University of Johannesburg
Department of Physics
PHYE0B1: Introductory Physics 1B
Exam – Version A (12 November 2019)
Time: 3 hours

Student No.: _____ **Surname, Initials:**_____

Instructions:

- Enter your Surname, Initials and Student # above.
- Read all questions and instructions carefully. It is your responsibility to make sure that your paper has 21 pages (excluding the coversheet(s)).
- Answer the written questions on the question paper in pen ONLY.

Written Questions

- **Draw** diagrams where appropriate. Marks are allocated for diagrams.
- **Show** all work, clearly and in order, if you want to get full credit. **Justify** the steps you take to ensure full marks. We reserve the right to take off marks if we cannot see how you arrived at your answer (even if your final answer is correct). Please keep your written answers **brief**; be clear and to the point. We reserve the right to take points off for rambling, incorrect or irrelevant statements.
- Do algebra with variables. Numerical values can be substituted at the end. Numerical work will only be evaluated at the last step.
- Underline or otherwise indicate your final answers.

Multiple Choice Questions (MCQ)

- Mark your answer for the question clearly on the script.
- There is only one correct answer per question. Entering more than one answer for a question will result in 0 marks.
- If you change an answer make sure you **completely** erase your first one. **Failure to erase well enough could result in 0 marks for the question if the marker reads both answers.**

Written Marks	
Q 1	/16
Q 2	/12
Q 3	/12
Q 4	/06
Q 5	/09
Q 6	/08
Q 7	/17
Tot.	/80

Mark Summary
7 Written: 80^{pts}
8 MCQ: 20^{pts}
Full-marks: 100^{pts}

Some useful formula

Coulomb's force law	$F = \dfrac{kq_1q_2}{r^2}$
Gauss' law	$\varepsilon_0 \oint \vec{E} \cdot d\vec{A} = q_{enc}$
Potential difference	$V_{ab} = -\int_a^b \vec{E} \cdot d\vec{\ell}$
Ohm's law	$V = IR$
Capacitance	$Q = CV$ and $U = \dfrac{1}{2}CV^2$
Lorentz force law	$\vec{F} = q\vec{E} + q\vec{v} \times \vec{B}$
Ampère's law	$\oint \vec{B} \cdot d\vec{\ell} = \mu_0 I$
Biot-Savart law	$d\vec{B} = \dfrac{\mu_0}{4\pi}\dfrac{id\vec{\ell} \times \hat{r}}{r^2}$
Faraday's law	$\varepsilon = -N\dfrac{d\Phi_B}{dt}$
Magnetic flux	$\Phi_B = \int \vec{B} \cdot d\vec{A}$
Inductance	$Li = N\Phi_B$ and $U = \dfrac{1}{2}Li^2$

Fundamental constants and useful numbers

Quantity	**Symbol**	**Value**
speed of light in vacuum	c_0	$3.00 \times 10^8\,\mathrm{m/s}$
Gravitational constant	G	$6.67 \times 10^{-11}\,\mathrm{N \cdot m^2/kg^2}$
Avogadro's number	N_A	$6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
Boltzmann's constant	k_B	$1.38 \times 10^{-23}\,\mathrm{J/K}$
Magnitude of electron charge	e	$1.60 \times 10^{-19}\,\mathrm{C}$
Permittivity constant	ϵ_0	$8.85 \times 10^{-12}\,\mathrm{C^2/N \cdot m^2}$
Permeability constant	μ_0	$4\pi \times 10^{-7}\,\mathrm{T \cdot m/A}$
Coulomb's law constant	$k = 1/4\pi\epsilon_0$	$8.99 \times 10^9\,\mathrm{N \cdot m^2/C^2}$
Planck's constant	h	$6.63 \times 10^{-34}\,\mathrm{J \cdot s}$
Electron mass	m_e	$9.11 \times 10^{-31}\,\mathrm{kg}$
Proton mass	m_p	$1.6726 \times 10^{-27}\,\mathrm{kg}$
Neutron mass	m_n	$1.6749 \times 10^{-27}\,\mathrm{kg}$
average acceleration due to gravity near Earth	g	$9.8\,\mathrm{m/s^2}$

Written Questions 80 *points* (80.0% of available marks) (pgs 2-18)

1.

16 pts

A metal cylinder of radius, r_1, is concentric with another metal cylinder of radius r_2. The space between the cylinders is filled with air. The length of the cylinders is l. You may assume that the length of the cylinders l is much larger than r_1 and r_2.

(a) (8 pts) Suppose the inner cylinder carries a charge, $-q$, and the outer cylinder carries as charge, q. Use Gauss' law to determine the electric field between the cylinders.

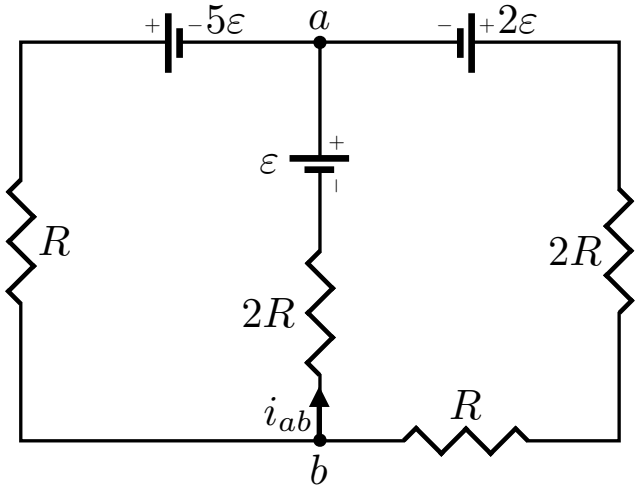
(b) (5 pts) Determine the potential difference between the inner and outer cylinder

(c) (3 pts) If r_1=2.0 mm, r_2=5.0 mm and l=50 cm, determine the capacitance of the cylinders.

2.

Using Kirchhoff's rules, find the current i_{ab} in the circuit shown below, where $\varepsilon = 1\,\mathrm{V}$ and $R = 1\,\Omega$

12 pts



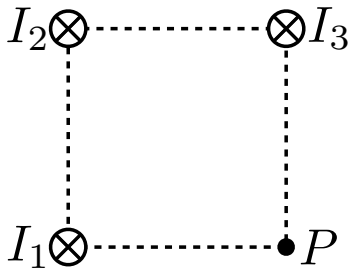
Extra space:

3.

12 pts

(a) (4 pts) A proton moving in a circular path perpendicular to a constant magnetic field takes 2.00 μs to complete one revolution. Determine the magnitude of the magnetic field.

(b) (8 pts) Three wires sit at the corners of a square, all carrying currents of 2.0 A into the page as shown in the figure below. Calculate the magnitude of the magnetic field at the other corner of the square (at point P) if the length of each side of the square is 1.0 cm.

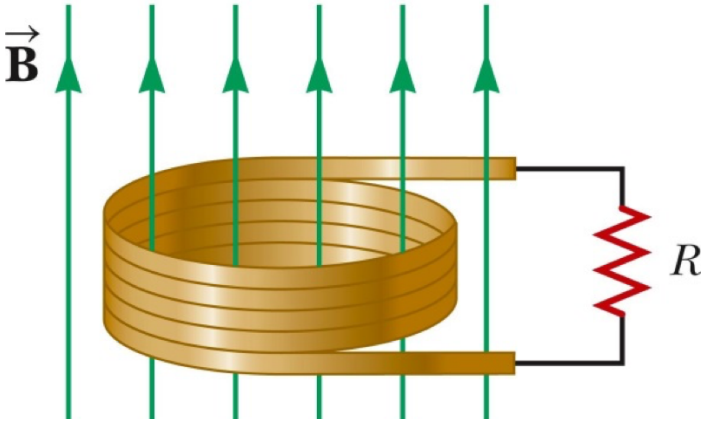


Extra space:

4.

6 pts

A circular coil enclosing an area $A = 0.01\,\mathrm{m}^2$ is made of 200 turns of copper as shown in the figure below. Initially a uniform magnetic field of magnitude $B = 1.1\,\mathrm{T}$ points upward in a direction perpendicular to the plane of the coil. The direction of the field then reverses in a time interval Δt. Calculate how much charge enters one end of the resistor during this time interval if $R = 5.0\,\Omega$.



Extra space:

5.

9 pts

(a) (3 pts) Stare Ampère's law and define all the parameters in this formula.

(b) (6 pts) A long cylindrical wire of radius R carries a steady current I that is uniformly distributed through the cross-section of the wire. Make use of Ampère's law to calculate the magnetic field a distance r from the wire in the region where $r < R$.

Extra space:

6.

8 pts

An electromagnetic wave with frequency 5.70×10^{14} Hz propagates with a speed of 2.35×10^{8} m/s in a certain piece of glass. Find

(a) (2 pts) the wavelength of the wave in the glass

(b) (2 pts) the wavelength of the wave of the same frequency propagating in air

(c) (2 pts) the index of refraction n of the glass for an electromagnetic wave with this frequency

(d) (2 pts) the dielectric constant for glass at this frequency, assuming that the relative permeability is unity.

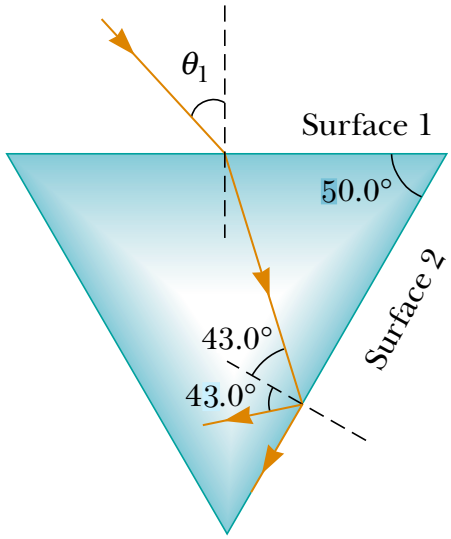
Extra space:

7.

17 pts

(a) (5 pts) A thin layer of ice ($n_{ice} = 1.309$) floats on the surface of water ($n_{water} = 1.333$) in a bucket. A ray of light from the bottom of the bucket travels upward through the water. What is the largest angle with respect to the normal that the ray can make at the ice-water interface and still pass out into the air above the ice? And what is this angle after the ice melts?

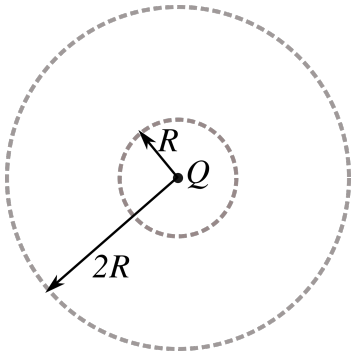
(b) (1 pt)2 The light beam illustrated strikes surface 2 at the critical angle. Determine the angle of incidence θ_1.



Extra space:

Multiple Choice Questions 20 *points* (20.0% of available marks) (pgs 19-21)

MCQ 1. (2 pts)



Two concentric imaginary spherical surfaces of radius R and $2R$ respectively surround a positive point charge Q located at the centre of the surfaces.

When compared to the electric flux, Φ_1, through the surface of radius R, the electric flux, Φ_2, through the surface of radius $2R$ is

Ⓐ $\Phi_2 = \frac{1}{4}\Phi_1$
Ⓑ $\Phi_2 = \frac{1}{2}\Phi_1$
Ⓒ $\Phi_2 = \Phi_1$
Ⓓ $\Phi_2 = 2\Phi_1$
Ⓔ $\Phi_2 = 4\Phi_1$

MCQ 2. (2 pts) Equipotentials are lines along which

Ⓐ a charge may be moved at constant speed without work against electrical forces.
Ⓑ charges move by themselves.
Ⓒ maximum work against electrical forces is required to move charges at constant speed.
Ⓓ the electric charge is constant in magnitude and direction.
Ⓔ the electric field is constant in magnitude and direction.

MCQ 3. (4 pts) A uniform linear charge of 3.0 nC/m is distributed along the y axis from $y = -3\,\mathrm{m}$ to $y = 2\,\mathrm{m}$. Which of the following integrals is correct for the magnitude of the electric field at $y = 4\,\mathrm{m}$ on the y axis?

Ⓐ $\displaystyle\int_{-3\,\mathrm{m}}^{2\,\mathrm{m}} \frac{(135\,\mathrm{N}\cdot\mathrm{m/C})dy}{(4\,\mathrm{m} - y)^2}$

Ⓑ $\displaystyle\int_{-3\,\mathrm{m}}^{2\,\mathrm{m}} \frac{(135\,\mathrm{N}\cdot\mathrm{m/C})dy}{16\,\mathrm{m}^2 + y^2}$

Ⓒ $\displaystyle\int_{-3\,\mathrm{m}}^{2\,\mathrm{m}} \frac{(27\,\mathrm{N}\cdot\mathrm{m/C})dy}{16\,\mathrm{m}^2 + y^2}$

Ⓓ $\displaystyle\int_{-3\,\mathrm{m}}^{2\,\mathrm{m}} \frac{(27\,\mathrm{N}\cdot\mathrm{m/C})dy}{(4\,\mathrm{m} - y)^2}$

Ⓔ none of these

MCQ 4. (2 pts) A sphere of radius R is placed near a long, straight wire that carries a steady current I. The magnetic field generated by the current is B. The total magnetic flux passing through the sphere is

Ⓐ $\mu_0 I/4\pi R^2$
Ⓑ $4\pi R^2 \mu_0 I$
Ⓒ $\mu_0 I$
Ⓓ 0
Ⓔ need more information

MCQ 5. (3 pts) A ten-loop coil having an area of $0.23\,\mathrm{m}^2$ and a very large resistance is in a 0.047 T uniform magnetic field oriented so that the maximum flux goes through the coil. The coil is then rotated so that the flux through it goes to zero in 0.34 s. What is the magnitude of the average emf induced in the coil during the 0.34 s?

Ⓐ 0.032 V
Ⓑ 0.00 V
Ⓒ 1.0 V
Ⓓ 0.32 V
Ⓔ 0.0032 V

MCQ 6. (3 pts) A current of 4.0 A is maintained in a single circular loop having a circumference of 80 cm. An external magnetic field of 2.0 T is directed so that the angle between the field and the plane of the loop is 20°. Determine the magnitude of the torque exerted on the loop by the magnetic forces acting upon it.

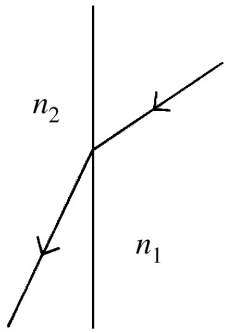
Ⓐ 0.14 N.m
Ⓑ 0.27 N.m
Ⓒ 0.41 N.m
Ⓓ 0.77 N.m
Ⓔ 0.38 N.m

Rough Work:

MCQ 7. (2 pts) The energy per unit volume in an electromagnetic wave is

Ⓐ all in the electric field.
Ⓑ mostly in the magnetic field.
Ⓒ all in the magnetic field.
Ⓓ mostly in the electric field.
Ⓔ equally divided between the electric and magnetic fields.

MCQ 8. (2 pts)



A ray of light goes from one transparent material into another, as shown in the figure. What can you conclude about the indices of refraction of these two materials?

Ⓐ $n_1 \geq n_2$
Ⓑ $n_2 \geq n_1$
Ⓒ $n_1 > n_2$
Ⓓ $n_2 > n_1$
Ⓔ $n_1 = n_2$

Rough Work: