18. Electric Fields

18.4 Electric field of a point charge

Paper 4

Marking Scheme

Q1.

(c)(ii)	$E_X = Q / 4\pi\varepsilon_0 x^2$	**A1**
(c)(iii)	$E_Y = 2Q / 4\pi\varepsilon_0 (2x)^2$ $(= Q / 8\pi\varepsilon_0 x^2)$	**C1**
	(opposite charges so fields in same direction so magnitudes add): $E = (Q / 4\pi\varepsilon_0 x^2) + (Q / 8\pi\varepsilon_0 x^2)$ $= 3Q / 8\pi\varepsilon_0 x^2$	**A1**

Q2.

(c)(i)	radius = 3.2 cm	**A1**
(c)(ii)	$E = Q / (4\pi\varepsilon_0 x^2)$	**C1**
	Q = e.g. $2.2 \times 10^5 \times 4\pi \times 8.85 \times 10^{-12} \times 0.032^2$	**C1**
	$= 2.5 \times 10^{-8}$ C	**A1**

Q3.

(b)(ii)	$\alpha = 1 / (4\pi \times 6.67 \times 10^{-11} \times 8.85 \times 10^{-12}) = 1.35 \times 10^{20}$ (kg^2 C^{-2}) **or** $\alpha = (8.99 \times 10^9) / (6.67 \times 10^{-11}) = 1.35 \times 10^{20}$ (kg^2 C^{-2})	**A1**
(c)(i)	$E = \alpha g Q / M$ $= (1.35 \times 10^{20} \times 9.81 \times 4.80 \times 10^5) / (5.98 \times 10^{24})$	**C1**
	$= 106$ N C^{-1} **or** 106 V m^{-1}	**A1**

Q4.

(a)	from $x = 0$ to $x = r$: $E = 0$	**B1**
	from $x = r$ to $x = 3r$: curve with negative gradient of decreasing magnitude passing through (r, E_0)	**B1**
	line passing through ($2r$, $E_0 / 4$) and ($3r$, $E_0 / 9$)	**B1**

Q5.

(a)	similarity: both are radial **or** both have inverse square (variations)	**B1**
	difference: direction is always/only towards the mass **or** direction can be towards or away from charge	**B1**
(b)	field strength = $Q / 4\pi\varepsilon_0 x^2$	**C1**
	$E = Q / 36\pi\varepsilon_0 R^2$	**A1**
(c)(i)	fields (due to each sphere) are in same direction	**B1**

Q6.

(b)(ii)	$E = Q / (4\pi\varepsilon_0 x^2)$	**C1**
	clear correct read-off of a pair of values of E and x	**C1**
	e.g. $Q = 18 \times 10^5 \times 4\pi \times 8.85 \times 10^{-12} \times (4.5 \times 10^{-2})^2$ $= 4.0 \times 10^{-7}$ C **or** 4.1×10^{-7} C	**A1**

Q7.

(a)(ii)	similarity – any one point from: • both have an inverse square variation • both decrease with distance • both are radial	**B1**
	difference – any one point from: • gravitational field always towards (the mass) • electric field can be towards or away from (the charge)	**B1**
(b)(i)	$E = Q / 4\pi\varepsilon_0 x^2$	**C1**
	$Q = 4\pi \times 8.85 \times 10^{-12} \times 84 \times 0.15^2$ $= 2.1 \times 10^{-10}$ C	**A1**
(b)(ii)	$E = 84 \times (0.15 / 0.45)^2$ **or** $E = (2.1 \times 10^{-10}) / (4\pi \times 8.85 \times 10^{-12} \times 0.45^2)$	**C1**
	$E = 9.3$ V m^{-1}	**A1**
(c)	line at $E = 0$ from $x = 0$ to $x = 0.15$ m	**B1**
	smooth curve with decreasing negative gradient throughout, from $x = 0.15$ m to $x = 0.45$ m, passing through (0.15, 84)	**B1**
	line passing through (0.45, 9.3)	**B1**

Q8.

(b)(i)	field changes direction (between A and B)/field is zero at a point (between A and B)	**M1**
	so charges have same sign	**A1**
(b)(ii)	Any one from: • field is (also) influenced by charge B • charge A is not isolated/is not the only charge present • field is due to two/both charges • field is the resultant of two fields	**B1**
(b)(iii)	$E = Q / (4\pi\varepsilon_0 x^2)$	**C1**
	at $x = 10$ cm, $E_A = E_B$	**C1**
	$Q_A / 10^2 = Q_B / 5^2$ $Q_A / Q_B = 4.0$	**A1**

Q9.

(a)	($E =$) $Q / 4\pi\varepsilon_0 r^2$	**M1**
	where ε_0 is permittivity (of free space)	**A1**
(b)(i)	field does not change direction/field does not become zero	**M1**
	so (charges have) opposite (sign)	**A1**
(b)(ii)	minimum is at the midpoint (between the charges)	**M1**
	so (magnitudes are the) same	**A1**

Q10.

(b)	$E = Q/(4\pi\varepsilon_0 r^2)$	**C1**
	$2.0 \times 10^4 = Q / (4\pi \times 8.85 \times 10^{-12} \times 0.26^2)$ charge = 1.5×10^{-7} C	**A1**
(c)	charge ($= Q\,[52/26]^2$) $= 4Q$	**C1**
	additional charge = 3Q	**A1**