**University of Johannesburg**
**Department of Physics**
**PHYE0B1: Introductory Physics 1B**
Supplementary Exam – Version C (XX January 2020)
Time: 3 hours

UNIVERSITY OF JOHANNESBURG

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

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**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 18 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 | /10 |
| Q 2 | /15 |
| Q 3 | /12 |
| Q 4 | /08 |
| Q 5 | /07 |
| Q 6 | /10 |
| Q 7 | /16 |
| Tot. | /78 |

**Mark Summary**
7 Written: $78^{pts}$
9 MCQ: $22^{pts}$
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 | $V_{ab} = -\displaystyle\int_a^b \vec{E} \cdot d\vec{\ell}$ |
| 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 | $\Phi_B = \displaystyle\int \vec{B} \cdot d\vec{A}$ |
| Inductance | $Li = N\Phi_B$ and $U = \dfrac{1}{2}Li^2$ |

**Fundamental constants and useful numbers**

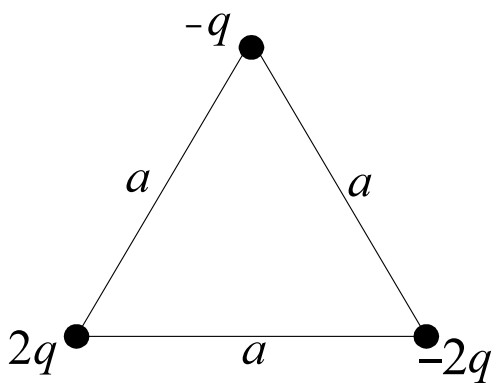
| **Quantity** | **Symbol** | **Value** |
|---|---|---|
| speed of light in vacuum | $c_0$ | $3.00 \times 10^8\,\mathrm{m/s}$ |
| Gravitational constant | $G$ | $6.67 \times 10^{-11}\,\mathrm{N \cdot m^2/kg^2}$ |
| Avogadro's number | $N_A$ | $6.02 \times 10^{23}\,\mathrm{mol^{-1}}$ |
| Boltzmann's constant | $k_B$ | $1.38 \times 10^{-23}\,\mathrm{J/K}$ |
| Magnitude of electron charge | $e$ | $1.60 \times 10^{-19}\,\mathrm{C}$ |
| Permittivity constant | $\epsilon_0$ | $8.85 \times 10^{-12}\,\mathrm{C^2/N \cdot m^2}$ |
| Permeability constant | $\mu_0$ | $4\pi \times 10^{-7}\,\mathrm{T \cdot m/A}$ |
| 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** 78 *points* (78.0% of available marks) (pgs 2-15)

**1.**

| |
|---|
| 10 pts |

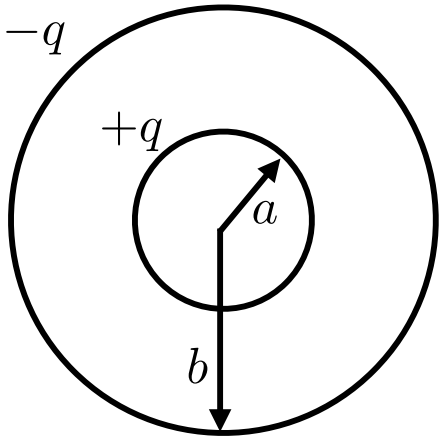
Find the magnitude and direction of the electrostatic force on the charge, $2q$, due to the other two charges, shown in the figure below, if $q = 10^{-8}\,\text{C}$ and $a = 3\,\text{mm}$.



**2.**

15 pts

The figure below shows a capacitor made up of two concentric spheres of radii $a$ and $b$, with charges as shown in the diagram.




(a) (6 pts) Show that the electric field in the region between the two spheres is

$$E = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2} \quad a \leq r \leq b$$

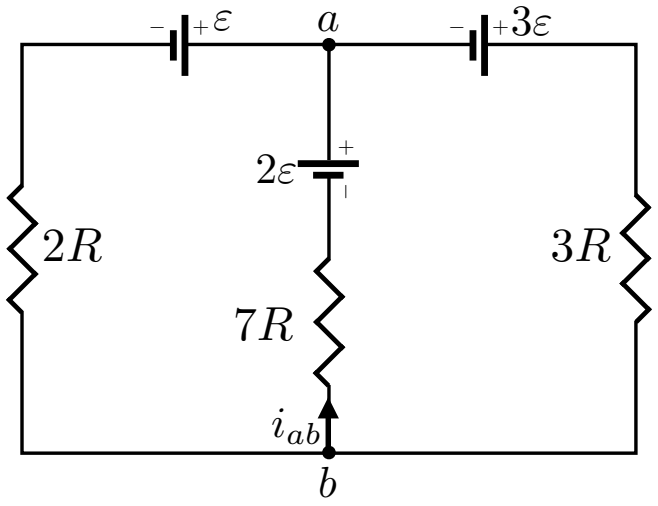
(b) (9 pts) Use the result from (a) above to show that the two sphere's capacitance is given by

$$C = 4\pi\epsilon_0 \frac{ab}{b-a}$$

**3.**

12 pts

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



**Extra space:**

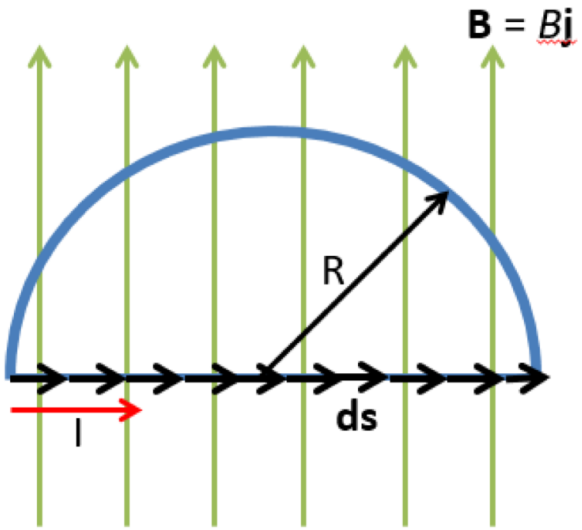
**4.**

| |
|---|
| 8 pts |

Calculate the total magnetic force on

(a) (3 pts) the straight and

(b) (5 pts) the curved sections of a semi-circular wire in a uniform magnetic field.

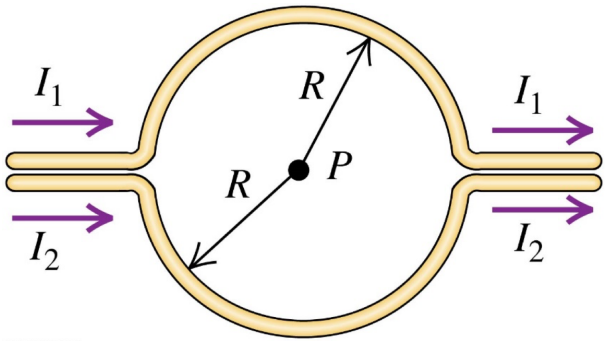


**Extra space:**

**5.**

Using the Biot-Savart law, calculate the magnitude of the magnetic field at point $P$ in terms of $R$, $I_1$ and $I_2$.

7 pts

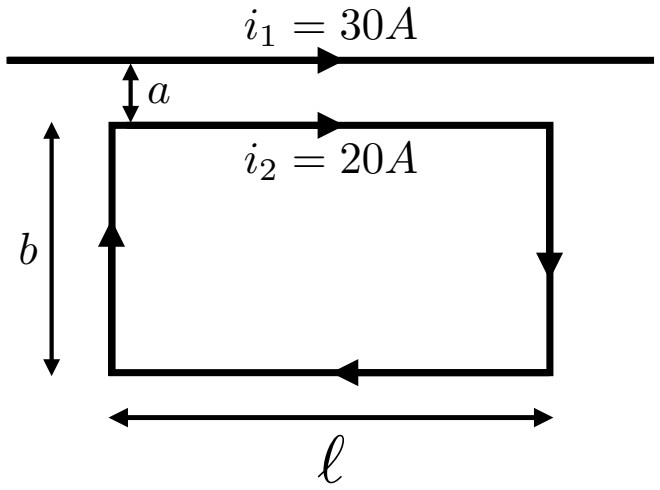


**Extra space:**

**6.**

10 pts

The figure below shows a long wire carrying a current 30 A. The rectangular loop carries a current of 20 A. Calculate the resultant force acting on the loop. Assume that $a$ is 1.0 cm, $b$ is 8.0 cm and $\ell$ is 30 cm.

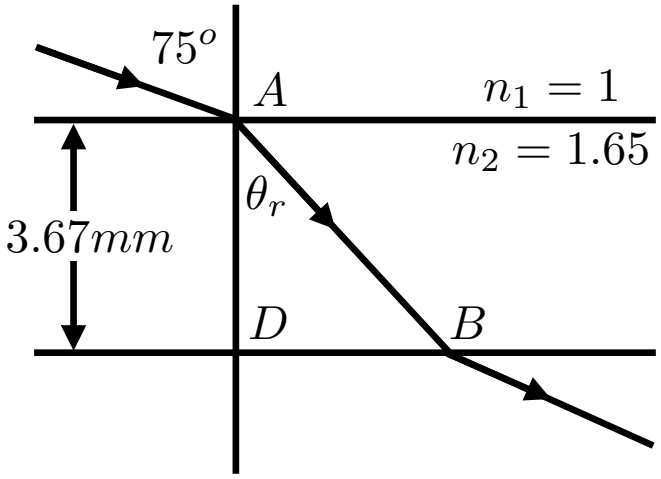


**Extra space:**

**7.**

16 pts

In the diagram below we show light of a vacuum wavelength $\lambda_0 = 565\,\text{nm}$ passing obliquely through a glass plate of refractive index 1.65 and thickness 3.67 mm. Calculate the following quantities




(a) (2 pts) the frequency

(b) (2 pts) the wavelength $\lambda$ in the glass

(c) (2 pts) the velocity of light $v$ in the glass

(d) (2 pts) the angle $\theta_r$

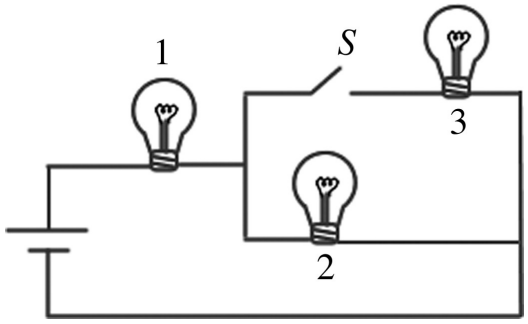
(e) (2 pts) the distance $AB$

(f) (2 pts) the optical path length in the glass.

(g) (4 pts) Finally, with the help of diagrams, explain what (in general) is meant by total internal reflection.

**Multiple Choice Questions** 22 *points* (22.0% of available marks) (pgs 16-18)

**MCQ 1.** (3 pts)




The figure shows three identical lightbulbs connected to a battery having a constant voltage across its terminals.

What happens to the brightness of lightbulb 1 when the switch $S$ is closed?

Ⓐ The brightness will increase momentarily then return to its previous level.
Ⓑ The brightness increases permanently.
Ⓒ The brightness will decrease momentarily then return to its previous level.
Ⓓ The brightness remains the same as before the switch is closed.
Ⓔ The brightness decreases permanently.

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

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

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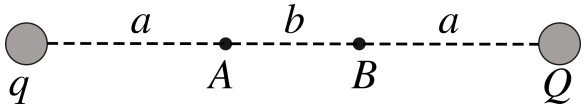
**MCQ 3.** (3 pts)




If $a = 30\,\text{cm}$, $b = 20\,\text{cm}$, $q = +2.0\,\text{nC}$, and $Q = -3.0\,\text{nC}$ in the figure above, what is the potential difference $V_A - V_B$?

Ⓐ $+72\,\text{V}$
Ⓑ $+96\,\text{V}$
Ⓒ $+48\,\text{V}$
Ⓓ $+60\,\text{V}$
Ⓔ $+84\,\text{V}$

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**MCQ 4.** (2 pts)


A horizontal wire carries a positive current straight toward you as shown. From your point of view, the magnetic field at a point, $P$, directly below the wire points:

Ⓐ directly toward you.
Ⓑ directly away from you.
Ⓒ to the left.
Ⓓ vertically upward.
Ⓔ to the right.

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**MCQ 5.** (3 pts) Calculate the magnetic field intensity ($B$) at a point on the centre of the circular conductor of radius 2 m with current 8 A.

Ⓐ $8\pi \times 10^{-7}$ T
Ⓑ $2\pi \times 10^{-7}$ T
Ⓒ 0
Ⓓ $6\pi \times 10^{-7}$ T
Ⓔ Insufficient information to calculate

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**MCQ 6.** (2 pts) An emf can be induced by

Ⓐ a change in the area of the cross-section only
Ⓑ a change in the magnetic field, area or angle between them
Ⓒ a change of shoes
Ⓓ a change in the angle between the magnetic field and area only
Ⓔ a change in the magnetic field only

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**MCQ 7.** (3 pts) Calculate the length of a conductor which is moving with a velocity 0.4 m/s in a magnetic field of 8 T, inducing an emf of 20 V if the magnetic field, velocity and length of conductor are mutually perpendicular to each other

Ⓐ 0.5 m
Ⓑ 67.5 m
Ⓒ 50 m
Ⓓ 5 m
Ⓔ 6.25 m

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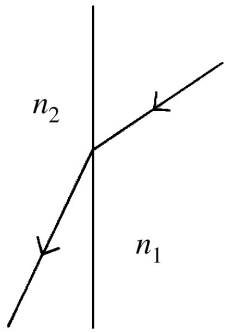
**MCQ 8.** (2 pts) The energy per unit volume in an electromagnetic wave is

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

**MCQ 9.** (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?

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

**Rough Work:**