



**Topic Test: OxfordAQA**  
**International A level Physics**  
Electric fields and capacitance

Name: \_\_\_\_\_

Class: \_\_\_\_\_

Date: \_\_\_\_\_

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Time: **57 minutes**

Marks: **44 marks**

Comments:

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1

(a) (i) Define the *electric field strength*,  $E$ , at a point in an electric field.

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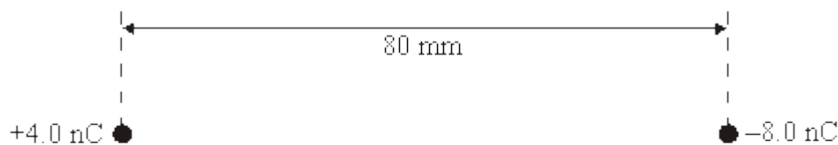
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(ii) State whether  $E$  is a scalar or a vector quantity.

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(3)

(b) Point charges of  $+4.0 \text{ nC}$  and  $-8.0 \text{ nC}$  are placed  $80 \text{ mm}$  apart, as shown in the figure below.



(i) Calculate the magnitude of the force exerted on the  $+4.0 \text{ nC}$  charge by the  $-8.0 \text{ nC}$  charge.

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(ii) Determine the distance from the  $+4.0 \text{ nC}$  charge to the point, along the straight line between the charges, where the electric potential is zero.

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(4)

- (c) Point **P** in the figure above is equidistant from the two charges.
- Draw two arrows on the figure above at **P** to represent the directions and relative magnitudes of the components of the electric field at **P** due to each of the charges.
  - Hence draw an arrow, labelled **R**, on the figure above at **P** to represent the direction of the resultant electric field at **P**.

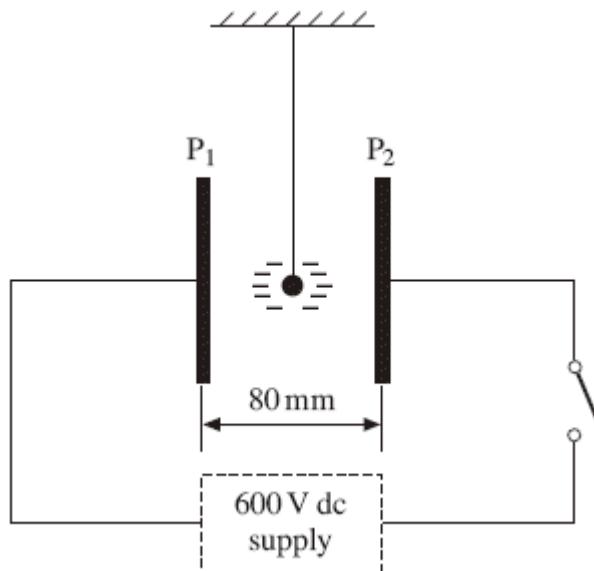
(3)

(Total 10 marks)

2

**Figure 1** shows a small polystyrene ball which is suspended between two vertical metal plates, **P**<sub>1</sub> and **P**<sub>2</sub>, 80 mm apart, that are initially uncharged. The ball carries a charge of  $-0.17 \mu\text{C}$ .

**Figure 1**



- A pd of 600 V is applied between **P**<sub>1</sub> and **P**<sub>2</sub> when the switch is closed. Calculate the magnitude of the electric field strength between the plates, assuming it is uniform.

answer = \_\_\_\_\_ V m<sup>-1</sup>

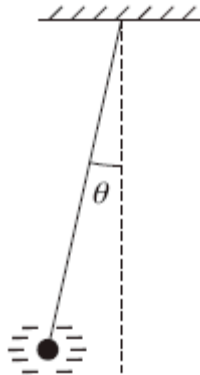
(2)

- (ii) Show that the magnitude of the electrostatic force that acts on the ball under these conditions is 1.3 mN.

(1)

- (b) Because of the electrostatic force acting on it, the ball is displaced from its original position. It comes to rest when the suspended thread makes an angle  $\theta$  with the vertical, as shown in **Figure 2**.

**Figure 2**



- (i) On **Figure 2**, mark and label the forces that act on the ball when in this position.

(2)

- (ii) The mass of the ball is  $4.8 \times 10^{-4}$  kg. By considering the equilibrium of the ball, determine the value of  $\theta$ .

answer = \_\_\_\_\_ degrees

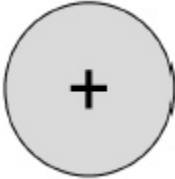
(3)

(Total 8 marks)

3

**Figure 1** shows an isolated spherical oil drop carrying a charge of  $+6.4 \times 10^{-19}$  C. Assume that the oil drop behaves as a charged, conducting sphere.

**Figure 1**



(a) Draw electric field lines onto **Figure 1** to show the electric field around the oil drop.

(1)

(b) Define the absolute electrical potential at a point in an electric field.

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(1)

(c) The oil drop has a radius of  $1.4 \times 10^{-6}$  m.

Calculate the absolute electric potential at the surface of the oil drop.

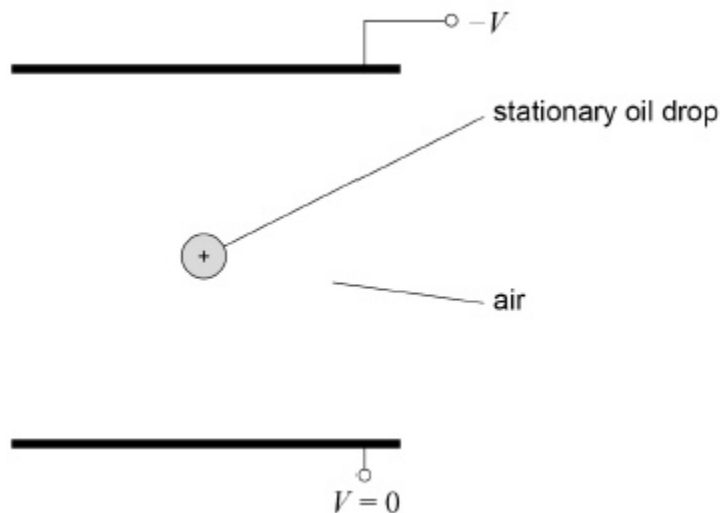
absolute electric potential = \_\_\_\_\_ V

(2)

- (d) **Figure 2** shows the charged oil drop stationary in air in an electric field between two parallel plates. The potential difference between the plates is  $V$ .

Draw and label arrows on **Figure 2** to represent the forces acting on the oil drop.

**Figure 2**



(1)

- (e) The potential difference between the plates is now reversed so that the oil drop is attracted towards the lower plate.

Explain why the initial acceleration of the oil drop is approximately  $20 \text{ m s}^{-2}$ .

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(2)

- (f) Describe and explain the motion of the oil drop after the potential difference between the plates is reversed.

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(2)

(Total 9 marks)

4

- (a) A capacitor has a capacitance of  $80 \mu\text{F}$ .

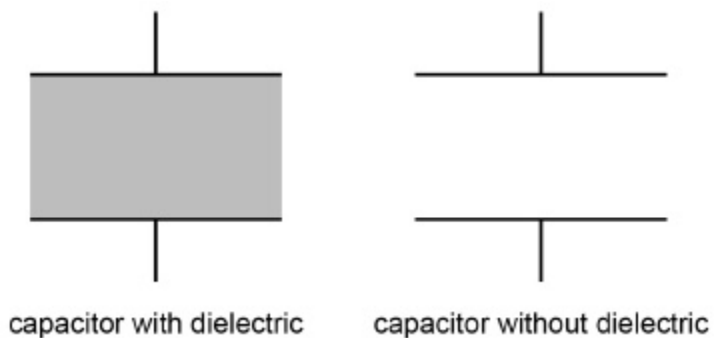
State what is meant by a capacitance of  $80 \mu\text{F}$ .

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(1)

- (b) The diagram shows a parallel plate capacitor with and without a dielectric between the plates.



Explain how the presence of a dielectric between the plates increases the capacitance of the capacitor.

You may add to the diagram to assist your explanation.

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**(3)**

- (c) An  $80 \mu\text{F}$  capacitor is charged so that the potential difference across it is  $5.0 \text{ V}$ . The capacitor is then partially discharged, losing  $120 \mu\text{C}$  of charge.

Calculate the percentage reduction in the energy stored in the capacitor due to the partial discharge.

percentage reduction in energy = \_\_\_\_\_

(4)

(Total 8 marks)

5

What is a unit for the permittivity of free space,  $\epsilon_0$

A  $\text{A}^2 \text{kg}^{-1} \text{m}^{-3} \text{s}^{+4}$

B  $\text{A}^2 \text{kg}^{-2} \text{m}^{-3} \text{s}^{-4}$

C  $\text{A}^2 \text{kg}^{-1} \text{m}^{-1} \text{s}^{+4}$

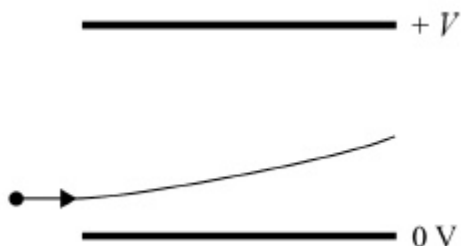
D  $\text{A}^2 \text{kg}^{-1} \text{m}^{-3} \text{s}^{-2}$

(Total 1 mark)

6

The diagram shows two horizontal plates with an electric field between them.

A charged particle enters at right angles to the field. The force due to the electric field is the only force acting on the particle.



Which change increases the vertical velocity of the particle as it leaves the electric field?

- A Decreasing the length of the plates.
- B Increasing the separation of the plates.
- C Decreasing the initial velocity of the particle.
- D Using a particle of greater mass but the same charge.

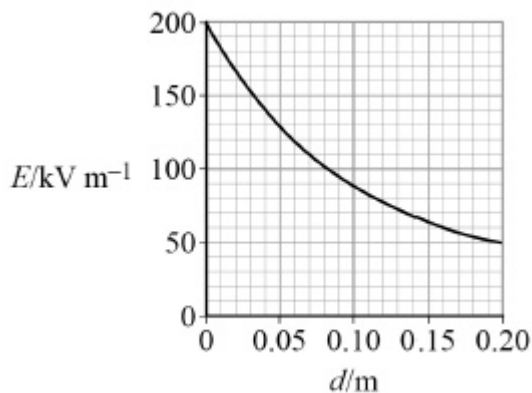
(Total 1 mark)

**7** X and Y are two points in an electric field a distance  $d$  apart. The potential difference between X and Y is  $V$ . A particle carrying a charge  $Q$  is accelerated by that field from X to Y in a time  $t$ . The gain in kinetic energy of the particle is

- A  $QV$
- B  $\frac{1}{2}QV^2$
- C  $\frac{QVt}{d}$
- D  $QVd$

(Total 1 mark)

**8** The graph shows the variation in electric field strength  $E$  with distance  $d$  from the surface of a charged sphere of radius 0.20 m.



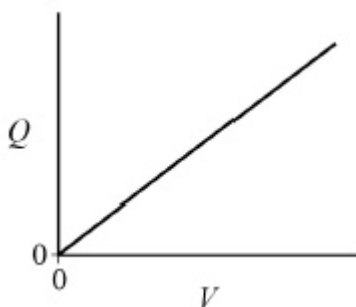
What is the potential difference between a point on the surface of the sphere and a point 0.20 m above the surface?

- A 20 kV
- B 40 kV
- C 50 kV
- D 150 kV

(Total 1 mark)

9

The graph shows the variation of the charge  $Q$  on a capacitor with the potential difference  $V$  across it.



Which row shows the significance of the gradient of the graph and the area between the line and the  $V$  axis?

	Gradient of the graph	Area between the line and the $V$ axis	
A	Charging current	Time constant	<input type="checkbox"/>
B	Charging current	Energy stored in the capacitor	<input type="checkbox"/>
C	Capacitance of the capacitor	Time constant	<input type="checkbox"/>
D	Capacitance of the capacitor	Energy stored in the capacitor	<input type="checkbox"/>

(Total 1 mark)

**10**

A capacitor of capacitance  $9.0 \text{ nF}$  has plates with an overlapping area of  $18 \text{ cm}^2$  separated by a dielectric of thickness  $0.15 \text{ mm}$ .

What is the relative permittivity of the dielectric?

**A**  $8.5 \times 10^1$

**B**  $8.5 \times 10^3$

**C**  $7.5 \times 10^6$

**D**  $7.5 \times 10^8$

**(Total 1 mark)**

## Mark schemes

**1** (a) (i) force per unit charge **(1)**  
acting on a positive charge **(1)**

(ii) vector **(1)**

3

(b) (i) 
$$F \left( = \frac{Q_1 Q_2}{4\pi\epsilon_0 r^2} \right) = \frac{4.0 \times 10^{-9} \times 8.0 \times 10^{-9}}{4\pi \times 8.85 \times 10^{-12} \times (80 \times 10^{-3})^2} \quad \mathbf{(1)}$$

$$= 4.5(0) \times 10^{-5} \text{N} \quad \mathbf{(1)}$$

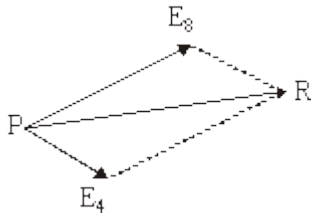
(ii) (use of  $V = \frac{Q}{4\pi\epsilon_0 r}$  gives) 
$$0 = \left( \frac{4.0 \times 10^{-9}}{4\pi\epsilon_0 x} \right) - \left( \frac{8.0 \times 10^{-9}}{4\pi\epsilon_0 (80 \times 10^{-3} - x)} \right)$$

or 
$$\frac{4}{x} = \frac{8}{80 - x} \quad \mathbf{(1)}$$

$$x = 26.7 \text{mm} \quad \mathbf{(1)}$$

4

(c) correct directions for  $E_4$  and  $E_8$  **(1)**  
 $E_8$  approx twice as long as  $E_4$  **(1)**  
correct direction of resultant R  
shown **(1)**



3

[10]

**2** (a) (i) 
$$E \left( = \frac{V}{d} \right) = \frac{600}{80 \times 10^{-3}} \quad \mathbf{(1)}$$

$$= 7.5 \times 10^3 \text{ (V m}^{-1}\text{)} \quad \mathbf{(1)}$$

2

(ii) force  $F (= EQ) = 7500 \times 0.17 \times 10^{-6} \quad \mathbf{(1)}$  ( $= 1.28 \times 10^{-3} \text{ N}$ )

1

- (b) (i) correct labelled arrows placed on diagram to show the three forces acting;

- electric force  $F$  (or 1.3 mN) horizontally to left **(1)**
- $W$  (or  $mg$ ) vertically down **and**
- tension  $T$  upwards along the thread **(1)**

2

- (ii)  $F = T \sin\theta$  and  $mg = T \cos\theta$  give  $F = mg \tan\theta$  **(1)**  
(or by triangle or parallelogram methods)

$$\tan\theta \left( = \frac{F}{mg} \right) = \frac{1.28 \times 10^{-8}}{4.8 \times 10^{-4} \times 9.81} (= 0.272) \quad \mathbf{(1)}$$

gives  $\theta = 15(.2)^\circ$  **(1)**

3

**[8]**

**3**

- (a) At least 6 radial lines, straight and evenly spaced by eye with arrows away from the centre ✓

*Accept lines not drawn with a ruler if they are straight and symmetrical*

*Condone field shown within the drop*

1

- (b) Work done moving unit charge from infinity (to the point in the field) ✓

*Accept equation with terms defined*

1

- (c) Substitution into  $V = \frac{1}{4\pi\epsilon_0} \frac{Q}{r}$  ie  $\frac{6.4 \times 10^{-19}}{4\pi \times 8.85 \times 10^{-12} \times 5.8 \times 10^{-5}}$  ✓

*Condone use of  $1.6 \times 10^{-19}$  for the 1<sup>st</sup> MP only*

$4.11 \times 10^{-3}$  ✓

2

- (d) Up arrow labelled  $F_E$  or  $\frac{Vq}{d}$  or similar **and** down arrow labelled weight,  $W$ , or  $mg$  or similar ✓

*Condone difference in length of arrows. Accept if the upward pointing arrow is labelled  $F$*

1

- (e) Recognition that  $F_E$  is equal (and opposite) to weight ✓

New resultant force is 2 mg owtte ✓

*$2 \times 9.81$  or  $19.62$  seen gets only 1 mark if it is without acceptable explanation*

2

- (f) (Drop moves downwards)  
 (Weight and) electrostatic force remain constant ✓  
 Air resistance increases (with speed) ✓  
 Terminal speed reached **or** acceleration gets smaller ✓

ANY 2

max 2

[9]

**4** (a) Charge stored per unit pd or per unit volt is  $80 \mu\text{C}$  wtte ✓ 1

- (b) Increases the permittivity **or** has a greater permittivity than vacuum ✓  
 Reduces the electric field strength...✓  
 ... because polarised molecules rotate (to align with field)✓  
 ... so reduces the pd across the plates or more charge can be stored for the same pd  
 ✓

Any three

3

- (c) Uses  $Q = CV$  at some point in the calculation ✓

Uses  $E = \frac{1}{2} CV^2$  or  $E = \frac{1}{2} QV$  or  $E = \frac{1}{2} \frac{Q^2}{C}$  at some point in the calculation ✓

Calculates initial energy stored ( $1000 \mu\text{J}$ ) or final energy stored ( $490 \mu\text{J}$ ) ✓

51 (%) **cao** ✓

4

[8]

**5** A [1]

**6** C [1]

**7** A [1]

**8** A [1]

**9** D [1]

**10** A [1]