Point Charges & Electric Potential

Question paper 2

Level	International A Level
Subject	Physics
Exam Board	CIE
Topic	Electric Fields
Sub Topic	Point Charges & Electric Potential
Paper Type	Theory
Booklet	Question paper 2

Time Allowed: **64 minutes**

Score: **/53**

Percentage: **/100**

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

1 A helium nucleus contains two protons.

In a model of the helium nucleus, each proton is considered to be a charged point mass. The separation of these point masses is assumed to be 2.0×10^{-15} m.

(a) For the two protons in this model, calculate

(i) the electrostatic force,

electrostatic force = ... N [2]

(ii) the gravitational force.

gravitational force = ... N [2]

(b) Using your answers in **(a)**, suggest why

(i) there must be some other force between the protons in the nucleus,

.....

.....

.....

..... [3]

(ii) this additional force must have a short range.

.....

.....

..... [2]

2 An α-particle and a proton are at rest a distance 20μm apart in a vacuum, as illustrated in Fig. 4.1.

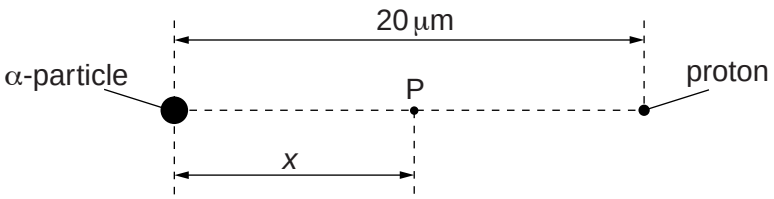

Fig. 4.1

(a) (i) State Coulomb's law.

.....

.....

.....[2]

(ii) The α-particle and the proton may be considered to be point charges.
Calculate the electric force between the α-particle and the proton.

force = ... N [2]

(b) (i) Define *electric field strength*.

.....

.....

.....[2]

(ii) A point P is distance x from the α-particle along the line joining the α-particle to the proton (see Fig. 4.1). The variation with distance x of the electric field strength E_α due to the α-particle alone is shown in Fig. 4.2.

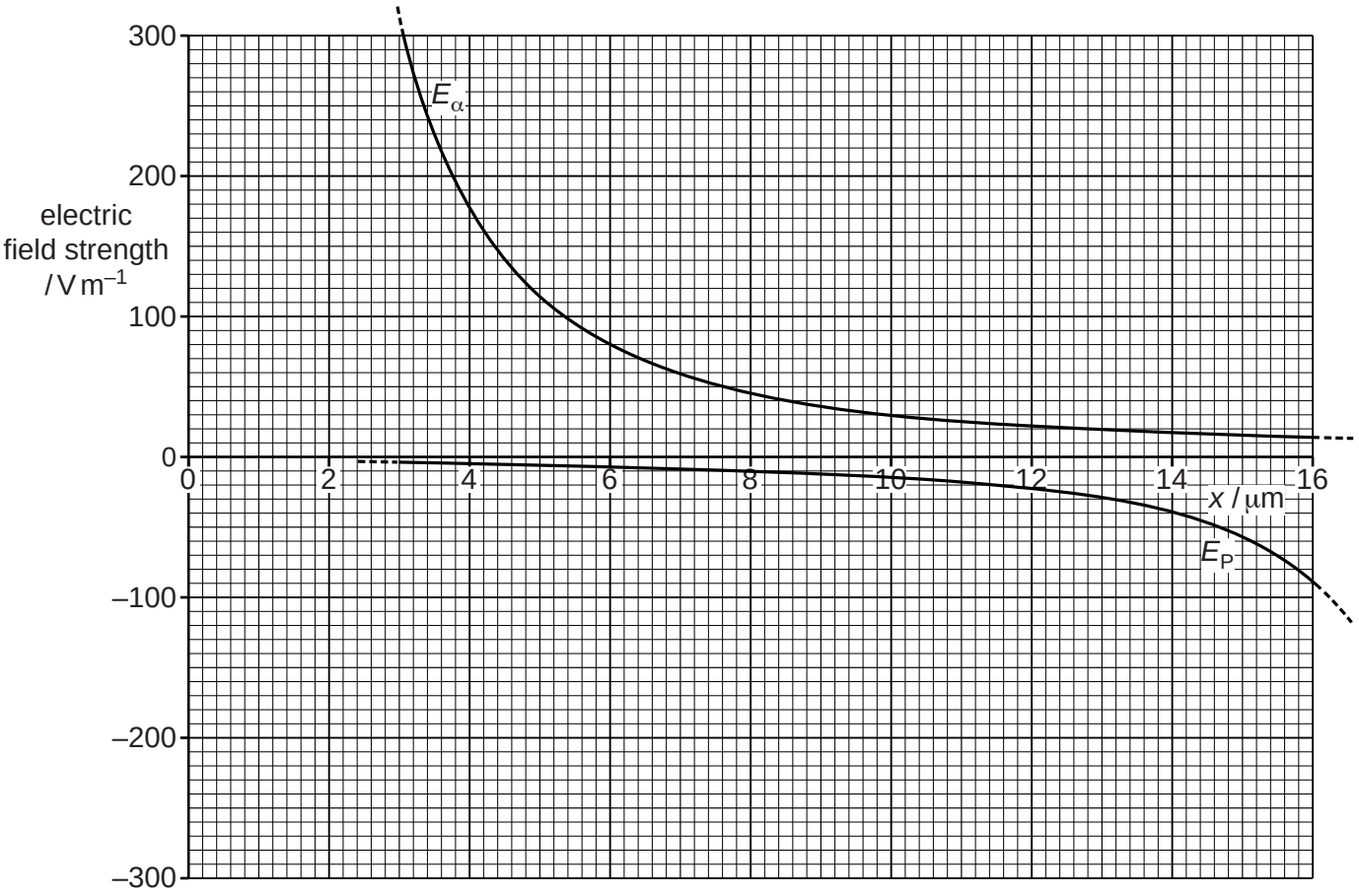

Fig. 4.2

The variation with distance x of the electric field strength E_P due to the proton alone is also shown in Fig. 4.2.

1. Explain why the two separate electric fields have opposite signs.

.....

.....

..... [2]

2. On Fig. 4.2, sketch the variation with x of the combined electric field due to the α-particle and the proton for values of x from 4 μm to 16 μm. [3]

3 **(a)** Define *electric potential* at a point.

.....

.....

..... [2]

(b) Two point charges A and B are separated by a distance of 20 nm in a vacuum, as illustrated in Fig. 3.1.

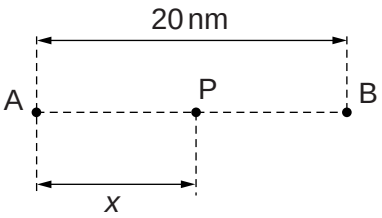

Fig. 3.1

A point P is a distance x from A along the line AB.
The variation with distance x of the electric potential V_A due to charge A alone is shown in Fig. 3.2.

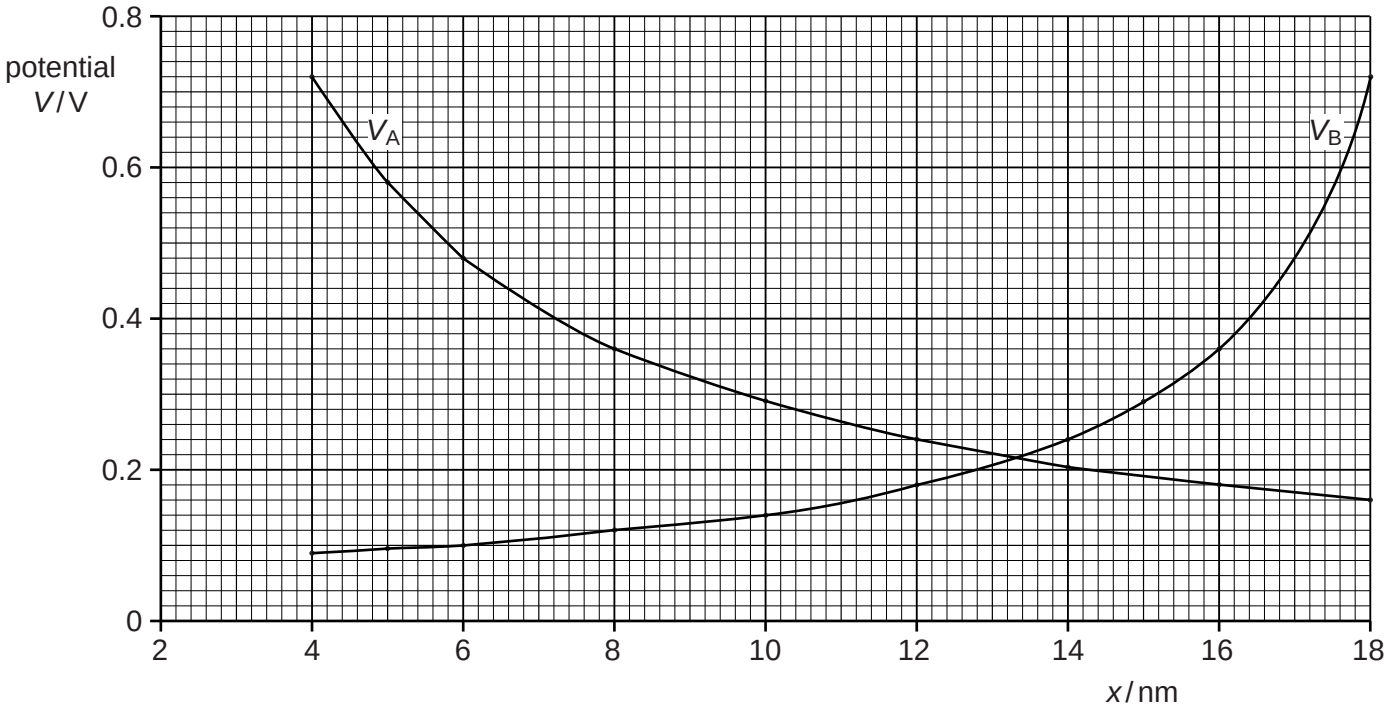

Fig. 3.2

The variation with distance x of the electric potential V_B due to charge B alone is also shown in Fig. 3.2.

(i) State and explain whether the charges A and B are of the same, or opposite, sign.

.....

.....

.....[2]

(ii) By reference to Fig. 3.2, state how the combined electric potential due to both charges may be determined.

.....

.....[1]

(iii) Without any calculation, use Fig. 3.2 to estimate the distance x at which the combined electric potential of the two charges is a minimum.

x = ... nm [1]

(iv) The point P is a distance x = 10 nm from A.
An α-particle has kinetic energy E_K when at infinity.

Use Fig. 3.2 to determine the minimum value of E_K such that the α-particle may travel from infinity to point P.

E_K = ... J [3]

4 **(a)** Define *electric potential* at a point.

.....

.....

..... [2]

(b) A charged particle is accelerated from rest in a vacuum through a potential difference V. Show that the final speed v of the particle is given by the expression

$$v = \sqrt{\left(\frac{2Vq}{m}\right)}$$

where $\frac{q}{m}$ is the ratio of the charge to the mass (the specific charge) of the particle.

[2]

(c) A particle with specific charge $+9.58 \times 10^7\,\text{C kg}^{-1}$ is moving in a vacuum towards a fixed metal sphere, as illustrated in Fig. 4.1.

Fig. 4.1

The initial speed of the particle is $2.5 \times 10^5\,\text{m s}^{-1}$ when it is a long distance from the sphere.
The sphere is positively charged and has a potential of +470V.

Use the expression in **(b)** to determine whether the particle will reach the surface of the sphere.

[3]

5 **(a)** An insulated metal sphere of radius R is situated in a vacuum. The charge q on the sphere may be considered to be a point charge at the centre of the sphere.

(i) State a formula, in terms of R and q, for the potential V on the surface of the sphere.

..... [1]

(ii) Define capacitance and hence show that the capacitance C of the sphere is given by the expression

$$C = 4\pi\varepsilon_0 R.$$

[1]

(b) An isolated metal sphere has radius 45 cm.

(i) Use the expression in **(a)(ii)** to calculate the capacitance, in picofarad, of the sphere.

capacitance = ... pF [2]

(ii) The sphere is charged to a potential of 9.0×10^5 V.
A spark occurs, partially discharging the sphere so that its potential is reduced to 3.6×10^5 V.

Determine the energy of the spark.

energy = ... J [3]

6 **(a)** State what is meant by a line of force in

(i) a gravitational field,

.....

..... [1]

(ii) an electric field.

.....

..... [2]

(b) A charged metal sphere is isolated in space.
State one similarity and one difference between the gravitational force field and the electric force field around the sphere.

similarity: .....

.....

difference: .....

.....

..... [3]

(c) Two horizontal metal plates are separated by a distance of 1.8 cm in a vacuum.
A potential difference of 270 V is maintained between the plates, as shown in Fig. 3.1.

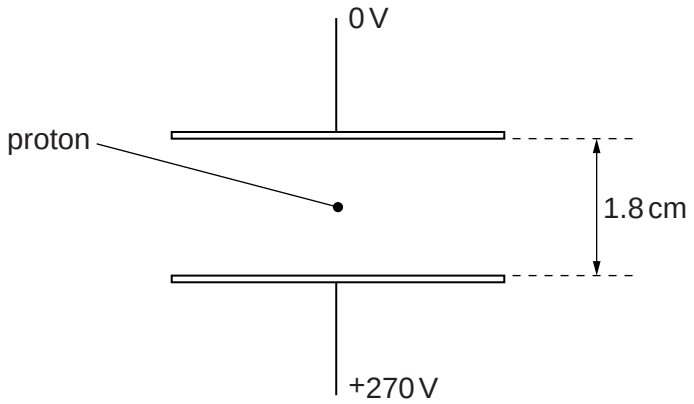

Fig. 3.1

A proton is in the space between the plates.
Explain quantitatively why, when predicting the motion of the proton between the plates, the gravitational field is not taken into consideration.

[4]