InkPhysics

ANSWER BOOK

Electric potential

Electric fields · Year 13

AQA 3.7.3.3 · CIE 18.5.1, 18.5.2, 18.5.3, 18.5.4
OCR A 6.2.4(a), 6.2.4(b), 6.2.4(c), 6.2.4(d), 6.2.4(e)

19 questions · 51 marks

NAVY EDITION

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SECTION A · Warm-up

A1 Work done per unit positive charge (1); in bringing a small test charge from infinity to the point (where the potential at infinity is zero) (1). [2]

A2 $V = kQ/r = (8.99 \times 10^9 \times 5.0 \times 10^{-9})/0.10$ (1) [2]
$V = 449.5$ V (1)

A3 Concentric spheres centred on the charge (1); everywhere perpendicular to the radial field lines (and no work is done moving a charge along an equipotential) (1). [2]

A4 Zero: the potential difference along an equipotential is zero (1). [1]

A5 $V \propto 1/r$, so at 2r the potential is 400 V (1) and at 4r it is 200 V (1). [2]

A6 One joule of energy is transferred per coulomb of charge moved through it (1). [1]

SECTION B · Standard

B1 $V = kQ/r = (8.99 \times 10^9 \times (-3.0 \times 10^{-9}))/0.20$ (1) [2]
$V = -135$ V (negative because the charge is negative) (1)

B2 V at 0.10 m = 449.5 V (1) [4]
V at 0.30 m = 149.8 V (1)
$\Delta V = 299.7$ V (1)
$W = Q\Delta V = 2.0 \times 10^{-9} \times 299.7 = 5.99 \times 10^{-7}$ J (1)

B3 $E = \Delta V/\Delta d = 200/0.050$ (1) [2]
$E = 4000$ V m^{-1} (1)

B4 Potential is a scalar, so the contributions add (1) [3]
$V = 2 \times kQ/r = 2 \times (8.99 \times 10^9 \times 4.0 \times 10^{-6}/0.20)$ (1)
$V = 3.60 \times 10^5$ V (1)

B5 $V = kQ/r$, so $r = kQ/V$ (1) [3]
$r = (8.99 \times 10^9 \times 12 \times 10^{-9})/450$ (1)
$r = 0.24$ m (1)

B6 $\Delta V = 650 - 150 = 500$ V (1) [3]
The electron's charge is negative, so moving to the higher potential lowers its potential energy by $q\Delta V$ and that fall becomes kinetic energy: $\Delta E_k = e\Delta V = 1.60 \times 10^{-19} \times 500 = 8.0 \times 10^{-17}$ J (1)
= 500 eV (1)

B7 The work done is the same (1); it depends only on the potential difference between X and Y, not on the path taken (1). [2]

SECTION C · Stretch

C1 $E_p = QV = 5.0 \times 10^{-6} \times 2000$ (1) [3]
$E_p = 0.010$ J (1)
Work done from infinity = 0.010 J, equal to the potential energy gained (1).

C2 $V = kQ_1/r + kQ_2/r$ (1) [4]
$V = (8.99 \times 10^9 \times 6.0 \times 10^{-6}/0.30) + (8.99 \times 10^9 \times (-6.0 \times 10^{-6})/0.30)$ (1)
$V = 0$ V (1)
The two contributions are equal in magnitude but opposite in sign, and potential is a scalar, so they cancel exactly (1).

C3 E equals the magnitude of the gradient of the potential-distance graph at that point, $E = \Delta V/\Delta r$ (1); the field is directed from high to low potential (1). Conversely, the change in potential between two points equals the area under the field strength-distance graph (1). [3]

C4 Potential is a scalar, so the two contributions must sum to zero: in magnitude, [4]
$kQ_A/d = kQ_B/(0.50 - d)$ (1)
$8.0(0.50 - d) = 2.0d$ (1)
$d = (8.0 \times 0.50)/10.0$ (1)
$d = 0.40$ m from A (1)

C5 Potential at the released proton due to the fixed one: $V = ke/r = 1438$ V (1) [5]
$E_p = QV = 1.60 \times 10^{-19} \times 1438 = 2.30 \times 10^{-16}$ J (1)
Far away $V \rightarrow 0$, so all this potential energy becomes kinetic energy (1)
$\frac{1}{2}mv^2 = E_p$ (1)
$v = \sqrt{(2E_p/m)} = 5.2 \times 10^5$ m s^{-1} (1)

C6 Both feet touch the same cable, so they are at almost exactly the same potential (1); the potential difference across the bird is therefore almost zero (1). Since $W = Q\Delta V$, almost no energy is transferred through the bird and no significant current flows in it (1). [3]