Visit http://www.mathsmadeeasy.co.uk/ for more fantastic resources.

AQA, Edexcel, OCR

A Level

A Level Physics

Electric Fields 2 (Answers)

Name:

MME

Mathsmadeeasy.co.uk

Total Marks: /30

1. A parallel-plate capacitor is made using two perfectly overlapping 5 m $\times$ 5 m plates separated by a vacuum.

Total for Question 1: 15

(a) The capacitance of the capacitor is 5 nF. Calculate the separation, d, of the plates. [2]

Solution: 0.044 m

(b) The potential difference across the capacitor is 6 V. Calculate the field strength, E. [2]

Solution: 140 Vm^{-1}

An electron enters the vacuum at a distance of $\frac{d}{2}$ from each plate and at right angles to the field. Its velocity, u, is 1.5×10^8 ms^{-1}.

(c) Calculate the time taken for the electron to travel 5 m. [1]

Solution: 33 ns

(d) Show that the electron passes through the capacitor without colliding with either plate. [4]

Solution: $s = ut + \frac{1}{2}at^2$; initially the vertical velocity is zero so $s = \frac{1}{2}at^2$.
But, since $F = m_e a = Eq_e$, $a = \frac{Eq_e}{m_e}$.
$t = L/u$
Combining: $s = \frac{Eq_e L^2}{2m_e u^2} = 0.013$ m. This is less than d/2.

(e) Calculate the angle between the electron's initial velocity vector and its velocity vector when it emerges from the capacitor. [3]

Solution: 0.30°

(f) Calculate the electron's final kinetic energy, giving your answer in units of keV. [3]

Solution: 64 keV

2. The Earth, when stripped of its atmosphere, has a net negative charge. Here you will consider this naked Earth as a spherical charge.

Total for Question 2: 15

(a) Define the electric potential at a point in space. State its value at a distance of infinity. [2]

Solution: The work done per unit charge in bringing a positive charge from infinity to that point.
Zero.

(b) Using the equation for the electric potential, show that the capacitance of a sphere is given by $4\pi\epsilon_0 r$. [2]

Solution: $V = \frac{Q}{4\pi\epsilon_0 r}$ and $Q = CV$.
Combining gives $\frac{Q}{C} = \frac{Q}{4\pi\epsilon_0 r} \rightarrow C = 4\pi\epsilon_0 r$

(c) Earth's radius is 6400 km and its surface has a negative charge of 5×10^5 C. Ignoring its atmosphere, calculate the following:

i. The electric potential at an altitude of 100 km. [2]

Solution: 690 MV

ii. The electric potential at an altitude of 100000 km. [2]

Solution: 42 MV

(d) Lines of equipotential trace out contours along which the electric potential is constant. What shape would these be in the case of the naked Earth above? What can you conclude about the geometrical relationship between field lines and lines of equipotential? [2]

Solution: Circles.
Always at right-angles to each other.

(e) Sketch, for a pair of oppositely-charged spheres, the lines of equipotential and the field lines. [2]

Solution: Field lines from + to -; more densely spaced between the spheres than elsewhere. Equipotential lines are circles, but their centres are incrementally offset towards the outside as the potential decreases i.e. lines are most bunched between the spheres.

An electron is forced from the depths of the universe towards the naked Earth. Since both are negatively charged, this is not an easy thing to do. The astronaut responsible plots a graph of the force required against the separation of the Earth's and the electron's centres of mass.

(f) What is represented by the area underneath the curve? [1]

Solution: Work done bringing the electron from infinity to r.

(g) Calculate the electric potential energy when the electron is at an altitude of 10 km. [2]

Solution: 1.1×10^{-10} J