9 **(a)** State *Coulomb's Law.*

……

……

…… [1]

(b) In a simple model of the structure of an atom, a hydrogen atom can be thought of as consisting of an electron in circular orbit around a proton, as shown in Fig. 9.1.

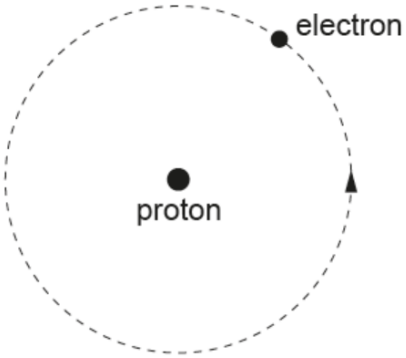

Fig. 9.1

(i) Show that the speed v of the electron is given by

$$v = \frac{e}{\sqrt{4\pi\varepsilon_0 mr}}$$

where e is the elementary charge, r is the radius of the orbit and m is the mass of the electron.

[2]

(ii) Hence, show that the total energy E_T of this system is given by

$$E_T = -\frac{e^2}{8\pi\varepsilon_0 r}$$

[2]

(iii) The ground state energy of an electron in a hydrogen atom is -13.6 eV.

Use the expression in **(b)(ii)** to show that the radius of orbit of an electron in its ground state in a hydrogen atom is approximately 5 x 10^{-11} m.

[2]

(c) Gravitational fields and electric fields are similar in that they can both be described as regions in which force is applied to an object. However, there are some differences between the two fields as well.

State, in words, a further *similarity* and a *difference* between gravitational and electric fields.

Similarity: ……

……

……

Difference: ……

……

……

[2]

(d) The table shows data relating to the Moon orbiting the Earth and an electron orbiting the nucleus of a hydrogen atom.

	Moon orbiting Earth	electron orbiting nucleus
mass / kg	7×10^{22}	9×10^{-31}
speed / m s^{-1}	1×10^{3}	2×10^{7}
orbital radius / m	4×10^{8}	5×10^{-11}

(i) Use the data in the table to determine

1. the de Broglie wavelength of the Moon orbiting the Earth,

wavelength = …… m [1]

2. the de Broglie wavelength of the electron orbiting the nucleus.

wavelength = …… m [1]

(ii) Use your answers to **(d)(i)** to explain why it is more reasonable to consider an electron in orbit around the nucleus as a wave while the Moon in orbit around the Earth as a particle.

……...

……...

…… [1]

(e) A mixture of 2 different powdered minerals can sometimes be separated in the laboratory by using an electric field.

The mixture to be separated is first placed in a vibrating tray in which the two types of powdered minerals become oppositely charged by friction. The tray has a small opening through which the minerals fall vertically from rest through a constant horizontal electric field set up between a pair of charged parallel plates. Fig. 9.2 shows a possible setup.

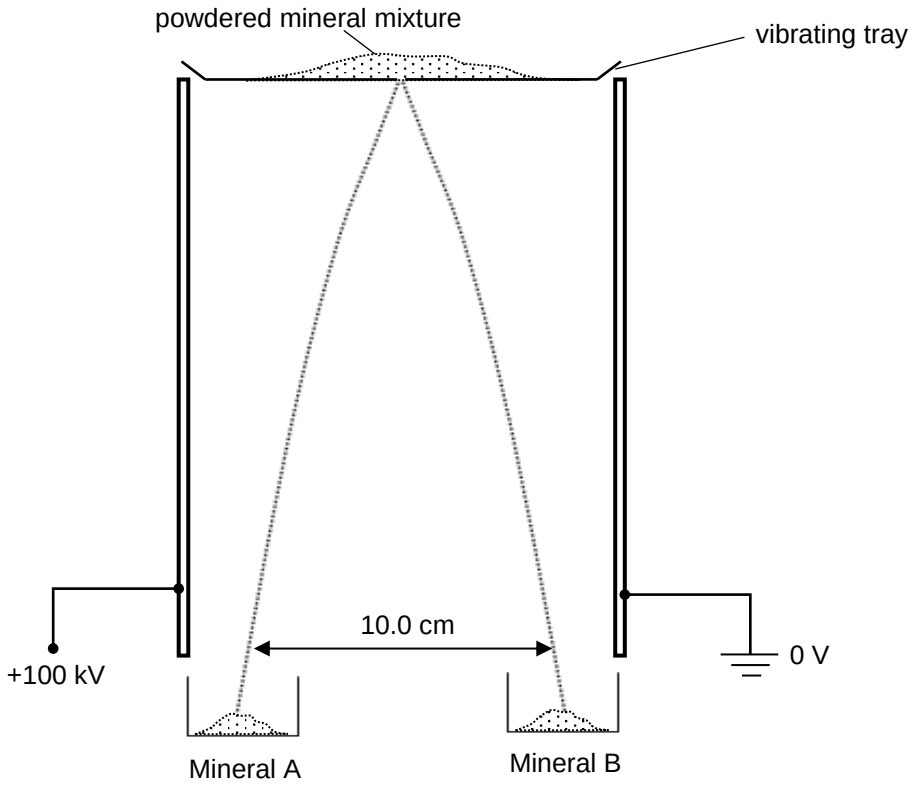

Fig. 9.2

In the above setup, a potential difference of 100 kV is maintained between the two large parallel plates which are separated horizontally by a distance of 15.0 cm. After falling through the plates, the minerals are separated by a horizontal distance of 10.0 cm.

The individual grains of the powdered minerals can be modelled as spheres of diameter 100 μm, each carrying a charge of magnitude 1.60×10^{-17} C.

(You may assume that air resistance and upthrust is negligible.)

(i) Determine the magnitude of the force on a grain due to the electric field produced by the two large parallel plates.

force = …… N [2]

(ii) With the support of an appropriate calculation, explain why the electrical force between two charged mineral grains that are adjacent to each other can be ignored when considering the motion of the grains in the electric field.

……..……..……..……...

……..……..……..……...

……..……..…….. [3]

(iii) Given that the magnitude of charge per unit mass of the minerals is 2.00×10^{-6} C kg^{-1}, show that the horizontal acceleration of each mineral grain is 1.33 m s^{-2}.

[1]

(iv) Hence, determine the time taken for the minerals to pass out of the parallel plates.

time taken = …… s [2]

[Total: 20]

End of Paper 3 Section B