INSTITUTIONAL-BASED (IB) UNIVERSITY EXAMINATIONS 2017/2018 ACADEMIC YEAR

2nd YEAR EXAMINATION FOR THE DEGREE OF BACHELOR OF EDUCATION (SCIENCE)

COURSE CODE (TITLE): SPH B202 (ELECTRICITY & MAGNETISM II)

END OF SEMESTER: II **DURATION: 2 HOURS**

DAY/TIME: MONDAY 15:00 – 17:00 PM **DATE: 15.04.2019 (LIB)**

- Answer **questions 1, 2 & 3** in Section A, and any other **two questions** from Section B.
- Each question must **start** from a fresh sheet of paper.
- Marks for each part of a question are indicated in brackets on the right side.

E&M II Set of constants (April, 2019)

Where necessary, use:

Permittivity constant	$\varepsilon_0 = 8.854 \times 10^{-12}\mathrm{N^{-1}m^{-2}C^2}$
Permeability of free space	$\mu_0 = 1.356 \times 10^{-6}\mathrm{m\,kg\,C^{-2}}$
Speed of light (in a vacuum)	$c = 2.998 \times 10^8\mathrm{ms^{-1}}$
Electron charge	$\lvert e\rvert = 1.602 \times 10^{-19}\mathrm{C}$
Electron mass	$m_e = 9.109 \times 10^{-31}\mathrm{kg}$
Proton mass	$m_p = 1.673 \times 10^{-27}\mathrm{kg}$

SECTION A (40 marks) – Compulsory

1. (a) Differentiate between paramagnetic and diamagnetic materials. (4)

   (b) Calculate the minimum work that must be done by an external force to bring a charge $q = 3\,\mu\text{C}$ from a great distance away (take $r = \infty$) to a point 0.5 m from a charge $Q = 20\,\mu\text{C}$. (6)

   (c) A 4.0-m-long circular coil of wire has diameter $d = 20\,\text{cm}$ and contains $N = 10000$ loops. If the coil produces an *emf* of 2.5 V when the current in it changes from 3 A to -2 A in 10 seconds, what is the inductance, L of the coil? (7)

2. A charged air-filled capacitor stores 3×10^{-8} J of energy. Without changing the charge on the plates, it is now filled with a dielectric of dielectric constant, $\kappa = 5$.

   (a) Does the capacitance increase or decrease when the capacitor is filled with the dielectric? By what factor? (2)

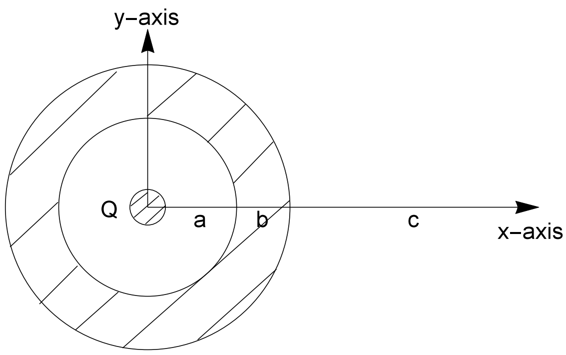
   (b) Does the potential difference across the capacitor increase or decrease and by what factor? (2)

   (c) By considering the change in energy stored in the capacitor, find how much work must be done to now remove the dielectric from the capacitor, again keeping the charge on the capacitor plates fixed. (6)

3. The figure below shows two concentric conducting spheres. The larger sphere is hollow and has a net charge of zero. Its inside diameter is 50 cm and its outer diameter is 80 cm. The smaller sphere has a charge of $Q = 4 \times 10^{-9}\,\text{C}$ and a diameter of 10 cm. (Take $k = 9 \times 10^{9}\,\text{Nm}^2/\text{C}^2$; $\epsilon_0 = 8.85 \times 10^{-12}\,\text{C}^2/(\text{Nm}^2)$.)

   (a) What is the electric field (magnitude and direction) for a point at $x = 20\,\text{cm}$, near "a" on the diagram above? (4)

   (b) What is the electric field (magnitude and direction) for a point at $x = 35\,\text{cm}$, inside the larger sphere near "b" on the diagram above? (3)

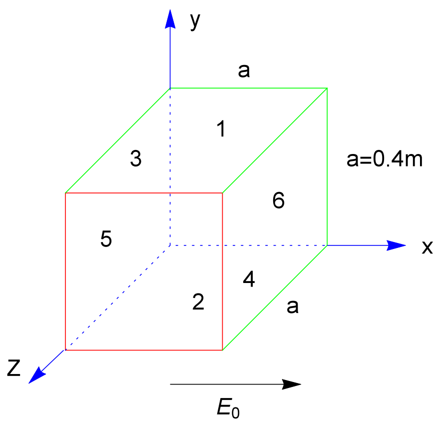


(c) What is the electric field (magnitude and direction) for a point at $x = 110\,\text{cm}$, near "c" on the diagram above? (4)

(d) What is the net charge on the outer surface of the larger of the two spheres? (2)

SEC. B (30 marks) – Answer any two questions only

4. A cube is located as shown in the diagram.



One vertex is at the origin and three edges lie along the coordinate axes. The length of the cube edge is $a = 0.4\,\text{m}$. The faces of the cube are numbered: 1–top, 2–bottom, 3– left, 4–right, 5–front, 6–back. There is a uniform electric field $E_0 = 5\,\text{N/C}$ in the x-direction throughout the region occupied by the cube.

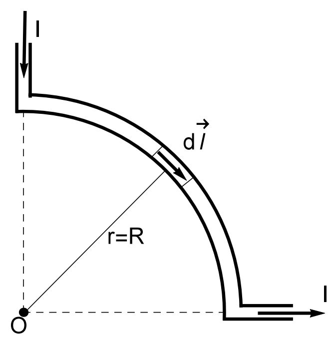
(a) What is the electric flux through each face of the cube? (5)

(b) What is the total flux through the cube? (3)

(c) A charge $q = 3 \times 10^{-8}\,\mathrm{C}$ is placed at the center of the cube. Now what is the total flux throughout the cube, and the flux through each face? If the charge is moved off center (but still inside the cube), will the total flux remains the same? Explain. (7)

5. (a) State the Biot-Savart law. (3)

(b) One quarter of a circular loop of wire carries a current I, that enters and leaves on straight segments of wire, as shown in the figure below.



The straight wires are along the radial direction from the center O of the circular portion. Use the Biot-Savart law to calculate the magnetic field at point O. (7)

(c) A model train transformer plugs into 120 V *ac* and draws 0.3 A while supplying 7.5 A to the train. Find the voltage present across the tracks, and explain whether the transformer is a *step-up* or a *step-down* type. (5)

6. Aggie is a Second Year Physics student. She goes to a lab to conduct an exprerient and finds the following on the bench: a resistor R, a capacitor C, and an inductor L (values initially unknown). She then connects the three components in series with an AC generator to form an RLC circuit. The *rms* voltage of the generator, $V_{rms} = 30\,\mathrm{volts}$. The only electrical quantity she can measure is the *rms* power produced in R. By playing with the frequency dial on the generator, she finds that the power in R attains

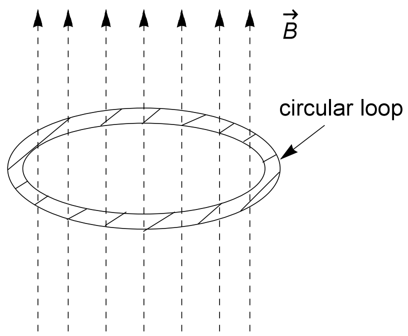
a sharp maximum at $f = 60\,\text{MHz}$ ($6.0 \times 10^7\,\text{Hz}$), with the *rms* value of the peak power being 15 watts.

(a) Explain in words why the power is a maximum, rather than a minimum, at a particular frequency? (Do not resort to equations please!). (5)

(b) What is the value of R? (4)

(c) By measuring the dimensions of the inductor, she deduces that $L = 1.4 \times 10^{-6}\,\text{H}$. What is the capacitance C? (6)

7. The figure below shows a perspective of a planar and circular copper coil. The diameter of the coil is 0.5 m and the cross section of the copper is $1\,\text{mm}^2$ while the resistivity of copper is $1.72 \times 10^{-8}\,\Omega\text{m}$. A uniform magnetic field points upward, is perpendicular to the plane of coil, and fills the area of the loop. The magnetic field changes uniformly in time from 1.1 Tesla at $t = 0\,\text{s}$ to 2.3 Tesla at $t = 60\,\text{s}$.



Determine

(a) the resistance of the copper coil, (6)

(b) the induced *emf* in the coil between $t = 0\,\text{s}$ and $t = 60\,\text{s}$, and (6)

(c) the induced current in the coil between $t = 0\,\text{s}$ and $t = 60\,\text{s}$. (3)

The End