

15. The angular velocity of the ball when it has rotated through an angle θ is $\left(\theta < 180^\circ\right)$, is

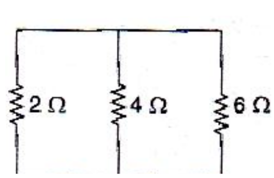
(a) $\sqrt{\frac{10}{7}\left(\frac{\pi n I B}{m}\right)\sin\theta}$ (b) $\sqrt{\frac{5}{14}\left(\frac{\pi n I B}{m}\right)\sin\theta}$

(c) $\sqrt{\frac{5}{14}\left(\frac{\pi n I B}{m}\right)\cos\theta}$ (d) $\sqrt{\frac{5}{7}\left(\frac{\pi n I B}{m}\right)\sin\theta}$

PART IV: Integer Answer Type

This section contains **4 questions.** The answer to each question is a **single digit integer**, ranging from 0 to 9 (both inclusive) **(+4,0)**

16. In which branch of the circuit shown in figure, an 11 V battery be inserted so that it dissipates minimum power. What will be the current, in ampere, through the 2Ω resistance for this position of the battery.

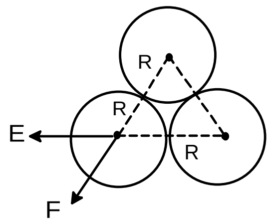


PAPER – II (SOLUTION)

1. **(d)**

$$F = \frac{1}{4\pi\varepsilon_0}\frac{(2q)^2}{(2R)^2} = \frac{q^2}{4\pi\varepsilon_0 R^2} \qquad F_{net} = \sqrt{F^2 + 2F^2\cos 60}$$

$$\Rightarrow F_{net} = \sqrt{3}F = \sqrt{3}\frac{q^2}{4\pi\varepsilon R^2}$$



$$\Rightarrow F_{net} = \frac{\sqrt{3}q^2}{4\pi\varepsilon_0 R^2}$$

2. **(a)**

The ratio $\frac{AC}{CB}$ will remain uncharged.

3. **(c)**

$$R_{max} = \frac{\rho \ell_{max}}{A_{min}} \qquad \Rightarrow R_{max} = \frac{\rho(3\ell_0)}{\ell_0^2}$$

$$\Rightarrow \ell_0 = \text{Minimum length} \qquad R_{min} = \frac{\rho \ell_{min}}{A_{max}}$$

$$\Rightarrow R_{min} = \frac{\rho(\ell_0)}{3\ell_0^2} \qquad \Rightarrow \frac{R_{max}}{R_{min}} = 9$$

4. **(c)**

$$B_{centre} = \frac{\mu_0 I}{2a}, B_{axis} = \frac{\mu_0 I a^2}{2\left(a^2 + 9a^2\right)^{3/2}}$$

So, the desired ratio is $\dfrac{\frac{\mu_0 I}{2a}}{\frac{\mu I a^2}{2\left(10a^2\right)^{3/2}}} = (10)^{3/2} = 10\sqrt{10}$

5. **(d)**

Magnetic force on a current carrying loop in uniform magnetic field is zero.

6. **(c)**

The width $(b-a)$ is having N turns. So number of turns per unit length is $n = \frac{N}{b-a}$ n=fN

Consider a circular coil of radius x, radial thickness dx and if dN is the number of turns in it, then

$$dN = \frac{Ndx}{b-a}$$

If dB is the field due to this element at the centre, then

$$dB = \frac{\mu_0 NI\,dx}{2(b-a)x}$$

$$\Rightarrow B = \int_a^b dB = \frac{\mu_0 NI}{2(b-a)} \log_e\left(\frac{b}{a}\right)$$

7. (b)

Force per unit length between two wires carrying currents I_1 and I_2 at distance r is given by

$$\frac{F}{\ell} = \frac{\mu_0}{2\pi}\frac{I_1 I_2}{r}$$

Here, $I = I_2 = I$ and $r = b$

$$\Rightarrow \frac{F}{\ell} = \frac{\mu_0 I^2}{2\pi b}$$

8. (d)

$$I = \frac{\xi}{R_{eq}} = \frac{B\ell v}{\left(\frac{R_{Half}}{2}\right)} \text{ where } \quad R_{Half} = \pi(2)\left(\frac{2}{\pi}\right) = 4\Omega$$

$$\Rightarrow I = \frac{(2)(4)(2)}{2} = 8A$$

So, if F_m is the magnetic force, then

$$F_m = BI\ell \qquad \Rightarrow F_m = (2)(8)(4) = 64\,N$$

9. (a,c)

$$I_g = 10mA = 0.01A \qquad V_A - V_B = (I - I_g)(0.1A) = I_g(9.9)$$

$$\Rightarrow I \times 0.1 = I_g \times 10 \qquad \Rightarrow I = \frac{0.01A \times 10}{0.1} = 1A$$

Similarly $(I' - I_g)(0.9) = I_g(9.1)$

$$\Rightarrow I'(0.9) = I_g(10) \qquad \Rightarrow I' = \frac{1}{9}A = 111mA$$

10. (b,c)

11. (a,b,c,d)

12. (b,c)

$$R = \sqrt{\frac{L}{C}} \qquad \Rightarrow R^2 = \frac{L}{C}$$

$$\Rightarrow RC = \frac{L}{R} \qquad \Rightarrow \tau_c = \tau_L = \tau(\text{say})$$

Since $I_L = I_0\left(1 - e^{\frac{1}{\tau_L}}\right) = \frac{V}{R}\left(1 - e^{-\frac{1}{\tau}}\right)$ and

PAPER – II

PHYSICS

1.	D	2.	A	3.	C	4.	C	5.	D	6.	C	7.	B
8.	D	9.	A, C	10.	B, C	11.	A, B, C, D			12.	B, C	13.	A
14.	A	15.	A	16.	(1)	17.	(2)	18.	(8)	19.	(2)		

20. $a \to (P); b \to (P, Q, S); c \to (Q); d \to (Q, R)$

CHEMISTRY

1.	(B)	2.	(C)	3.	(B)	4.	(A)	5.	(C)
6.	(B)	7.	(B)	8.	(B)	9.	(A,B,C,D)	10.	(B, C, D)
11.	(A, C, D)	12.	(A, D)	13.	(C)	14.	(D)	15.	(A)
16.	(1)	17.	(1)	18.	(1)	19.	(4)		

20. (A) – (R), (S), (B) – (R), (C) – (P), (Q), (D) – (R), (S)

MATHS

1.	C	2.	D	3.	C	4.	C	5.	A
6.	C	7.	B	8.	C	9.	A,B,C	10.	A,B,C,D
11.	A,B,C	12.	B,C	13.	C	14.	C	15.	D
16.	1210	17.	1	18.	6	19.	4		

20. $A \to R; B \to S; C \to P, S; D \to Q, R$