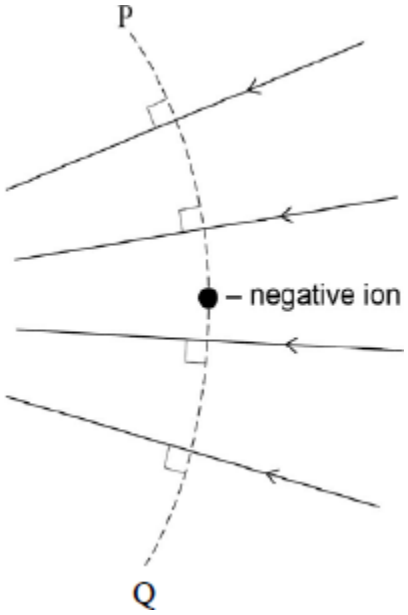
1 The diagram shows a small negative charge at a point in an electric field, which is represented by the arrowed field lines.



Which of the following statements, about what happens when the charge is displaced, is correct?

When the negative charge is displaced

A to the left the magnitude of the electric force on it decreases. ⬭

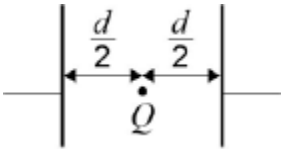
B to the right its potential energy increases. ⬭

C along the line PQ towards Q its potential energy decreases. ⬭

D along the line PQ towards P the magnitude of the electric force on it is unchanged. ⬭

(Total 1 mark)

2 Two parallel metal plates are separated by a distance d and have a potential difference V across them. Which expression gives the magnitude of the electrostatic force acting on a charge Q placed midway between the plates?



A $\frac{2VQ}{d}$ ⬭

B $\frac{VQ}{d}$ ⬭

C $\frac{VQ}{2d}$ ⬭

D $\frac{Qd}{v}$ ⬭

(Total 1 mark)

3 The electric potential at a distance *r* from a positive point charge is 45 V. The potential increases to 50 V when the distance from the point charge decreases by 1.5 m. What is the value of *r*?

A 1.3m ⬭

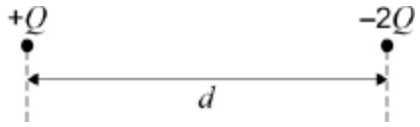
B 1.5m ⬭

C 7.9m ⬭

D 15m ⬭

(Total 1 mark)

4 The diagram shows two particles at distance d apart. One particle has charge $+Q$ and the other $-2Q$. The two particles exert an electrostatic force of attraction, F, on each other. Each particle is then given an additional charge $+Q$ and their separation is increased to distance $2d$.



Which of the following gives the force that now acts between the two particles?

A an attractive force of $\frac{F}{4}$ ⬭

B a repulsive force of $\frac{F}{4}$ ⬭

C an attractive force of $\frac{F}{2}$ ⬭

D a repulsive force of $\frac{F}{2}$ ⬭

(Total 1 mark)

5 Which of the following statements about a parallel plate capacitor is **incorrect**?

A The capacitance of the capacitor is the amount of charge stored by the capacitor when the pd across the plates is 1 V. ⬭

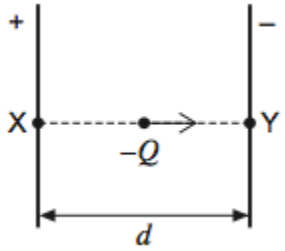
B A uniform electric field exists between the plates of the capacitor. ⬭

C The charge stored on the capacitor is inversely proportional to the pd across the plates. ⬭

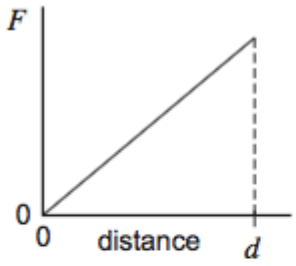
D The energy stored when the capacitor is fully charged is proportional to the square of the pd across the plates. ⬭

(Total 1 mark)

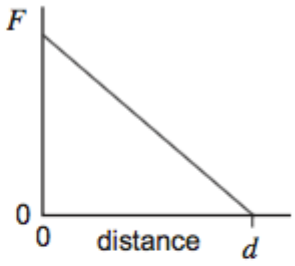
6 The diagram shows a charge $-Q$ being moved from point X to point Y between two charged parallel plates separated by a distance d.



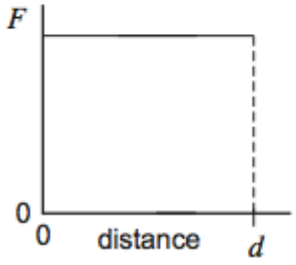
Which one of the following graphs best illustrates how the magnitude of force F on the charge varies with distance as it moves towards Y?



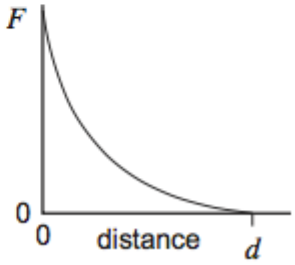
A



B



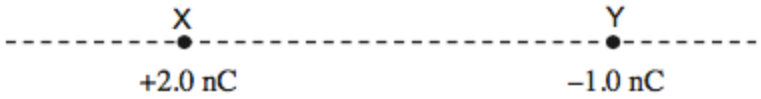
C



D

(Total 1 mark)

7 A +2.0 nC point charge X is at a fixed distance from a –1.0 nC point charge Y. The force between the two charges is F.

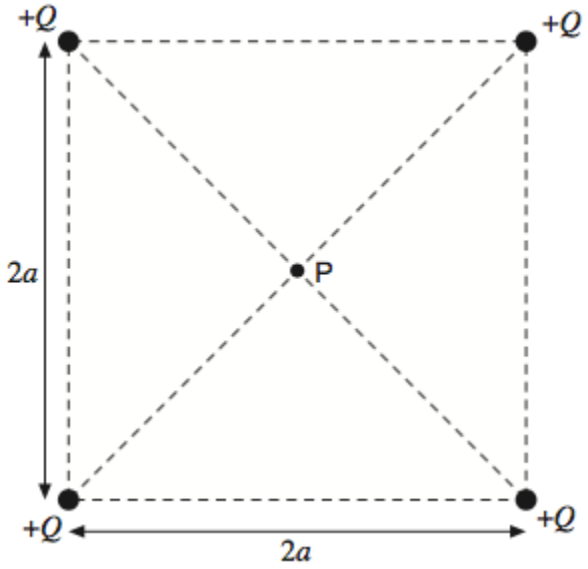


If an **additional** charge of +2.0 nC is supplied to both X and Y, which line, **A** to **D**, in the table gives the magnitude and direction of the force on X?

	Magnitude	**Direction**
A	$2F$	from X to Y
B	$4F$	from X to Y
C	$2F$	from Y to X
D	$4F$	from Y to X

(Total 1 mark)

8 The diagram shows four point charges, each $+Q$, at the corners of a square of side $2a$.



What is the electric field strength at P, the centre of the square?

A zero

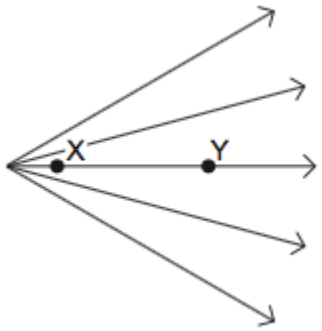
B $\frac{Q}{4\pi\varepsilon_0 a^2}$

C $\frac{Q}{2\pi\varepsilon_0 a^2}$

D $\frac{Q}{\pi\varepsilon_0 a^2}$

(Total 1 mark)

9 The diagram shows the field lines in a region of an electric field created by a positive charge.

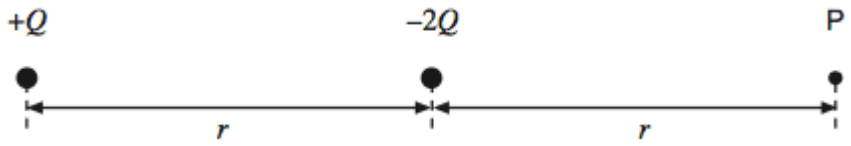


Which one of the following statements is correct?
When moving from X to Y

A the electric potential is constant.
B the electric potential increases.
C the electric potential decreases.
D the electric potential changes from positive to negative.

(Total 1 mark)

10 The diagram shows two point charges of magnitude $+Q$ and $-2Q$ placed a distance r apart.



What is the electric potential at point P, a distance r to the right of the $-2Q$ charge?

A $-\frac{3Q}{8\pi\varepsilon_0 r}$

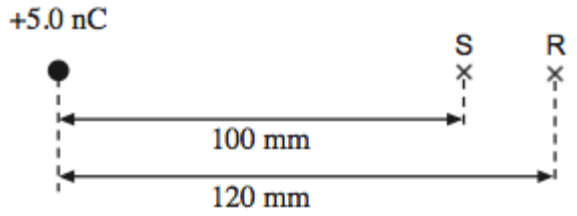
B $-\frac{Q}{2\pi\varepsilon_0 r}$

C $+\frac{Q}{8\pi\varepsilon_0 r}$

D $+\frac{5Q}{8\pi\varepsilon_0 r}$

(Total 1 mark)

11



The potentials at points R and S due to the +5.0 nC charge are 375 V and 450 V respectively.

How much work is done when a +2.0 nC charge is moved from R to S?

A 0.12 μJ
B 0.15 μJ
C 0.19 μJ
D 0.38 μJ

(Total 1 mark)

12

The gravitational constant, G, is a constant of proportionality in Newton's law of gravitation. The permittivity of free space, ε_0, is a constant of proportionality in Coulomb's law.

When comparing the electrostatic force acting on a pair of charged particles to the gravitational force between them, the product $\varepsilon_0 G$ can appear in the calculation.

Which is a unit for $\varepsilon_0 G$?

A $C^2\ kg^{-2}$
B $C^2\ m^{-2}$
C $F\ kg^2\ N^{-1}\ m^{-2}$
D it has no unit

(Total 1 mark)

13

A positive ion has a charge−to−mass ratio of 2.40×10^7 C kg^{-1}. It is held stationary in a vertical electric field.
Which line, **A** to **D**, in the table shows correctly both the strength and the direction of the electric field?

	Electric field strength / V m^{-1}	**Direction**
A	4.09×10^{-7}	upwards
B	4.09×10^{-7}	downwards
C	2.45×10^{6}	upwards
D	2.45×10^{6}	downwards

(Total 1 mark)

14

In the equation $X = \frac{ab}{r^n}$, X represents a physical variable in an electric or a gravitational field, a is a constant, b is either mass or charge and n is a number.

Which line, **A** to **D**, in the table provides a consistent representation of X, a and b according to the value of n?

The symbols E, g, V and r have their usual meanings.

	n	***X***	***a***	***b***
A	1	E	$\frac{1}{4\pi\varepsilon_0}$	charge
B	1	V	$\frac{1}{4\pi\varepsilon_0}$	mass
C	2	g	G	mass
D	2	V	G	charge

(Total 1 mark)

15

Which one of the following statements is correct?

An electron follows a circular path when it is moving at right angles to

A a uniform magnetic field.

B a uniform electric field.

C uniform electric and magnetic fields which are perpendicular.

D uniform electric and magnetic fields which are in opposite directions.

(Total 1 mark)

16

Which one of the following statements is correct?

The force between two charged particles

A is always attractive

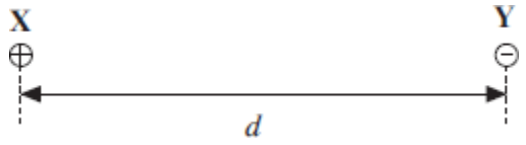
B can be measured in $\mathrm{C^2\ F^{-1}\ m^{-1}}$

C is directly proportional to the distance between them

D is independent of the magnitude of the charges

(Total 1 mark)

17 Two point charges, $\mathbf{X}$ and $\mathbf{Y}$, exert a force F on each other when they are at a distance d apart.



When the distance between them is 20 mm, the force they exert on each other is 0.5 F.

What is the distance d?

A 7 mm

B 14 mm

C 15 mm

D 28 mm

(Total 1 mark)

18 Which one of the following statements is correct?

When a negative ion is projected into an electric field

A the field can change the magnitude of the velocity but not its direction

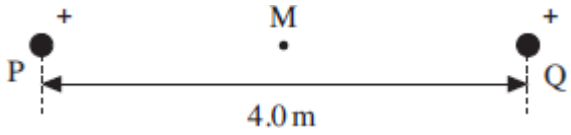
B the field can change the direction of the velocity but not its magnitude

C the field can change both the magnitude and the direction of the velocity

D the ion will accelerate in the direction of the field

(Total 1 mark)

19 Two identical positive point charges, P and Q, are separated by a distance of 4.0 m.
The resultant electric potential at point M, which is mid-way between the charges, is 25.0 V.



What would be the resultant electrical potential at a point 1.0 m closer to P?

A 8.3 V

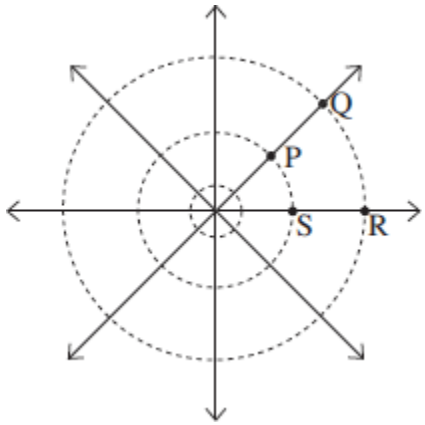
B 12.5 V

C 33.3 V

D 37.5 V

(Total 1 mark)

20 The diagram below shows the field lines and equipotential lines around an isolated positive point charge.



Which one of the following statements concerning the work done when a small charge is moved in the field is **incorrect**?

A when it is moved from either P to Q or S to R, the work done is the same in each case

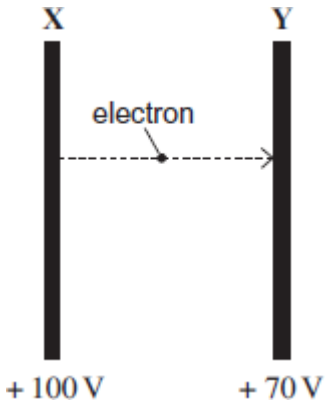
B when it is moved from Q to R no work is done

C when it is moved around the path PQRS, the overall work done is zero

D when it is moved around the path PQRS, the overall work done is equal to twice the work done in moving from P to Q

(Total 1 mark)

21 Two fixed parallel metal plates **X** and **Y** are at constant potentials of + 100 V and + 70 V respectively. An electron travelling from **X** to **Y** experiences a change of potential energy ΔE_p.

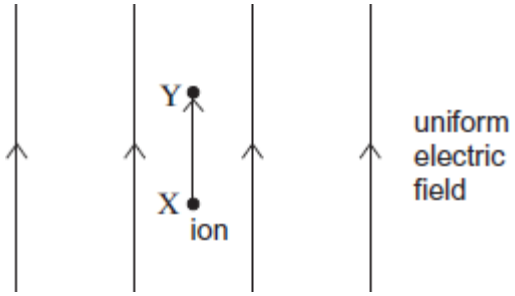


Which line, **A** to **D**, in the table shows correctly the direction of the electrostatic force F on the electron and the value of ΔE_p?

	Direction of F	ΔE_p
A	towards **X**	+ 30 eV
B	towards **Y**	– 30 eV
C	away from **X**	+ 30 eV
D	away from **Y**	– 30 eV

(Total 1 mark)

22 A uniform electric field of electric field strength E is aligned so it is vertical. An ion moves vertically through a small distance Δd from point X to point Y in the field.
There is a uniform gravitational field of field strength g throughout the region.



Which line, **A** to **D**, in the table correctly gives the gravitational potential difference, and the electric potential difference, between X and Y?

	Gravitational potential difference	**Electric potential difference**
A	$g\Delta d$	$E\Delta d$
B	$g\Delta d$	$\frac{E}{\Delta d}$
C	$\frac{g}{\Delta d}$	$E\Delta d$
D	$\frac{g}{\Delta d}$	$\frac{E}{\Delta d}$

(Total 1 mark)

23 Two horizontal parallel plate conductors are separated by a distance of 5.0 mm in air. The lower plate is earthed and the potential of the upper plate is +50 V.

Which line, **A** to **D**, in the table gives correctly the electric field strength, *E*, and the potential, *V*, at a point midway between the plates?

	electric field strength *E* / Vm^{-1}	**potential *V* / V**
A	1.0×10^4 upwards	25
B	1.0×10^4 downwards	25
C	1.0×10^4 upwards	50
D	1.0×10^4 downwards	50

(Total 1 mark)

24 Two identical positive point charges, P and Q, separated by a distance *r*, repel each other with a force *F*. If *r* is decreased so that the electrical potential energy of Q is doubled, what is the force of repulsion?

A 0.5 *F*

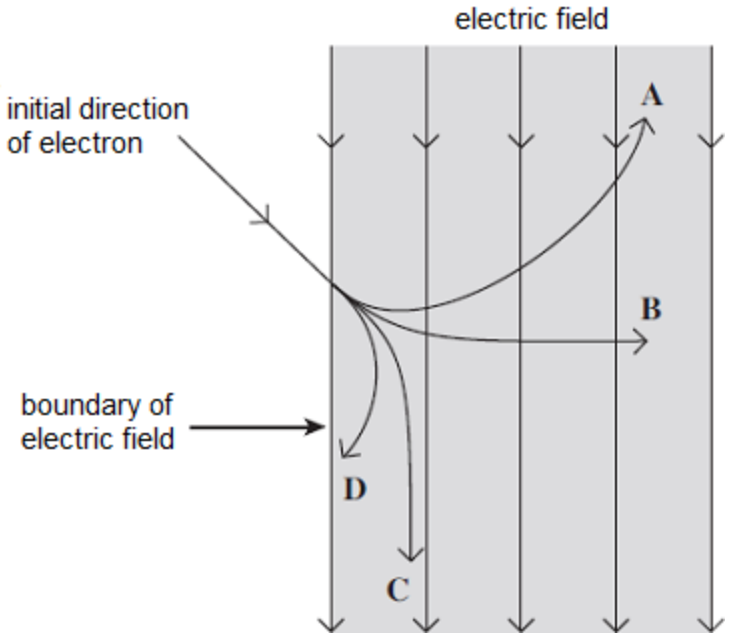
B *F*

C 2*F*

D 4*F*

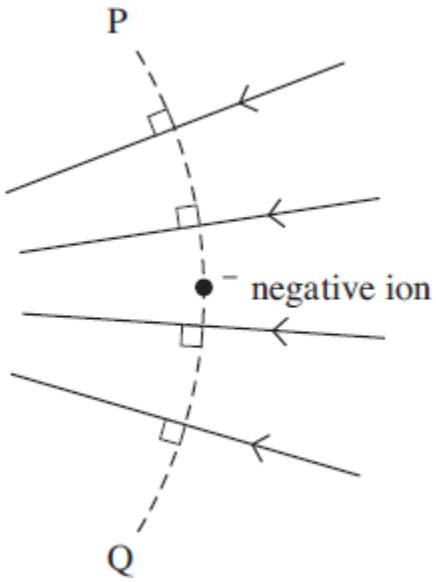
(Total 1 mark)

25 Which path, **A** to **D**, shows how an electron moves in the uniform electric field represented in the diagram?



(Total 1 mark)

26 The diagram shows a negative ion at a point in an electric field, which is represented by the arrowed field lines.



Which one of the following statements correctly describes what happens when the ion is displaced?

When the negative ion is displaced

A to the left the magnitude of the electric force on it decreases.

B to the right its potential energy increases.

C along the line PQ towards Q its potential energy decreases.

D along the line PQ towards P the magnitude of the electric force on it is unchanged.

(Total 1 mark)

27 When a charge moves between two points in an electric field, or a mass moves between two points in a gravitational field, energy may be transferred.
Which one of the following statements is correct?

A No energy is transferred when the movement is parallel to the direction of the field.

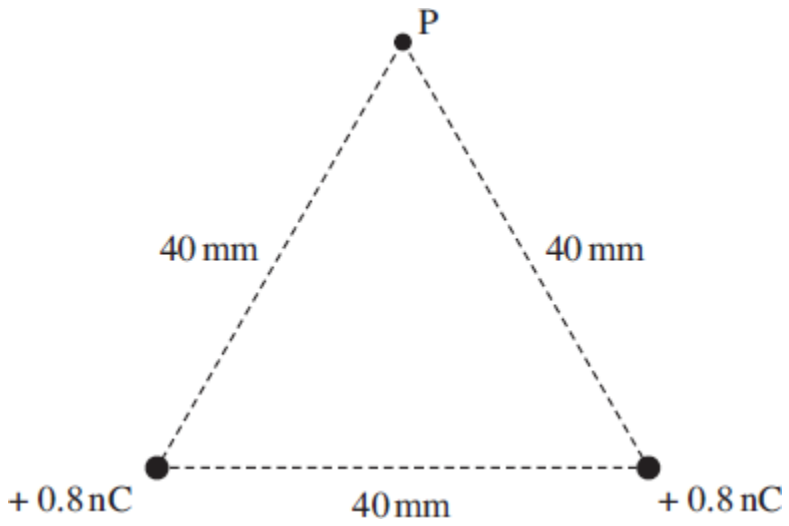
B The energy transferred is independent of the path followed.

C The energy transferred is independent of the start and finish points.

D Energy is transferred when the movement is perpendicular to the field lines.

(Total 1 mark)

28 Two charges, each of + 0.8 nC, are 40 mm apart. Point P is 40 mm from each of the charges.



What is the electric potential at P?

A zero

B 180 V

C 360 V

D 4500 V

(Total 1 mark)

29 Which line, **A** to **D**, in the table correctly describes the trajectory of charged particles which enter separately, at right angles, a uniform electric field, and a uniform magnetic field?

	uniform electric field	**uniform magnetic field**
A	parabolic	circular
B	circular	parabolic
C	circular	circular
D	parabolic	parabolic

(Total 1 mark)

30 Which one of the following statements about a parallel plate capacitor is **incorrect**?

A The capacitance of the capacitor is the amount of charge stored by the capacitor when the pd across the plates is 1V.

B A uniform electric field exists between the plates of the capacitor.

C The charge stored on the capacitor is inversely proportional to the pd across the plates.

D The energy stored when the capacitor is fully charged is proportional to the square of the pd across the plates.

(Total 1 mark)

31 The force between two point charges is F when they are separated by a distance r.
If the separation is increased to $3r$, what is the force between the charges?

A $\frac{F}{3r}$

B $\frac{F}{9r}$

C $\frac{F}{3}$

D $\frac{F}{9}$

(Total 1 mark)

32 A repulsive force F acts between two positive point charges separated by a distance r.
What will be the force between them if each charge is doubled and the distance between them is halved?

A F

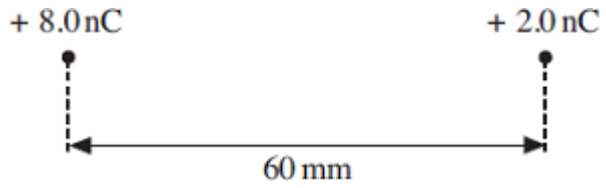
B $2F$

C $4F$

D $16F$

(Total 1 mark)

33 The distance between two point charges of + 8.0 nC and + 2.0 nC is 60 mm.



At a point between the charges, on the line joining them, the resultant electric field strength is zero. How far is this point from the + 8.0 nC charge?

A 20 mm

B 25 mm

C 40 mm

D 45 mm

(Total 1 mark)

Mark schemes

1 D **[1]**

2 B **[1]**

3 D **[1]**

4 A **[1]**

5 C **[1]**

6 **C** **[1]**

7 **C** **[1]**

8 **A** **[1]**

9 **C** **[1]**

10 **A** **[1]**

11 **B** **[1]**

12 **A** **[1]**

13 A **[1]**

14 C **[1]**

15 A **[1]**

16 B **[1]**

17 B **[1]**

18 C **[1]**

19	C	**[1]**
20	D	**[1]**
21	A	**[1]**
22	A	**[1]**
23	B	**[1]**
24	D	**[1]**
25	A	**[1]**
26	D	**[1]**
27	B	**[1]**
28	C	**[1]**
29	A	**[1]**
30	C	**[1]**
31	D	**[1]**
32	D	**[1]**
33	C	**[1]**

Examiner reports

6 This question question concerned *E* between two charged parallel plates, where the field strength is constant throughout the region between them. Hence the magnitude of the force on a charge does not vary with the distance across the gap. Just over half of the students chose the correct answer, but almost a quarter of them were tempted by distractor A, showing the force to increase linearly with the distance.

7 This question, with a facility of 34.6%, was the most demanding in this test. Actually 68.5% of the students realised that, once the charge on each of X and Y had been increased by +2.0 nC, the force on X would become 2*F*. But practically half of them failed to spot that both charges would now be positive, and the force on X would now be one of repulsion i.e. from Y to X.

8 The vector nature of *E* was the essential point in deciding the answer. At the centre of the square, equidistant from each of the four equal point charges, *E* is bound to be zero. This question had been used previously, and its facility improved from 53% then to 66% in 2016. A significant number of students chose distractors B and C.

9 This question concerned the relationship between field strength and potential in a region of a radial electric field created by a point positive charge. 71% correctly realised that the electric potential would decrease as the distance from the point charge was increased, but almost a quarter thought it would increase (distractor B).

10 This question, about the magnitude of the electric potential in a region close to two charges, was the most discriminating question in the test. Its facility was 58%. It appears that algebraic weakness caused 26% of the students to opt for distractor B.

11 This question was rather easy, with a facility of 71%. It was a direct test of $\Delta W = Q\Delta V$. The correct answer follows from $2.0 \times 10^{-9} \times (450 - 375)$. The most common incorrect choice was distractor D (0.38 μJ). This follows from $5.0 \times 10^{-9} \times (450 - 375)$, showing that those involved had not read the question properly: they thought that the charge being moved was +5.0 nC rather than +2.0 nC.

12 This was an unusual question on combinations of electrical units. 54% of the responses were correct, whilst 18% selected distractor C and 20% distractor D (no unit). The latter must have been tempting because both $\boldsymbol{\varepsilon_0}$ and **G** are constants.

13 This question concerned the strength and direction of an electric field in which a positive ion of given charge-to-mass ratio was held at rest. Application of $mg = EQ$ was the key to finding the field strength. This question was re-used from an earlier year and its facility improved only slightly, from 46% to 53%. The most popular wrong answers were distractor B (wrong direction), which was chosen by 18%, and distractor C (wrong strength), chosen by 19%.

14 This question proved to be somewhat easier, despite the rather abstract phrasing of the stem. 85% of the students knew that only alternative C gave a consistent expression i.e. $g = GM / r^2$.

15 This question required students to understand the trajectory of an electron moving in electric and / or magnetic fields. 73% gave a correct response.

16 This question was on Coulomb's law. In this question the incorrect statements were readily identifiable by those who had understood the topic. The correct one could then be found by a process of elimination, without necessarily working out that the electrostatic force could be measured in $C^2\ F^{-1}m^{-1}$. 80% of the answers were correct; perhaps it is remarkable that only 51% of the responses were correct when this question was pre-tested.

17 This question was on Coulomb's law. This question presented students with considerable mathematical demands, following from understanding that the electrostatic force obeys $F \propto (1 / r^2)$. Since the force between the charges is doubled from $0.5F$ to F, their separation must be decreased to $1 / \sqrt{2}$ of 20mm, i.e. to 14.1mm. 61% of the responses were correct, with incorrect ones fairly evenly spread amongst the other distractors.

18 In this question, 66% of the students knew that an electric field can change both the magnitude and the direction of a moving charge, in the same way that a gravitational field can for a moving projectile. Confusion with the effect of a magnetic field on a moving charge may have caused 20% of the responses being for distractor B (direction can be changed but magnitude is unaffected).

19 This question required an understanding of electric potential as a scalar, so that the contributions of the two charges to the total potential at any point around them can be found by simple addition. Combined with an appreciation that $V \propto (1 / r)$, it follows that the potential at the mid-point due to one charge is 12.5V − and that this becomes 25V when the distance is decreased to 1.0m, and 8.3V when increased to 3.0m. Therefore the resultant potential at the required point is 33.3V. Distractors B and D each attracted about one-fifth of the responses.

20 This question was the first of the two questions in this test where the students had to select a "wrong" statement. This always highlights the need for careful reading of the question. When a charge is moved completely around a closed path in an electric field the net work done is zero; this *correct* statement was given in distractor C, which was chosen by 26%. Distractor D – the correct response – directly contradicts distractor C. 67% made the right choice.

21 This question, with a facility of 37%, turned out to be the most demanding question in the test. Understanding that plate **X** was at a higher potential than plate **Y** should have enabled students to deduce that the electric field direction was from **X** to **Y**, and that an electron would experience an electrostatic force directed towards **X**. Hence an electron travelling from **X** to **Y** would be decelerated; its E_k would decrease and its E_p would increase. Therefore ΔE_p would be +30eV. Each of the distractors B and D received about 25% of the responses.

22 Familiarity with $E = V / d$ should have enabled students to realise in this question that potential difference can be calculated from (field strength) × Δd, for both gravitational end electric fields. 62% of students correctly gave answer A; the three other distractors were chosen fairly randomly by between 10% and 17% of the entry.

23 This question was another re-used question, and its facility of 43% this time was a slight improvement over the previous occasion. Candidates' responses showed that 75% of them recognised that the electric field acts downwards, but those who chose distractor D were evidently under the impression that there is a constant value of potential at all points between two parallel plates. Similar weaknesses in understanding the properties of the field between parallel plates were also evident in Section B of this Unit 4 test.

24 The question on Coulomb's law also needed candidates to know that $V \propto (1 / r)$ in an electric field; if V is doubled *r* must have been halved. Therefore the force must have been increased by a factor of 4. The facility of the question was 61%, and the most common incorrect choice (distractor C) had the force increasing by a factor of 2.

25 In this question, once it has been appreciated that this force acts in the opposite direction to the field direction, the choice is narrowed by the elimination of distractors C and D. The correct answer cannot be B, because the force continues to move the electron upwards whilst it remains in the field. 65% of the responses were correct, but 15% chose C and 13% chose B.>

26 This question was answered correctly by two-thirds of the candidates. No doubt it was misunderstanding of the direction of the force that acts on a negative ion that caused 19% of the candidates to select distractor B.

27 This question turned out to be the hardest in the test, with a facility less than 40%, possibly because it required rather abstract thinking about energy transfer in fields. More than one quarter of the candidates did not spot that the displacement described in distractor D amounts to movement along an equipotential line, and so selected this as the correct answer.

28 This question required students to understand that electric potential is a scalar, and that the potential at a point close to two charges is therefore the sum of the potentials due to each of them. This was understood by fewer than half of the candidates, and so the facility of the question was only 45%. Almost a third of responses were for distractor A (zero) and almost a fifth for distractor B (the potential due to one charge alone).

29 This question had appeared in an examination previously; it tested the fairly familiar knowledge of the trajectory of charged particles in electric and magnetic fields and this time had a facility of 71%.

30 The Capacitors were the topic tested by this question which needed knowledge of how to apply Q = I t for a constant current, C = Q/V and energy stored = ½ CV2.

31 This question moved on to electric fields. Question 15, a direct algebraic test of Coulomb's law, had appeared in a previous examination. The 2012 students dealt with it much better than their predecessors, causing the facility to increase from 49% to 80%.

32 This question was a fairly direct test of Coulomb's law for charges under changing circumstances; 70% of the students had the correct answer.

33 This question was also on electrostatics but, with a facility of 48%, was much more demanding. At first sight it appears necessary to solve a quadratic equation to answer the question, but this difficulty can be overcome by taking the square root of the expression obtained. Incorrect distractor D was chosen by 35% of the students and consequently the discrimination of the question was poor.