People's Democratic Republic of Algeria
Ministry of Higher Education and Scientific Research
Mila University Center
Institute of Science and Technology
Department of Science and Technology

الجمهورية الجزائرية الديمقراطية الشعبية
وزارة التعليم العالي و البحث العلمي
المركز الجامعي عبد الحفيظ بوصوف ميلة
معهد العلوم و التكنولوجيا
قسم علوم و التكنولوجيا

Student's name and surname	**Mock Exam 1**	اسم و لقب الطالب:
. ... **Date:** , 2025 **Time:** 15 minutes	**Electricity** **First semester** **1446 H** **2024/2025**	الرقم الجامعي: ملاحظة :

1 Exercise : Electric Forces and Potential in a System of Charges

Q: Calculate the intensity of the electrostatic force acting on the charge q (see figure 1) 1, given that: $q_1 = -1.5 \cdot 10^{-3}\,\mathrm{C}$; $q_2 = 0.5 \cdot 10^{-3}\,\mathrm{C}$; $q = -0.2 \cdot 10^{-3}\,\mathrm{C}$; $r_1 = 1.2\,\mathrm{m}$ and $r_2 = 0.5\,\mathrm{m}$.

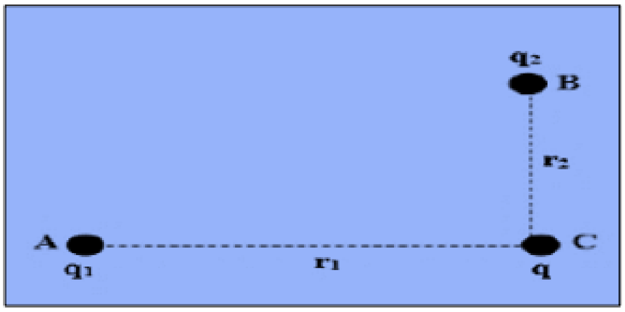

Figure 1: Figure 1 1

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1. Solution *(5 points total)*

(a) Force due to q_1 *(1.5 pts)*

$$F_1 = k \cdot \frac{|q_1 q|}{r_1^2} = 9 \times 10^9 \cdot \frac{1.5 \times 10^{-7} \cdot 0.2 \times 10^{-7}}{(1.2)^2}$$

$$F_1 = 9 \times 10^9 \cdot \frac{3 \times 10^{-15}}{1.44} \approx \frac{27 \times 10^{-6}}{1.44} \approx \boxed{1.875 \times 10^{-5}\ \text{N}}$$

Direction: Toward q_1 (left, attractive force).

(b) Force due to q_2 *(1.5 pts)*

$$F_2 = k \cdot \frac{|q_2 q|}{r_2^2} = 9 \times 10^9 \cdot \frac{0.5 \times 10^{-7} \cdot 0.2 \times 10^{-7}}{(0.5)^2} = 9 \times 10^9 \cdot \frac{1 \times 10^{-15}}{0.25}$$

$$= 9 \times 10^9 \cdot 4 \times 10^{-15} = \boxed{3.6 \times 10^{-5}\ \text{N}}$$

Direction: Toward q_2 (downward, attractive force).

(c) Resultant Force on q *(1.5 pts)*

$$F = \sqrt{F_1^2 + F_2^2} = \sqrt{(1.875 \times 10^{-5})^2 + (3.6 \times 10^{-5})^2}$$

$$= \sqrt{3.516 \times 10^{-10} + 1.296 \times 10^{-9}} = \sqrt{1.648 \times 10^{-9}} \approx \boxed{4.06 \times 10^{-5}\ \text{N}}$$

(d) Direction of Force *(0.5 pt)*

$$\tan(\theta) = \frac{F_2}{F_1} = \frac{3.6}{1.875} \Rightarrow \theta = \tan^{-1}(1.92) \approx \boxed{62.5^\circ}$$

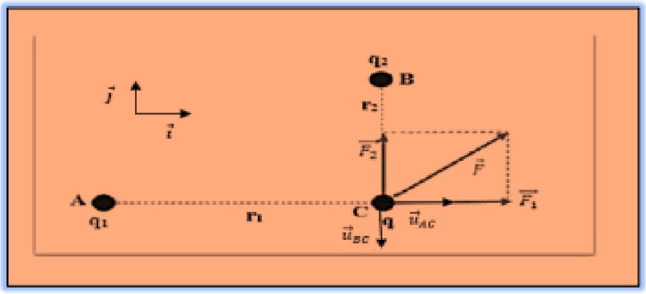

Figure 2: Figure 2. Representation of electrostatic forces

2. Final Answer

$$\boxed{F = 4.06 \times 10^{-5}\ \text{N}, \quad \theta \approx 62.5^\circ \text{ below the horizontal}}$$

5. Points Distribution

- Force from q_1: 1.5 pts
- Force from q_2: 1.5 pts
- Magnitude of resultant: 1.5 pts
- Direction (angle): 0.5 pt

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<table>
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<tr><td>. ....</td><td>الرقم الجامعي:</td></tr>
<tr><td>Date: , 2025
Time: 15 minutes</td><td>ملاحظة :</td></tr>
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1 Exercise : Applying Gauss's theorem to a sphere

Consider a sphere (S) with center O and radius R, uniformly charged on its surface with a surface charge density σ. Calculate the electrostatic field at every point in space using Gauss's theorem.

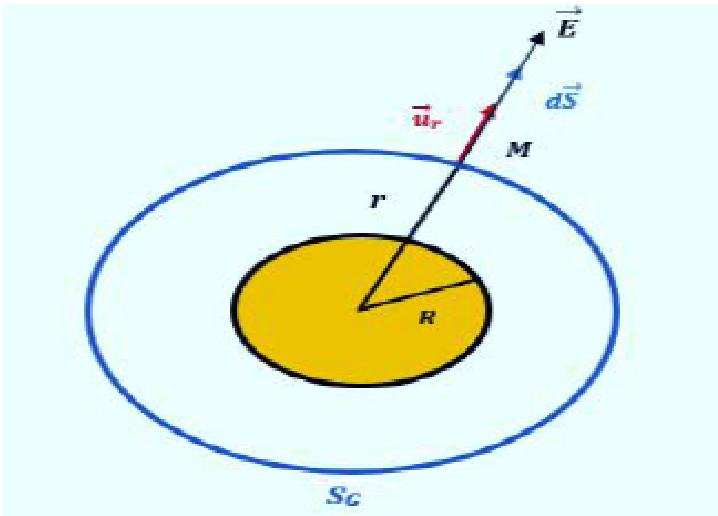

Figure 1: Gauss's theorem sphere

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2 Solution:

Total Points: 5

- Field inside the sphere: **1.5 pts**
- Field outside the sphere (derivation and result): **3 pts**
- Final summary with correct units and direction: **0.5 pt**

1. Inside the Sphere ($r < R$) *(1.5 pts)*

Since the charge is only distributed on the surface, any Gaussian surface inside the sphere encloses no charge:

$$Q_{\text{enclosed}} = 0 \quad \Rightarrow \quad \oint \vec{E} \cdot d\vec{S} = 0 \quad \Rightarrow \quad \boxed{\vec{E}_{in} = 0}$$

2. Outside the Sphere ($r \geq R$) *(3 pts)*

Step 1: Use symmetry. Take a spherical Gaussian surface of radius $r \geq R$. The electric field is radial and constant in magnitude on this surface.

Step 2: Apply Gauss's Law:

$$\oint \vec{E} \cdot d\vec{S} = E \cdot 4\pi r^2 = \frac{Q_{\text{enclosed}}}{\varepsilon_0}$$

Step 3: Total charge on the sphere:

$$Q = \sigma \cdot 4\pi R^2$$

Step 4: Solve for E:

$$E \cdot 4\pi r^2 = \frac{\sigma \cdot 4\pi R^2}{\varepsilon_0} \Rightarrow \boxed{E(r) = \frac{\sigma R^2}{\varepsilon_0 r^2} \quad \text{for } r \geq R}$$

3. Final Answer and Direction *(0.5 pt)*

$$\vec{E}(r) = \begin{cases} 0 & \text{for } r < R \\ \dfrac{\sigma R^2}{\varepsilon_0 r^2} \cdot \hat{r} & \text{for } r \geq R \end{cases}$$

Direction: Radially outward from the center of the sphere.

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1 Exercise : Applying Gauss's Theorem to a Cylinder

A detector cell consists of:

- A hollow cylinder (radius R, length L) with a negatively charged metallic lateral surface (−Q).
- A thin central wire with a positive charge (+Q).

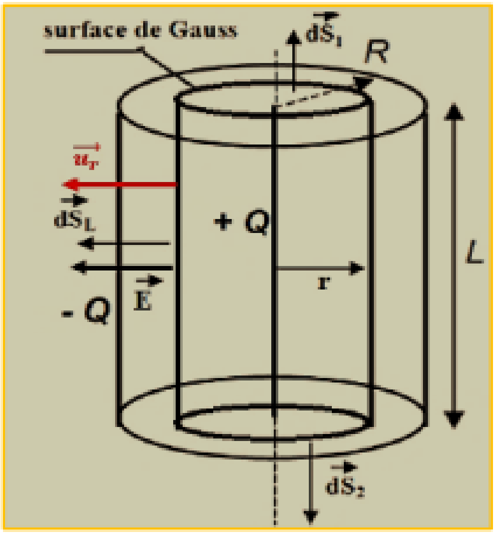

Figure 1: Applying Gauss's Theorem to a Cylinder

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Problem Statement

A detector cell consists of:

- A **hollow metallic cylinder** (radius R, length L) carrying a negative surface charge $-Q$.
- A **thin central wire** (length L) carrying a positive charge $+Q$.

Using Gauss's theorem, calculate the **electrostatic field** in the different regions:

1. Inside the cylinder (i.e., $r < R$)
2. Outside the cylinder (i.e., $r > R$)

Total Score: 5 points

- Use of Gauss's law and symmetry: **1 pt**
- Electric field for $r < R$: **2 pts**
- Electric field for $r > R$: **1 pt**
- Final conclusion and clarity of direction: **1 pt**

1. Symmetry and Gauss's Law *(1 pt)*

Due to cylindrical symmetry, the electric field is radial and depends only on the radial distance r. Use a cylindrical Gaussian surface of radius r and length L.

Gauss's law:

$$\oint \vec{E} \cdot d\vec{S} = \frac{Q_{enc}}{\varepsilon_0} \quad \Rightarrow \quad E(2\pi r L) = \frac{Q_{enc}}{\varepsilon_0} \Rightarrow E(r) = \frac{Q_{enc}}{2\pi\varepsilon_0 r L}$$

2. Case 1: Inside the Cylinder ($r < R$) *(2 pts)*

For $r < R$, the Gaussian surface encloses only the inner wire, which carries charge $+Q$.

$$Q_{enc} = +Q \quad \Rightarrow \quad E(r) = \frac{Q}{2\pi\varepsilon_0 r L}$$

$$\boxed{E(r) = \frac{Q}{2\pi\varepsilon_0 r L} \quad \text{for } r < R}$$

Direction: Radially outward from the wire.

3. Case 2: Outside the Cylinder ($r > R$) *(1 pt)*

Now the Gaussian surface encloses both the inner wire $+Q$ and the cylindrical shell $-Q$, so:

$$Q_{enc} = +Q + (-Q) = 0 \quad \Rightarrow \quad \boxed{E(r) = 0 \quad \text{for } r > R}$$

4. Final Answer and Direction *(1 pt)*

$$\vec{E}(r) = \begin{cases} \dfrac{Q}{2\pi\varepsilon_0 r L} \cdot \hat{r} & \text{if } 0 < r < R \\ 0 & \text{if } r > R \end{cases}$$

Note: The electric field exists only inside the cylinder and points radially outward due to the positive central wire.

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1 Exercise : Electric Forces and Potential in a System of Charges

1. **Given:**
   - Three point charges placed at the vertices of an equilateral triangle with side length $a = 2\,\text{cm}$.
   - Charge values: $q_1 = q$, $q_2 = 2q$, $q_3 = 3q$ where $q = 1\,\text{C}$.
2. **Required:**
   (a) Calculate the electric force acting on each charge.
   (b) Calculate the electric potential at the intersection point of the triangle's medians (centroid).

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2 . Solution

(a) Electric Force on Each Charge *(3 pts)*

Formula:

$$F = \frac{1}{4\pi\varepsilon_0}\frac{|q_i q_j|}{r^2} \quad \text{with } \varepsilon_0 = 8.854 \times 10^{-12}\,\text{F/m}$$

All sides are equal: $r = a = 0.02\text{m}$

Force on q_1 due to q_2:

$$F_{12} = \frac{9 \times 10^9 \cdot 1 \cdot 2}{(0.02)^2} = 4.5e13$$

Force on q_1 due to q_3:

$$F_{13} = \frac{9 \times 10^9 \cdot 1 \cdot 3}{(0.02)^2} = 6.75e13$$

Net Force on q_1 (vector sum):

$$F_{\text{net},1} = \sqrt{F_{12}^2 + F_{13}^2 + 2F_{12}F_{13}\cos(60^\circ)}$$

$$= \sqrt{(4.5e13)^2 + (6.75e13)^2 + 2 \cdot 4.5e13 \cdot 6.75e13 \cdot 0.5} \approx 1.09e14$$

(Repeat similarly for other charges using symmetry.)

Points distribution:

- Correct use of Coulomb's Law: **1 pt**
- Correct numerical calculations for pairwise forces: **1 pt**
- Vector addition with angle reasoning: **1 pt**

(b) Electric Potential at the Centroid *(2 pts)*

Formula:

$$V = \frac{1}{4\pi\varepsilon_0}\sum_i \frac{q_i}{r_i}$$

Centroid distance:

$$r = \frac{a}{\sqrt{3}} = \frac{0.02}{\sqrt{3}} \approx 0.01155\text{m}$$

$$V = \frac{9 \times 10^9}{0.01155}(1 + 2 + 3) = \frac{9 \times 10^9 \cdot 6}{0.01155} \approx 4.67e12$$

Points distribution:

- Correct application of potential formula and distance from centroid: **1 pt**
- Correct numerical calculation: **1 pt**

4. Final Answers

(a) The net force on q_1 is approximately $\boxed{1.09 \times 10^{14}\,\text{N}}$

(b) The electric potential at the centroid is $\boxed{4.67 \times 10^{12}\,\text{V}}$

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