Name	Date started	Target end date

GCE A LEVEL — ELECTRIC FIELDS QUESTION PACK

Legacy PH4 · New spec Unit 4 Topic 2 · A2 unit, 25% of A-level

REVISE
.wales

PHYSICS — UNIT 4 · ELECTRIC FIELDS

U4.2 Electrostatic fields of force — Coulomb's law, electric field strength & potential

Coulomb's law, electric field strength $E = kQ/r^2$, electric potential $V = kQ/r$, equipotentials, work done moving charges between points, accelerating charges in fields, and the direct comparison with gravity.

NEW 2015 SPEC · UNIT 4 TOPIC 2

Estimated time for entire question pack: ~2 h 50 min

Derived from the legacy PH4 paper's pace of ~1.3 min/mark (80 marks in 1¾ hours).

*You are advised to **not** attempt to complete all of this in one sitting.*

ABOUT THIS QUESTION PACK

This is a **comprehensive practice question pack**, not a single mock paper. It contains every electric fields question from the legacy WJEC PH4 papers (2008 modular spec) that maps onto new-spec Unit 4 Topic 2.

Questions are ordered chronologically.

INSTRUCTIONS

Use black ink or black ball-point pen. Answer all questions in the spaces provided.

The number of marks is given in brackets at the end of each question or part-question. A calculator is required. The Data Booklet is allowed.

For Examiner's use only

Q	Source	Max	Mark
1	Jun 15 Q6	9	
2	Jan 10 Q6	11	
3	Jan 12 Q5	12	
4	Jun 10 Q4	10	
5	Jun 11 Q4	18	
6	Jun 12 Q6	13	
7	Jun 16 Q6	10	
8	Jun 13 Q7	10	
9	Jan 13 Q4	13	
10	Jan 14 Q6	13	
11	Jun 14 Q6	12	
	Total	**131**	

Electric Fields — what the new spec asks

WJEC GCE A Level Physics (from 2015) · Unit 4: Fields & Options · Topic 4.2.

Coulomb's law A

- Force between two point charges: $F = (1/4\pi\varepsilon_0)(q_1q_2/r^2)$.
- $\varepsilon_0 = 8.85 \times 10^{-12}$ F m^{-1}; $1/(4\pi\varepsilon_0) \approx 9.0 \times 10^9$ N m^2 C^{-2}.
- Repulsive for like charges, attractive for unlike; inverse-square in r.

Electric field strength A

- $E = F/q$ — force per unit positive test charge (vector, N C^{-1} or V m^{-1}).
- Point charge: $E = (1/4\pi\varepsilon_0)(Q/r^2)$ radially outward from +Q.
- Superposition: vector sum of E from each source charge.

Electric potential A

- $V = W/q$ — work done per unit charge bringing q from infinity.
- Point charge: $V = (1/4\pi\varepsilon_0)(Q/r)$; $V \rightarrow 0$ at infinity.
- Work done moving q between points: $W = q\Delta V$.

Equipotentials & field lines A

- Field lines from + to −; equipotentials perpendicular to field lines.
- Equipotentials are surfaces of constant V — no work done moving along them.
- Concentric spheres around a point source.

Accelerating charges A

- KE gained: $\frac{1}{2}mv^2 = qV$ (electron in p.d. V from rest).
- Distance of closest approach: $KE_{initial} = (1/4\pi\varepsilon_0)(q_1q_2/r_{min})$.
- Rutherford alpha-scattering analysis.

Field-and-potential analogy A

- Same inverse-square structure as gravitational fields.
- Field-strength formulae and potential formulae have identical shape.
- Compare F_{elec} / F_{grav} ratio for two electrons ($\sim 10^{42}$).

Electric Fields in one page

Quick-reference notes — revisit before each section.

Coulomb's law

$F = (1/4\pi\varepsilon_0) \cdot q_1q_2/r^2$

$k = 1/(4\pi\varepsilon_0) \approx 8.99 \times 10^9$ N m² C⁻².

+ × + or − × − → repulsive; + × − → attractive.

E field

$E = F/q$ (N C⁻¹ or V m⁻¹), vector.

Point charge: $E = kQ/r^2$.

Uniform field between parallel plates: $E = V/d$.

Electric potential V

$V = kQ/r$ (scalar, $V \to 0$ at infinity).

Work done moving q between A and B: $W = q(V_B - V_A)$.

W is +ve when moving against the field.

Equipotentials

Field lines and equipotentials always perpendicular.

No work along an equipotential.

Around a point charge: concentric spheres.

Closest approach

α-particle (charge 2e, KE T) onto nucleus (Ze):

$T = (1/4\pi\varepsilon_0)(2e \cdot Ze)/r_{min}$.

Solve for r_{min} — Rutherford-style problem.

Field/grav analogy

$F = kq_1q_2/r^2 \leftrightarrow F = Gm_1m_2/r^2$.

$E = kQ/r^2 \leftrightarrow g = GM/r^2$.

$V = kQ/r \leftrightarrow V_g = -GM/r$ (note sign).

Questions begin overleaf.

Section index

All questions in this pack — chronological order by source paper.

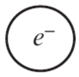
Section	Questions	Marks
A Electric Fields	Qs 1–11	131 marks

Examiner only

6. *(a)* The diagram shows an isolated electron. On the diagram, sketch and label:

(i) the electric field lines and direction (label as E);

(ii) the equipotential surfaces (label as V). [2]



(b) Determine the electric potential at a distance of 2.00 mm from the electron. [2]

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(c) A second electron is located at a distance of 2.00 mm from the first electron shown above. Determine the work required to bring this second electron from this distance of 2.00 mm to a point 1.20 mm away from the first electron, where the potential is –1.20 × 10^{-6} V. [2]

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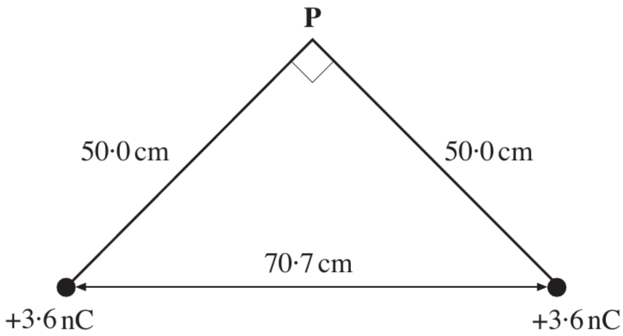
(d) Compare the magnitude **and** direction of the electrostatic forces that the electrons, separated by a distance of 1.20 mm, exert on each other with the gravitational forces that they exert at this separation. Support your answer with calculations. [3]

6.



(a) Calculate the force between the two 3·6 nC charges shown above. [2]

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(b) (i) Draw arrows at P to represent the directions of the electric fields due to the two 3·6 nC charges. [1]

(ii) State the direction of the resultant of these two fields. .... [1]

(iii) Calculate the magnitude of the electric field at **P**. [4]

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(c) Calculate the work done when a +1·0 nC charge is brought from a large distance away and placed at **P**. [3]

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Examiner only

5. The diagram shows an isolated positive charge (+57 μC).

(a) Sketch and label electric field lines and equipotential surfaces for the positive charge. [3]

(b) State **one** difference between this diagram and the equivalent diagram of the gravitational field due to a spherical mass. [1]

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(c) Calculate the magnitude of the electric field strength 15.8 cm from the centre of the +57 μC charge. [2]

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(d) (i) Calculate the potential 15.8 cm from the centre of the +57 μC charge. [2]

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(ii) State the potential a large (infinite) distance away from the +57 μC charge. [1]

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(e) A 2.45 μC point charge is placed 15.8 cm away from the +57 μC charge and then released. Use your answers to *(d)* to calculate the final kinetic energy of the point charge when it has travelled a large distance away from the +57 μC charge. [3]

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Examiner only

4. *(a)* The diagram shows a positively charged particle at rest. Draw and label the electric field on the diagram – include electric field lines and equipotential surfaces.

[2]

(b) (i) An alpha particle (helium nucleus) of charge 3.2×10^{-19} C and mass 6.6×10^{-27} kg travels with a speed of $5.0 \times 10^{6}\,\mathrm{m\,s^{-1}}$. Calculate its kinetic energy.

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[1]

(ii) If the alpha particle travels head-on towards a stationary copper nucleus of charge 4.6×10^{-18} C in thin copper foil, find their distance of closest approach.

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[4]

(iii) Describe in terms of energy what happens to the alpha particle after it has reached the point of closest approach.

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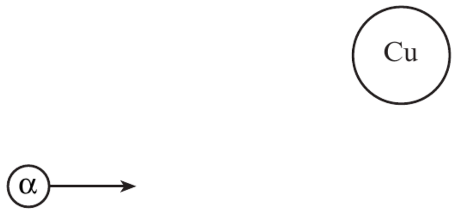
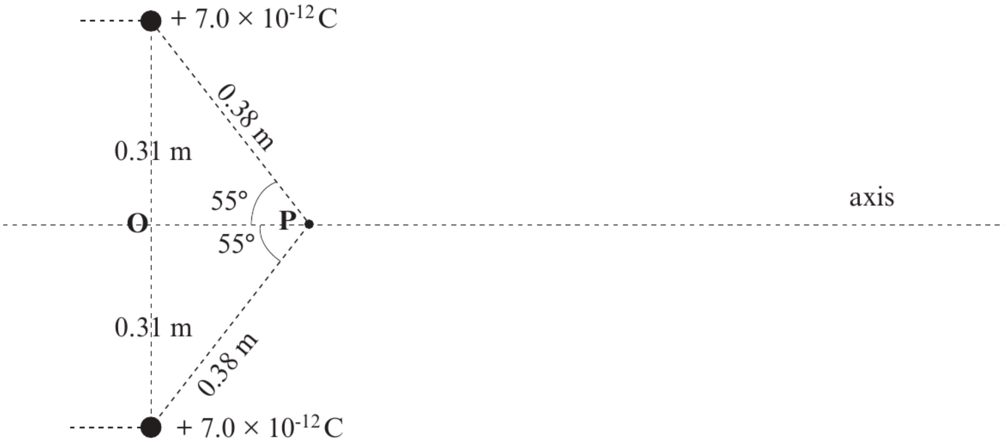
[2]

(iv) Complete the sketch below by showing the path of the alpha particle (α) if it was not travelling head-on towards the copper nucleus (Cu).



[1]

4. Two small positive charges are placed in empty space as shown.



(a) (i) Put arrows at point **P** to show the directions of the *electric fields* at **P** due to each charge. [1]

(ii) Calculate the **resultant** electric field strength at point **P**. [4]

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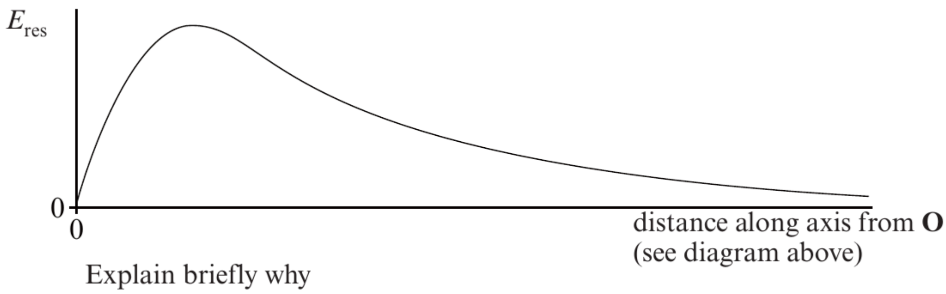
(iii) The graph shows how the resultant electric field strength, E_{res}, varies with distance along the axis from point **O**.



Explain briefly why

(I) E_{res} is zero at **O**. [1]

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(II) E_{res} decreases with distance along the axis, at large distances from **O**. [1]

(b) A positive ion with a charge of 4.8×10^{-19} C and mass 4.5×10^{-26} kg enters the region shown in the diagram, travelling along the axis. At point **O** the ion is moving to the right with a speed of 2000 m s^{-1}. Gravitational and resistive forces are negligible.

(i) Calculate the *acceleration* of the ion as it passes through point **P**. [Make use of your answer from *(a)*(ii).] [2]

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(ii) Describe how the *speed* of the ion changes as it travels along the axis from **O** until it is well beyond P. [2]

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(iii) Calculate the *total energy* (kinetic energy + electrical potential energy) of the ion as it passes through point **O**. [See diagram.] [4]

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(iv) Hence find the maximum speed eventually reached by the ion. [3]

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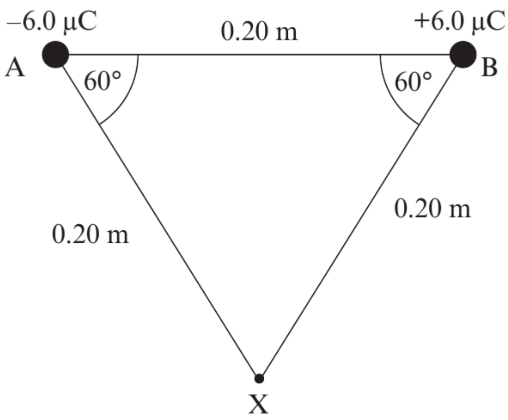
6. Two point charges of –6.0 μC and +6.0 μC are arranged at points A and B respectively as in the diagram. Point X lies as shown, with ABX being an equilateral triangle.



(a) Indicate clearly on the diagram the directions of

(i) the electric field at X due to the charge at A (label it E_A), [1]

(ii) the electric field at X due to the charge at B (label it E_B), [1]

(iii) the resultant (net) electric field at X due to the charges at A and B (label it E_R). [1]

(b) Calculate the magnitude of the resultant electric field at X, showing your working clearly. [3]

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(c) Point Y is at a distance 0.40 m to the right of B.

(i) Determine the electric potential at Y. [3]

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(ii) Calculate the work required to bring a small charge of +2.0 μC from a distant point to Y. [2]

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(iii) The small charge has a mass of $5{\cdot}0 \times 10^{-3}$ kg. If it is released from rest at point Y, determine its speed when it returns to a distant point. [2]

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6. A small sphere has a charge q = + 1.11 × 10^{-6} C.

(a) How many electrons have been removed from the sphere? [2]

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(b) On the grids below sketch curves between distances 0.5 m and 2.0 m from the centre of the sphere for:

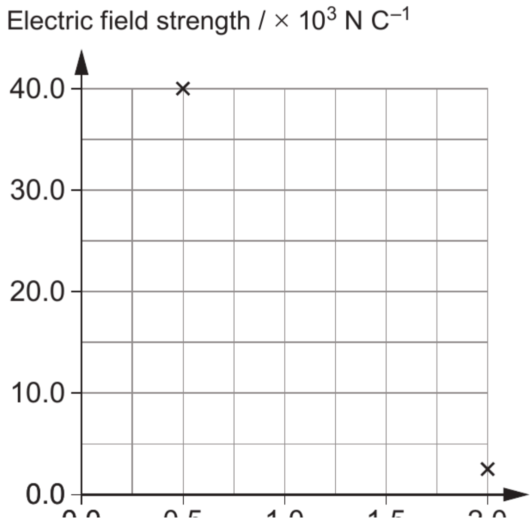
(i) the electric field strength (first grid);

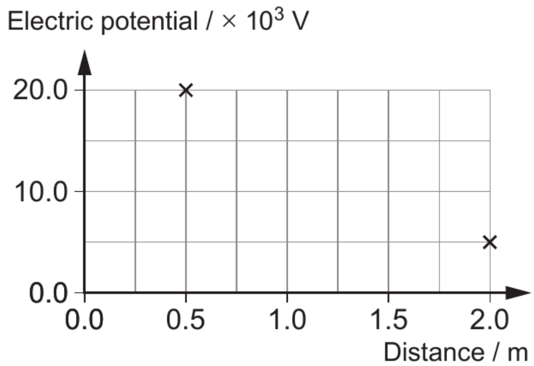
(ii) the electric potential (second grid).

The points at 0.5 m and 2.0 m are already shown. [3]

You may wish to use the approximation: $\frac{1}{4\pi\varepsilon_0}$ = 9.0 × 10^9 F^{-1} m.

Space for calculations if needed:





Examiner only

(c) (i) A second identical sphere also has a charge of + 1.11×10^{-6} C. It is brought from a distant point to a distance 1.2 m from the first sphere. Determine the work required to do this. [2]

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(ii) Determine the magnitude of the electric field strength at the point between the two spheres that is 0.7 m from the left-hand side sphere. Show the direction of the field at this point. [3]

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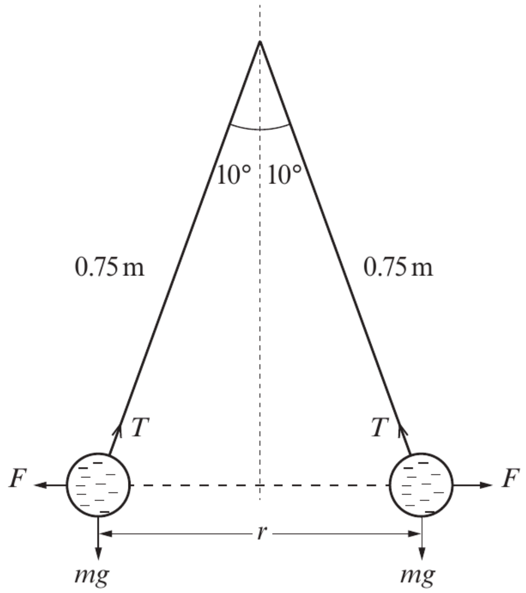
Examiner only

7. Two spherical balloons each of mass m carry equal numbers of excess electrons distributed uniformly over their surfaces. The total excess charge on each balloon is -2.55×10^{-7} C.

When both balloons are hung from the same point by light strings of lengths 0.75 m, each string makes an angle of 10° with the vertical.



The weight mg of each balloon, the electrostatic forces F acting on each balloon and the tensions T in the strings are shown in the diagram.

(a) (i) Use the information in the diagram to show that the separation r of the centres of the balloons is approximately 0.26 m. [2]

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(ii) Calculate the electrostatic force F on each balloon. [2]

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Examiner only

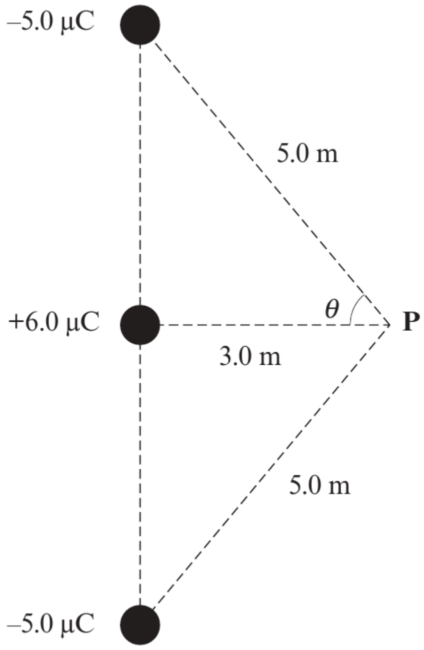
(iii) Show that the electrostatic potential energy of the system is 2.25×10^{-3} J. [2]

(b) (i) Use the answer to *(a)*(ii) to show that the tension T in each string is 0.050 N. [3]

(ii) Hence calculate the mass of each balloon. [1]

END OF PAPER

4. Three charges are placed in a line as shown.



[use the approximation $\frac{1}{4\pi\varepsilon_0} = 9.0 \times 10^9\,\mathrm{F^{-1}\,m}$]

(a) Draw **three arrows** at **P** representing the electric fields due to **each** of the three charges. [2]

(b) Calculate the electric field at **P** due to the +6.0 μC charge only. [2]

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(c) Calculate the resultant electric field at **P** (hint: cos θ = 0.6). [3]

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Examiner only

(d) (i) Show that the total electric potential at **P** is zero. [3]

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(ii) A positive charge is released from rest at point **P** and encounters **no resistive forces**. Explain in terms of energy and forces why the charge initially accelerates to the right but eventually becomes stationary a long way away from the three charges. [3]

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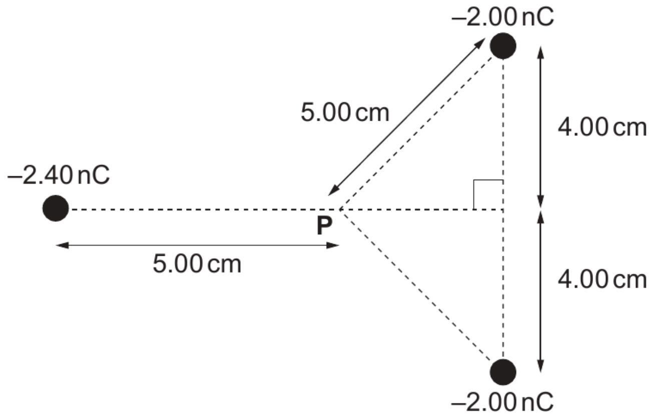
6. Three negative charges are arranged as shown.

(a) **Draw arrows at P** to represent the three electric fields due to the three charges. [2]



(b) Show that the resultant electric field at **P** is zero.

(You may like to use the approximation $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9\ \text{F}^{-1}\text{m}$.) [5]

(c) Calculate the electric potential at **P**. [3]

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(d) An electron starts to accelerate from rest from point **P** (in a direction out of the plane of the paper). Calculate its speed when it arrives at another point where the potential is –200 V. [3]

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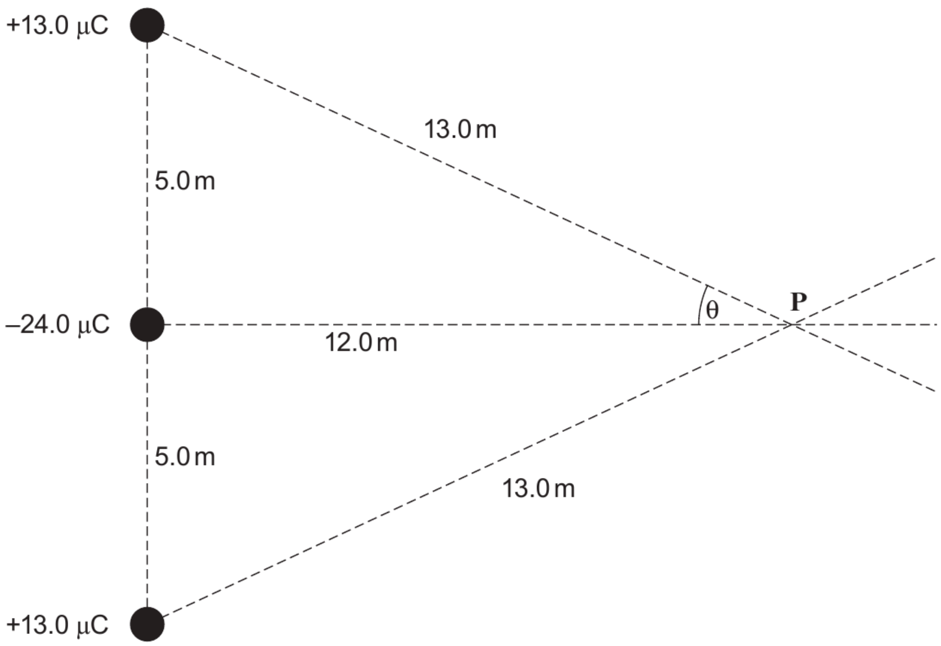
Examiner only

6. Three charges are arranged as shown.



(a) **Draw three arrows at P** to represent the electric fields due to **each** of the three charges. [2]

(b) Calculate the electric field strength at **P** due to the –24.0 μC charge only (you may use the approximation $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9\ \text{F}^{-1}\ \text{m}$). [2]

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(c) Calculate the resultant electric field strength at **P** (you may use the approximation $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9 \text{ F}^{-1}\text{ m}$). [3]

(d) Show that the electric potential at **P** is zero. [2]

(e) A negative charge is released from rest at point **P** and encounters **no resistive forces.** Explain in terms of energy and forces why the charge initially accelerates to the right but eventually becomes stationary a long way away from the three charges. [3]

END OF QUESTION PACK

11 questions · 131 marks · ~2 h 50 min
Source: WJEC PH4 (2008 modular spec)
Curated for WJEC Physics 2015 spec A2 Unit 4 — Topic 2