InkPhysics

ANSWER BOOK

Coulomb's law and electric field strength

Electric fields · Year 13

AQA 3.7.3.1, 3.7.3.2 · CIE 18.1.1, 18.1.2, 18.1.3, 18.2.1, 18.2.2, 18.3.1, 18.3.2, 18.4.1
OCR A 6.2.1(a), 6.2.1(b), 6.2.1(c), 6.2.1(d), 6.2.2(a), 6.2.2(b), 6.2.3(a), 6.2.3(c)

19 questions · 52 marks

NAVY EDITION

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SECTION A · Warm-up

A1 The force is proportional to the product of the charges (1); and inversely proportional to the square of their separation, $F = kQ_1Q_2/r^2$ where $k = 1/4\pi\varepsilon_0$ (1). [2]

A2 $F = kQ_1Q_2/r^2 = (8.99 \times 10^9 \times (2.0 \times 10^{-6})^2)/0.10^2$ (1)
$F = 3.60$ N (repulsive) (1) [2]

A3 $E = F/Q = (6.0 \times 10^{-3})/(2.0 \times 10^{-6})$ (1)
$E = 3000$ N C^{-1} (1) [2]

A4 $F/4$, because the force follows an inverse-square law (1). [1]

A5 1 V = 1 J C^{-1}, so 1 V m^{-1} = 1 J C^{-1} m^{-1} (1). 1 J = 1 N m, so 1 J C^{-1} m^{-1} = 1 N m C^{-1} m^{-1} = 1 N C^{-1} (1). [2]

A6 $r = 8.0$ cm (0.080 m), the distance between the centres (1). A charged sphere behaves as if all its charge were concentrated at its centre (1). [2]

SECTION B · Standard

B1 $F = ke^2/r^2 = (8.99 \times 10^9 \times (1.60 \times 10^{-19})^2)/(5.3 \times 10^{-11})^2$ (1)
$F = 8.19 \times 10^{-8}$ N (1) [2]

B2 $E = V/d = 2000/0.050 = 40000$ V m^{-1} (2)
$F = EQ = 40000 \times 3.0 \times 10^{-6} = 0.12$ N (1) [3]

B3 $E = kQ/r^2 = (8.99 \times 10^9 \times 5.0 \times 10^{-9})/0.20^2$ (1)
$E = 1124$ N C^{-1} (1) [2]

B4 $F = kQ_1Q_2/r^2 = (8.99 \times 10^9 \times 3.0 \times 10^{-6} \times 2.0 \times 10^{-6})/0.15^2$ (1)
$F = 2.40$ N (1)
Attractive, because the charges have opposite signs (1). [3]

B5 $F = ke^2/r^2$, so $r = \sqrt{(ke^2/F)}$ (1)
$r = \sqrt{((8.99 \times 10^9 \times (1.60 \times 10^{-19})^2)/(2.3 \times 10^{-4}))}$ (1)
$r = 1.0 \times 10^{-12}$ m (1) [3]

B6 $E = kQ/r^2$, so $Q = Er^2/k$ (1) [3]
$Q = (8.0 \times 10^3 \times 0.15^2)/(8.99 \times 10^9)$ (1)
$Q = 2.0 \times 10^{-8}$ C (20 nC) (1)

B7 $F \propto Q_1Q_2/r^2$: doubling both charges multiplies F by 4, and halving r multiplies it by another 4 (1). The force increases by a factor of 16 (1). [2]

SECTION C · Stretch

C1 $F = eE$ (1) [3]
$a = eE/m = (1.60 \times 10^{-19} \times 1.0 \times 10^4)/(9.11 \times 10^{-31})$ (1)
$a = 1.76 \times 10^{15}$ m s^{-2} (1)

C2 $E = kQ/r^2 = (8.99 \times 10^9 \times 8.0 \times 10^{-9})/0.30^2$ (1) [4]
$E = 799$ N C^{-1} (1)
$F = EQ = 799 \times 2.0 \times 10^{-9}$ (1)
$F = 1.60 \times 10^{-6}$ N (repulsive) (1)

C3 The path is parabolic (1). The field exerts a constant force, and so a constant acceleration, parallel to the field lines (1); the velocity component perpendicular to the field is unchanged, so the motion is like that of a projectile (1). [3]

C4 $E = V/d = 80/0.020 = 4000$ V m^{-1} (1) [5]
$a = eE/m = (1.60 \times 10^{-19} \times 4000)/(9.11 \times 10^{-31}) = 7.03 \times 10^{14}$ m s^{-2} (1)
time in the field $t = L/v = 0.040/(2.0 \times 10^7) = 2.0 \times 10^{-9}$ s (1)
deflection $s = \frac{1}{2}at^2$ (1)
$s = 1.4$ mm (1)

C5 The dome acts as a point charge at its centre, so at the surface $E = kQ/r^2$ (1) [4]
$E = (8.99 \times 10^9 \times 8.0 \times 10^{-6})/0.15^2$ (1)
$E = 3.2 \times 10^6$ V m^{-1} (1)
This exceeds 3.0×10^6 V m^{-1}, so the air breaks down and a spark is likely (1)

C6 (a) A uniform field: the field lines are parallel, equally spaced, and run from the positive plate to the negative plate (1); the field strength $E = V/d$ is the same everywhere between the plates (1). (b) A radial field: the lines point outward from the charge in every direction (1); the field strength falls with the inverse square of the distance, $E = kQ/r^2$ (1). [4]