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ELECTROSTATICS (A2)

ELECTRIC FORCE & POTENTIAL:

Q.1 Two point charges A and B each have a charge of + 6.4 × 10^{-19} C. They are separated in a vacuum by a distance of 12.0 μm, as shown in Fig. 1.1.

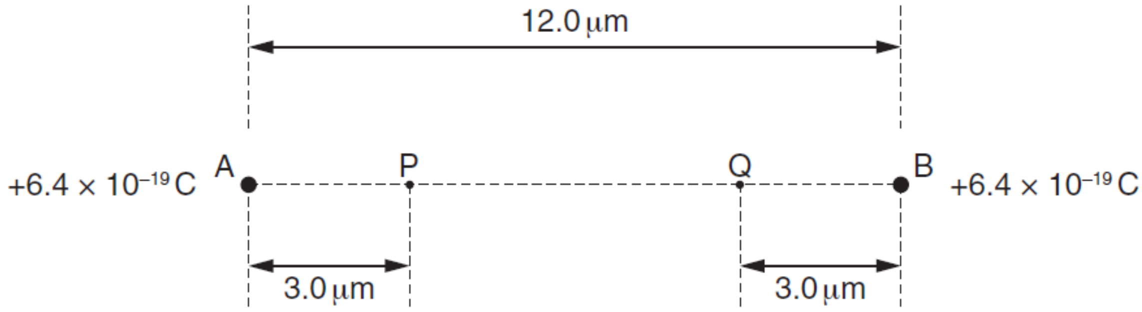

Fig. 1.1

Points P and Q are situated on the line AB. Point P is 3.0 μm from charge A and point Q is 3.0 μm from charge B.

(a) Calculate the force of repulsion between the charges A and B.

force = ... N [3]

(b) Explain why, without any calculation, when a small test charge is moved from point P to point Q, the net work done is zero.

....

....

.... [2]

{*Q.4/9702/42/M/J/10*}

Q.2 A small charged metal sphere is situated in an earthed metal box. Fig. 2.1 illustrates the electric field between the sphere and the metal box.

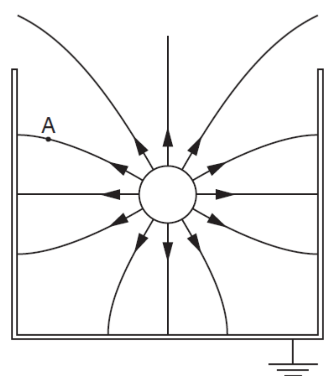

Fig. 2.1

(a) By reference to Fig. 2.1, state and explain

(i) whether the sphere is positively or negatively charged,

....

....

....[2]

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(ii) why it appears as if the charge on the sphere is concentrated at the centre of the sphere.

....

....[1]

(b) On Fig. 2.1, draw an arrow to show the direction of the force on a stationary electron situated at point A. [2]

(c) The radius *r* of the sphere is 2.4 cm. The magnitude of the charge *q* on the sphere is 0.76 nC.

(i) Use the expression

$$V = \frac{Q}{4\pi\varepsilon_0 r}$$

to calculate a value for the magnitude of the potential *V* at the surface of the sphere.

V = ...V [2]

(ii) State the sign of the charge induced on the inside of the metal box. Hence explain whether the actual magnitude of the potential will be greater or smaller than the value calculated in **(i)**.

....

....

....

....[3]

(d) A lead sphere is placed in a lead box in free space, in a similar arrangement to that shown in Fig. 2.1. Explain why it is **not** possible for the gravitational field to have a similar shape to that of the electric field.

....

....

....[1]

{*Q.4/9702/04/O/N/07*}

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

....

.... [2]

(b) Two isolated point charges A and B are separated by a distance of 30.0 cm, as shown in Fig. 3.1.

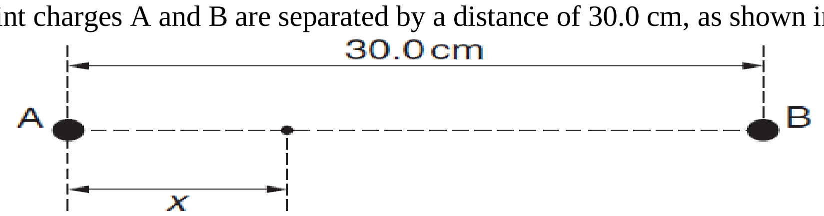

Fig. 3.1

The charge at A is + 3.6 × 10^{-9} C.
The variation with distance *x* from A along AB of the potential *V* is shown in Fig. 3.2. (next page)

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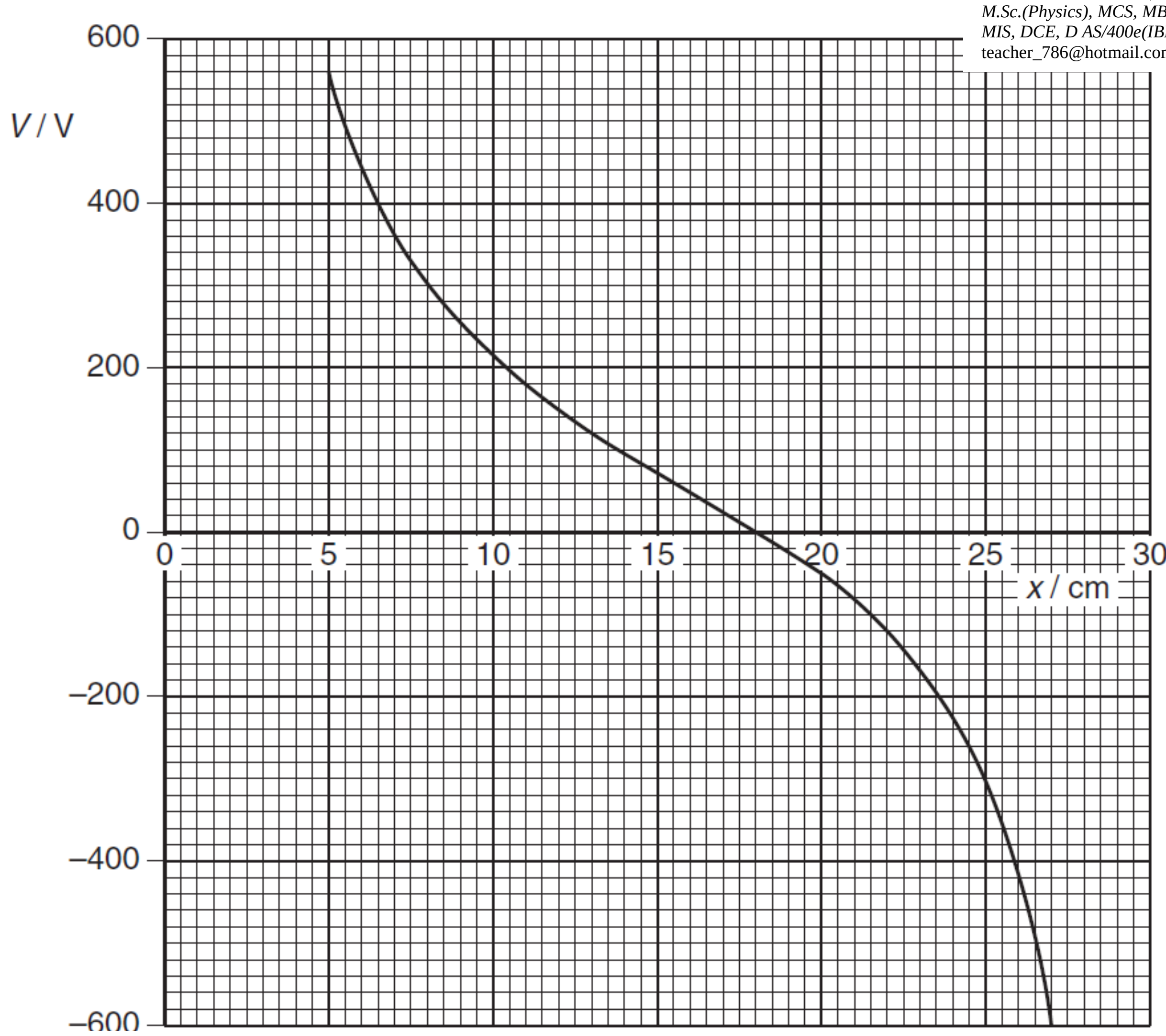

Fig. 3.2

(i) State the value of *x* at which the potential is zero.

x = ... cm [1]

(ii) Use your answer in **(i)** to determine the charge at B.

charge = ... C [3]

(c) A small test charge is now moved along the line AB in **(b)** from x = 5.0 cm to x = 27 cm.
State and explain the value of *x* at which the force on the test charge will be maximum.

....

....

....

.... [3]

ELECTRIC POTENTIAL ENERGY:

Q.4 (a) Define *electric potential* at a point. [2]

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(b) Two small spherical charged particles P and Q may be assumed to be point charges located at their centres. The particles are in a vacuum.

Particle P is fixed in position. Particle Q is moved along the line joining the two charges, as illustrated in Fig.4.1.

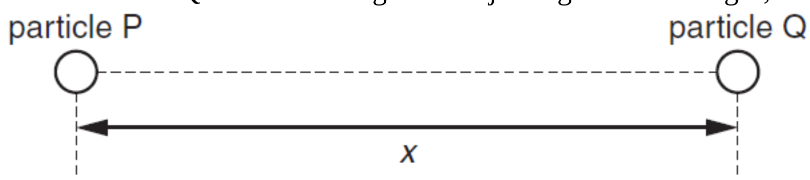

Fig 4.1

The variation with separation *x* of the electric potential energy E_P of particle Q is shown in Fig. 4.2.

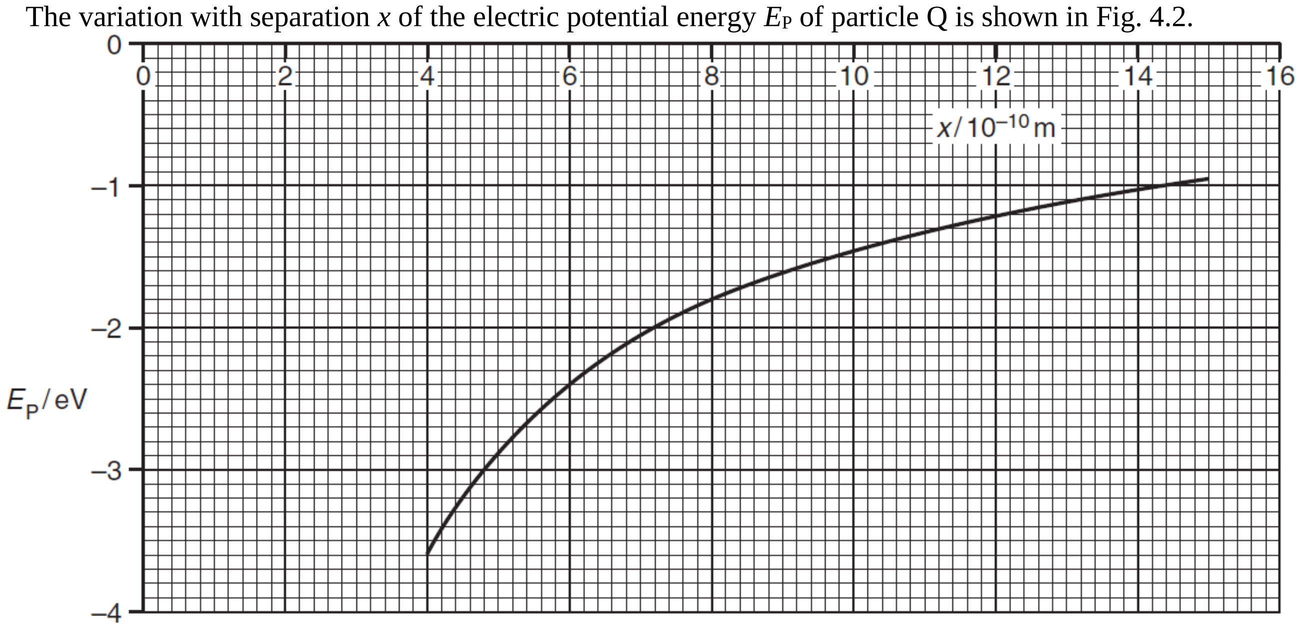

Fig. 4.2

(i) State how the magnitude of the electric field strength is related to potential gradient.

....

.... [1]

(ii) Use your answer in **(i)** to show that the force on particle Q is proportional to the gradient of the curve of Fig. 3.2.

....

....

.... [2]

(c) The magnitude of the charge on each of the particles P and Q is 1.6×10^{-19} C. Calculate the separation of the particles at the point where particle Q has electric potential energy equal to –5.1 eV.

separation = ... m [4]

(d) By reference to Fig. 4.2, state and explain

(i) whether the two charges have the same, or opposite, sign,

....

....

.... [2]

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(ii) the effect, if any, on the shape of the graph of doubling the charge on particle P.

....

....

.... [2]

{*Q.4/9702/41/M/J/11*}

Q.5 (a) Explain what is meant by the *potential energy* of a body.

....

....

.... [2]

(b) Two deuterium $({}^{2}_{1}H)$ nuclei each have initial kinetic energy E_K and are initially separated by a large distance.
The nuclei may be considered to be spheres of diameter 3.8×10^{-15} m with their masses and charges concentrated at their centres.
The nuclei move from their initial positions to their final position of just touching, as illustrated in Fig. 5.1.

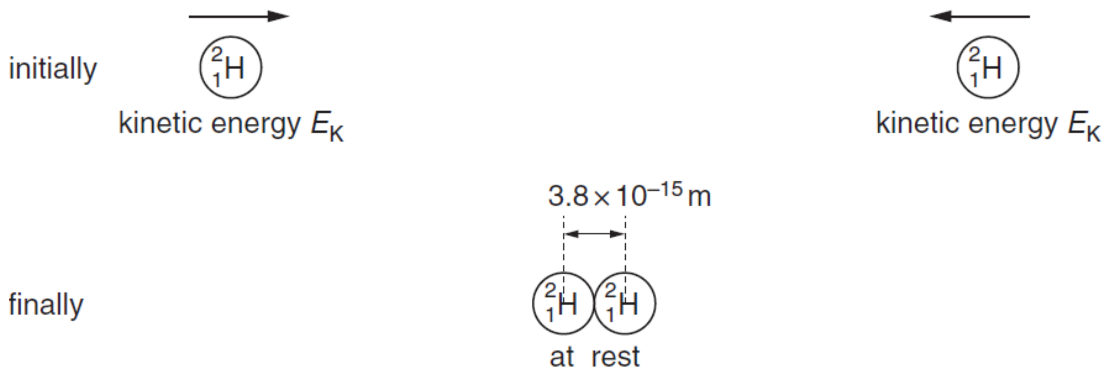

Fig. 5.1

(i) For the two nuclei approaching each other, calculate the total change in
1. gravitational potential energy,

energy = ... J [3]

2. electric potential energy.

energy = ... J [3]

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(ii) Use your answers in **(i)** to show that the initial kinetic energy E_K of each nucleus is 0.19 MeV.

[2]

(iii) The two nuclei may rebound from each other. Suggest one other effect that could happen to the two nuclei if the initial kinetic energy of each nucleus is greater than that calculated in **(ii)**.

....

.... [1]

{*Q. 4/9702/41/M/J/10*}

Q. 6. Two deuterium (^2_1H) nuclei are travelling directly towards one another. When their separation is large compared with their diameters, they each have speed *v* as illustrated in Fig. 6.1.

Fig 6.1

The diameter of a deuterium nucleus is 1.1×10^{-14} m.

(a) Use energy considerations to show that the initial speed *v* of the deuterium nuclei must be approximately 2.5×10^6 m s^{-1} in order that they may come into contact. Explain your working. [3]

(*Remaining parts are from Ideal Gas and Nuclear Physics*)

{*Q.5/9702/04/O/N/08*}

Q. 7 An α-particle (^4He) is moving directly towards a stationary gold nucleus (^{197}Au).

The α-particle and the gold nucleus may be considered to be solid spheres with the charge and mass concentrated at the centre of each sphere.

When the two spheres are just touching, the separation of their centres is 9.6×10^{-15} m.

(a) The α-particle and the gold nucleus may be assumed to be an isolated system.

Calculate, for the α-particle just in contact with the gold nucleus,

(i) its gravitational potential energy,

gravitational potential energy = ... J [3]

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(ii) its electric potential energy.

electric potential energy = ... J [3]

(b) Using your answers in **(a)**, suggest why, when making calculations based on an α-particle scattering experiment, gravitational effects are not considered.

....

....[1]

(c) In the α-particle scattering experiment conducted in 1913, the maximum kinetic energy of the available α-particles was about 6MeV. Suggest why, in this experiment, the radius of the target nucleus could not be determined.

....

....

....[2]

{*Q.no. 2/Nov. 2004/9702-4*}

RELATION BETWEEN ELECTRIC FIELD STRENGTH & ELECTRIC POTENTIAL:

Q.8 An isolated conducting sphere of radius *r* is given a charge +*Q*. This charge may be assumed to act as a point charge situated at the centre of the sphere, as shown in Fig. 8.1.

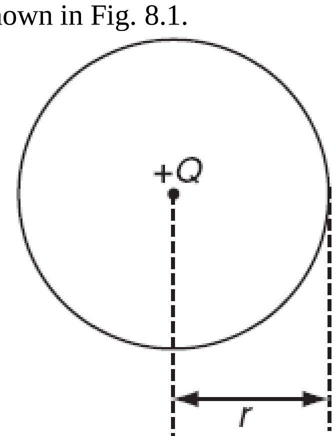

Fig. 8.1

Fig. 8.2. shows the variation with distance *x* from the centre of the sphere of the potential *V* due to the charge +*Q*.

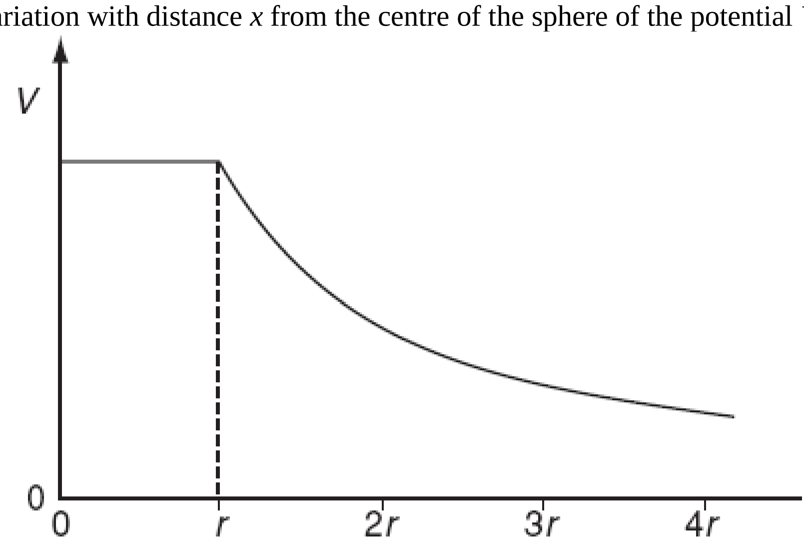

Fig. 8.2

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(a) State the relation between electric field and potential.

……………………………..[1]

(b) Using the relation in **(a)**, on Fig. 8.3 sketch a graph to show the variation with distance *x* of the electric field *E* due to the charge +*Q*.

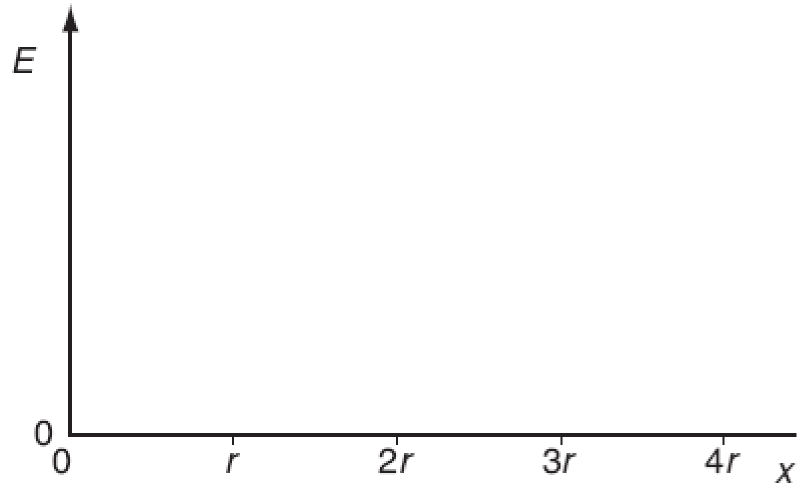


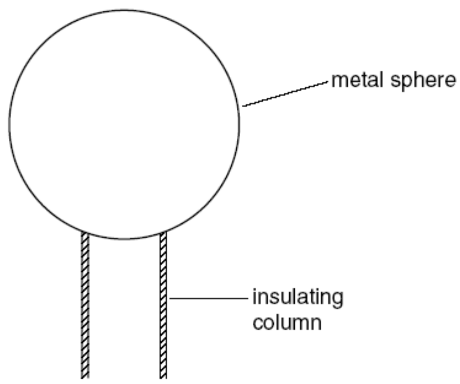
Fig.8.3

[3]

{Q*.5/June 2005***}**

ELECTRIC FIELD:

Q. 9 In a particular experiment, a high voltage is created by charging an isolated metal sphere, as illustrated in Fig. below.



The sphere has diameter 42 cm and any charge on its surface may be considered as if it were concentrated at its centre. The air surrounding the sphere loses its insulating properties, causing a spark, when the electric field exceeds 20 kV cm^{-1}.

(a) By reference to an atom in the air, suggest the mechanism by which the electric field causes the air to become conducting.

....

....

....[3]

(b) Calculate, for the charged sphere when a spark is about to occur,

(i) the charge on the sphere,

charge = ………………………………. C [3]

(ii) its potential.

potential = ………………………………. V [2]

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(c) Under certain conditions, a spark sometimes occurs before the potential reaches that calculated in **(b)(ii)**. Suggest a reason for this.

....

.... [1]

{Q.4/June 2003}

MISCELLIANCE QUESTIONS:

Q. 10 Estimate the ratio of the electrostatic force to the gravitational force between the protons in a helium nucleus. [3]

Answer (1.24×10^{36})

Q. 11 Explain whether it is possible for the electric field strength to be zero at a point where the electric potential is not zero *{Q 4/P3/ D87}*

……

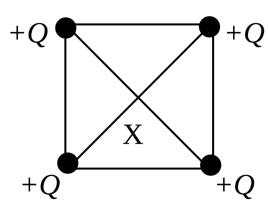
……

………...[2]

Q. 12 Write down a general expression relating electric field strength to electric potential. Hence, explain why the electric potential on the surface of an isolated charged conductor is everywhere the same. *{Q 5/P3/J88}*

[3]

Q. 13 Four identical point charges are arranged at the corners of a square as shown.



Which statement about the values of the electric field strength *E* and the electric potential *V* at point **X** in the middle of the square is true?

	E	*V*
A	not zero	zero
B	not zero	not zero
C	zero	not zero
D	zero	zero

{Q. 15 / N 2000}

Q. 14 Which graph correctly relates the electric field strength ***E*** or electric potential ***V*** in the field of a point charge, with distance *r* from the charge? *{Q. 17 / J 2000}*