3 Two identical metal spheres A and B, each with radius R and carrying charge $+Q$, are isolated in space with their centres a distance $2d$ apart as shown in Fig 3.1. Assume charges remain uniformly distributed on the surfaces of the spheres.

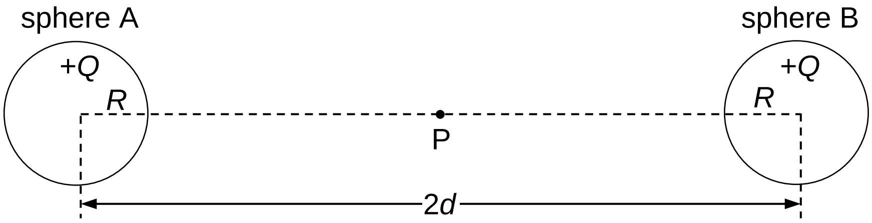

Fig. 3.1

Distance x is measured from the centre of sphere A along the line joining the centres of the two spheres.

Point P is the mid-point between the two metal spheres.

(a) (i) On Fig. 3.2, sketch the variation with distance x from $x = 0$ to $x = 2d$ of the electric potential V between the two spheres.

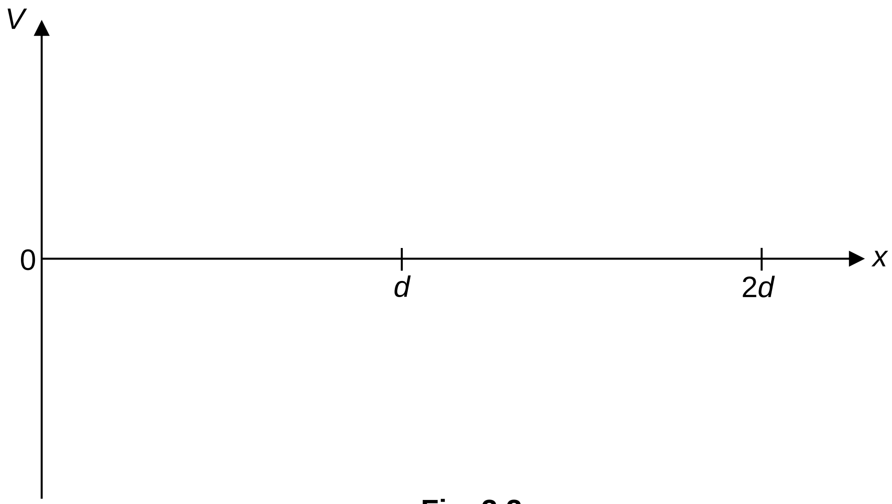

Fig. 3.2

[2]

(ii) On Fig. 3.3, sketch the variation with distance x from $x = 0$ to $x = 2d$ of the electric field strength E between the two spheres.

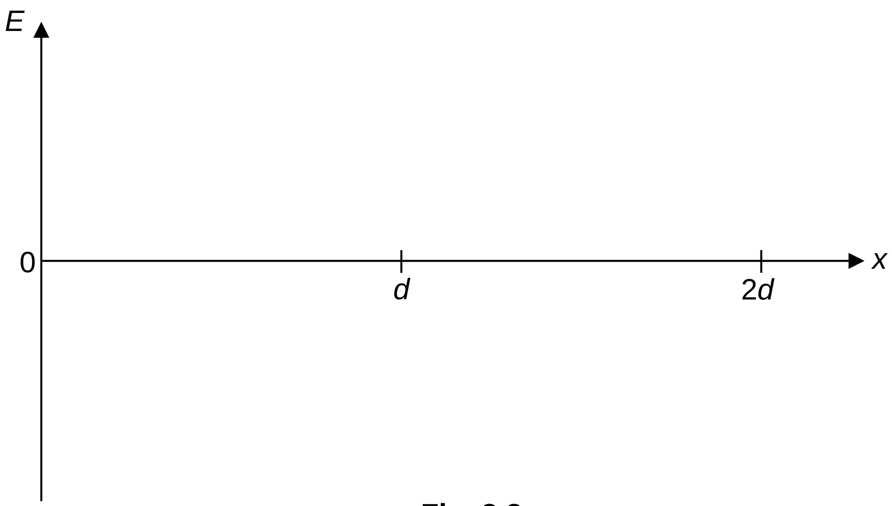

Fig. 3.3

[2]

(b) **(i)** An electron is placed at point P. State and explain the resultant force acting on the electron.

....

....

.... [1]

(ii) The electron is then displaced slightly upwards, perpendicular to the line joining the centres of the two spheres by a distance *y* from point P.

1. On Fig 3.4, draw and label with F_A and F_B, the force that sphere A and sphere B acts on the electron respectively.

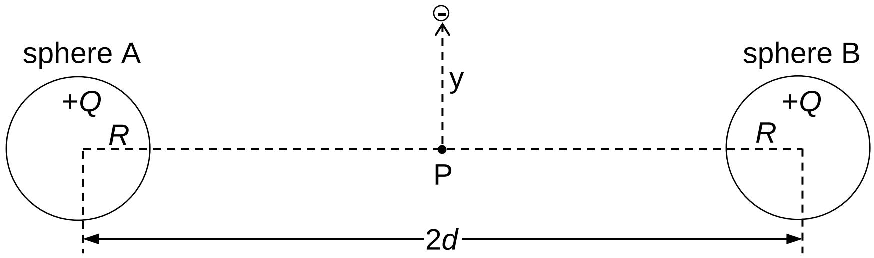

Fig. 3.4

[1]

2. Derive an expression, in terms of *Q*, *d*, *y*, elementary charge *e* and the permittivity of free space ε_0, for the resultant force F_R acting vertically on the electron when the displacement of the electron from its equilibrium position is *y*.

Explain your working.

[2]

3. For very small displacements, it can be shown from the expression derived in **(b)(ii)2.** that the acceleration a of the electron at displacement y is given by

$$a = -\frac{Qe}{2\pi\varepsilon_0 m_e d^3}y$$

where m_e is the mass of the electron.

Describe and explain the subsequent motion of the electron after it is released.

....

....

....

....

....

.... [2]