BIRLA INSTITUTE OF TECHNOLOGY AND SCIENCE, PILANI
Second Semester 2022-23
COMPREHENSIVE EXAMINATION

DATE 09.05.2023	**PHY F212**	**Electromagnetic Theory I**
PART –I (Closed book)	**TIME: 90 min**	**Max Mark: 20×3 = 60M**

Q1. Q1. A point charge *q* and mass m is released from rest at a distance of 4R from the center of a conducting sphere of radius R, which is grounded to the earth by a wire. [Assume the sphere is static and ignore gravity]

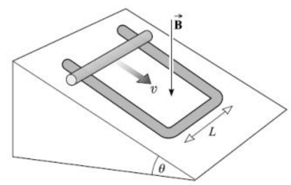
(a) What is the magnitude and direction of the force on the point charge?

(b) What is the kinetic energy of the point charge when it reaches a distance 2R from the center of the sphere?

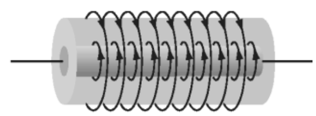
(c) How much charge flows through the wire when the point charge reaches 2R?

(d) What is the energy gain or loss when it reaches 2R? **[15M]**

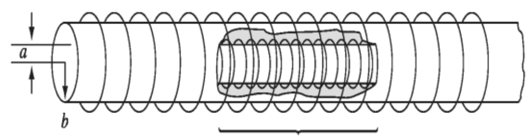
Q2. A metal bar of length *L*, mass *M* and resistance *R* slide without friction of a rectangular circuit composed of resistance wires on a inclined plane. There is a uniform vertical magnetic field ***B***. Find the terminal velocity of the bar (*i.e.*, the constant velocity it attains). **[15M]**



Q3. (a) Two long coaxial solenoids each carry current *I*, in opposite directions as shown in the figure. The inner solenoid (radius *a)* has n_1 turns per unit length, and the outer one (radius *b)* has n_2. Find **B** in: (i) inside the inner solenoid, (ii) between them, and (iii) outside both.

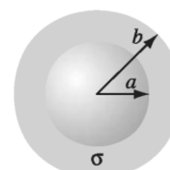


(b) A short solenoid (length *l* and radius *a*, with n_1 turns per unit length) lies on the axis of a very long solenoid (radius *b*, n_2 turns per unit length) as shown in Fig. Current *I* flows in the short solenoid. What is the flux ϕ through the long solenoid?



[10+10=20M]

Q4. Two concentric metal spherical shells of radii *a* and *b*, respectively, are separated by weakly conducting material of conductivity *σ*. What is the resistance between the shells? **[10M]**



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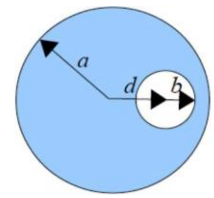
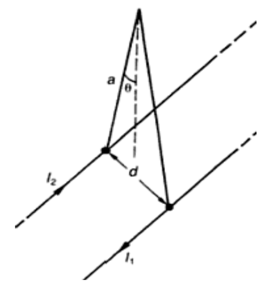
DATE 09.05.2023 **PHY F212** **Electromagnetic Theory I**

PART –II (Open book) **TIME: 90 min** **Max Mark: 60M**



Q1. (a) A cylindrical conductor of radius a has a hole of radius b bored parallel to, and centered a distance d from, the cylinder axis ($d + b < a$). The figure is showing the top view of the cylinder. The current density J_0 is uniform throughout the remaining metal of the cylinder and is parallel to the axis. Use Ampere's law to find the magnitude and direction of the magnetic-flux density in the hole. **[16M]**

*(**Hint:** Assume uniform current density J0 is flowing everywhere in the cylinder plus a uniform current density J_0 flowing in the negative z direction in the hole region. This method is called "superposition" method.)*



Q2. Two long parallel conducting wires carry currents $I_1 = 1\ A$ and $I_2 = 2\ A$ in opposite directions. They hang horizontally from pylon by pairs of insulating cables, each of length $a = 1\ m$, and are a distance $d\ (<< a)$ apart. The wires have mass m per unit length and the cable makes an angle θ to the vertical (see figure).

(a) Find the angle θ between the pylon and wire. [Assume $\tan\theta = \sin\theta$ as $d << a$]

(b) Calculate the magnetic field $\boldsymbol{B}$ at a point midway between the wires.

[10+6= 16M]

Q3. (a) A square loop of side $a = 1\ cm$ is placed at a distance $d = 5\ cm$ from a thin and long wire carrying a current $I = 5A$. Calculate the mutual inductance of the system.

(b) Consider a magnetic field given by $\boldsymbol{B} = B_0(t)$ (**k**) for $s < a$ and $\boldsymbol{B} = 0$ for $s > a$**.** Calculate the induced electric field $\boldsymbol{E}$ for both (i) $s < a$ *and* (ii) $s > a$**.**

(c) If the vector potential is given as $\boldsymbol{A} = A_0\, r \sin\theta\, \phi$, find the volume current density $\boldsymbol{J}$ **[9+10+9= 28M]**