

Solutions

Original-task marking: M1 method, A1 accuracy, B1 reasoning.

2.1 $F = kq_1q_2/r^2$, proportional to the product of the charges and the inverse square of their separation; two negative charges repel – forces point away from each other along the joining line.

2.2 $F = (9.0 \times 10^9 \times 2.0 \times 10^{-6} \times 3.0 \times 10^{-6})/(0.060)^2 = (5.4 \times 10^{-2})/(3.6 \times 10^{-3}) = 15 \text{ N}$, attractive since the signs are opposite.

2.3 Charge is quantized: every drop carried a whole-number multiple of the electron charge $e = 1.6 \times 10^{-19} \text{ C}$, never a fraction of it.

2.4 The rod's field separates the sphere's charges – near side opposite, far side like the rod; grounding drains the like charge away to Earth; after the ground is removed first and the rod leaves, the sphere keeps a net charge opposite to the rod – charging by induction.

2.5 $V_e = kQ/r = (9.0 \times 10^9 \times 2.0 \times 10^{-6})/0.30 = 6.0 \times 10^4 \text{ V}$.

3.1 $E = V/d = 250/5.0 \times 10^{-3} = 5.0 \times 10^4 \text{ V/m}$; $F = eE = 1.6 \times 10^{-19} \times 5.0 \times 10^4 = 8.0 \times 10^{-15} \text{ N}$; assumes a uniform field – ignoring edge effects.

3.2 Concentric circles centred on the wire, lying in the plane perpendicular to it; direction given by the right-hand grip rule with the thumb along the current; reversing the current reverses the sense of every circle.

3.3 Lines run from the positive charge to the negative, curving so pairs meet the charges symmetrically; the straight line joins the two charges through the middle; rules: lines start on positive and end on negative charge, never cross, and their local density represents the field strength – dense near each charge, weakest in the far field.

3.4 Rubbing transfers electrons, leaving the balloon charged; the charged balloon polarizes the neutral paper – induction separates its charges, opposite sign nearer the balloon; the nearer opposite charge feels the stronger attraction (inverse-square), so the paper is pulled to the balloon.

3.5 $W = q\Delta V_e = 500 \text{ eV} = 500 \times 1.6 \times 10^{-19} = 8.0 \times 10^{-17} \text{ J}$; $\frac{1}{2}mv^2 = W$ so $v = \sqrt{2W/m_e} = \sqrt{(1.6 \times 10^{-16})/(9.1 \times 10^{-31})} = 1.3 \times 10^7 \text{ m/s}$.