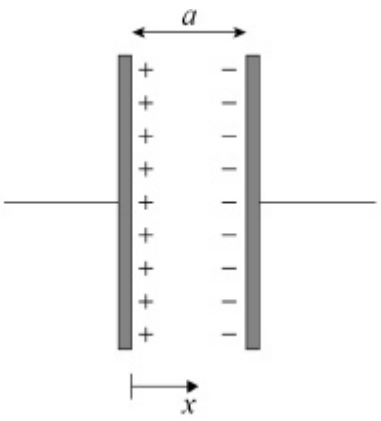
A LEVEL PHYSICS

WORKED SOLUTIONS

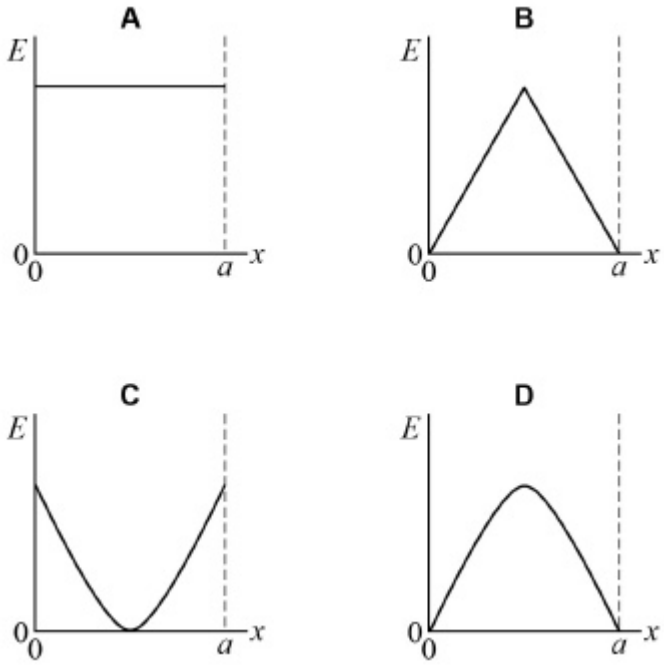
7.3. Electric Fields MCQ

Worked Solutions by Lewis Matheson from
ALevelPhysicsOnline.com in collaboration
with **PhysicsAndMathsTutor**.com

1. Two parallel metal plates of separation a carry equal and opposite charges.



Which graph best represents how the electric field strength E varies with the distance x in the space between the two plates?



A ● Electric field is constant

B ○

C ○

D ○

(Total 1 mark)

2. A particle of mass m and charge q is accelerated through a potential difference V over a distance d.

What is the average acceleration of the particle?

A $\frac{qV}{md}$ ●

B $\frac{mV}{qd}$ ○

C $\frac{V}{mqd}$ ○

D $\frac{dV}{mq}$ ○

$F = ma \qquad F = \frac{E}{d} = \frac{Vq}{d}$

$ma = \frac{Vq}{d}$

$a = \frac{Vq}{md}$

(Total 1 mark)

3. An electron on the surface of the Earth is placed in an electric field of strength 5000 N C^{-1}.

What is $\left(\frac{\text{electric force}}{\text{gravitational force}}\right)$ for the electron?

A 1.1×10^{-14} ○

B 2.9×10^{-10} ○

C 3.4×10^{9} ○

D 9.0×10^{13} ●

$\frac{F_E}{F_g} = \frac{QE}{(GmM/r^2)} = \frac{QEr^2}{GmM}$

$\frac{F_E}{F_g} = \frac{1.60\times10^{-19} \times 5000 \times (6.37\times10^{6})^2}{6.67\times10^{-11} \times 9.11\times10^{-31} \times 5.97\times10^{24}}$

$= 9.02\times10^{13}$

(Total 1 mark)

4. An α particle makes a head–on collision with a gold nucleus containing 79 protons. The distance of closest approach of the α particle to the nucleus is 4.0×10^{-14} m.

What electrostatic force acts on the gold nucleus when at this separation?

A 9.1×10^{-11} N ○

B 23 N ●

C 290 N ○

D 1.4×10^{20} N ○

$F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$

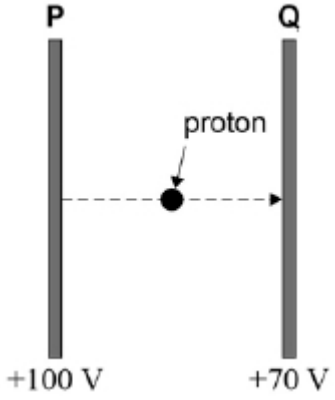
$F = \frac{2\times79\times(1.60\times10^{-19})^2}{4\times\pi\times8.85\times10^{-12}\times(4.0\times10^{-14})^2}$

$F = 22.7\ N$

(Total 1 mark)

5. Two fixed parallel metal plates **P** and **Q** are at constant electrical potentials of +100 V and +70 V respectively. A proton travelling from **P** to **Q** experiences a force F due to the electric field between **P** and **Q**, and a change of potential energy of ΔE_p.

Force in opposite direction to E_p gain



$\Delta E_p = E_Q - E_p$

$= 70eV - 100eV$

$= -30eV$

Which line, **A** to **B**, in the table gives the direction of F and the value of ΔE_p?

	Direction of F	ΔE_p	
A	towards **P**	+30 eV	○
B	towards **Q**	+30 eV	○
C	towards **Q**	−30 eV	●
D	towards **P**	−30 eV	○

(Total 1 mark)

6. An electron moves through a distance of 0.10 m parallel to the field lines of a uniform electric field of strength 2.0 kN C^{-1}.

What is the work done on the electron?

$W = Fs$ $F = EQ$

A zero ○

B 1.6×10^{-17} J ○

C 3.2×10^{-17} J ●

D 1.6×10^{-21} J ○

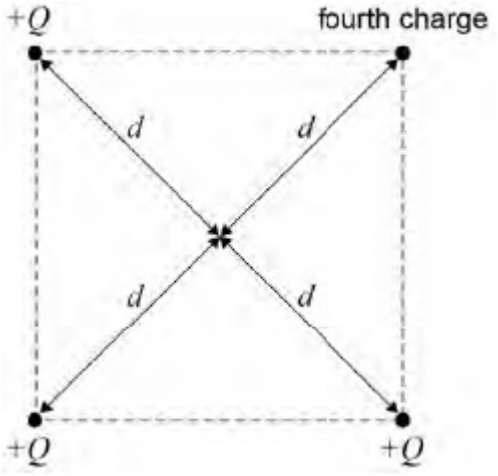
$W = EQs$

$W = 2000 \times 1.60 \times 10^{-19} \times 0.10$

$W = 3.2 \times 10^{-17}$ J

(Total 1 mark)

7. Four positive charges are fixed at the corners of a square as shown.



The total potential at the centre of the square, a distance d from each charge, is $\frac{5Q}{4\pi\varepsilon_0 d}$

Three of the charges have a charge of +Q

What is the magnitude of the fourth charge?

$V = \frac{Q}{4\pi\varepsilon_0 d}$

$V_T = \frac{\Sigma Q}{4\pi\varepsilon_0 d} = \frac{5Q}{4\pi\varepsilon_0 d}$

$\Sigma Q = 5Q$

4^{th} charge $= 5Q - Q - Q - Q = 2Q$

A $-\frac{7Q}{4}$ ○

B Q ○

C $\sqrt{2}Q$ ○

D $2Q$ ●

(Total 1 mark)

8. A charged spherical conductor has a radius r. An electric field of strength E exists at the surface due to the charge.

What is the potential of the spherical conductor?

$E = \frac{V}{d}$

$V = Ed = rE$

A $r^2 E$ ○

B $r E^2$ ○

C $\frac{E}{r}$ ○

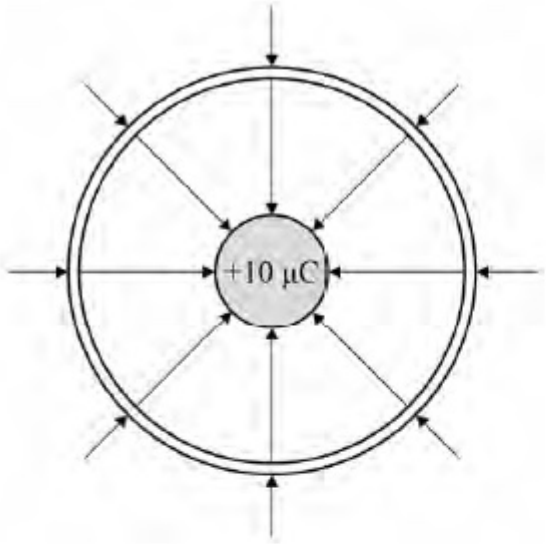
D $r E$ ●

(Total 1 mark)

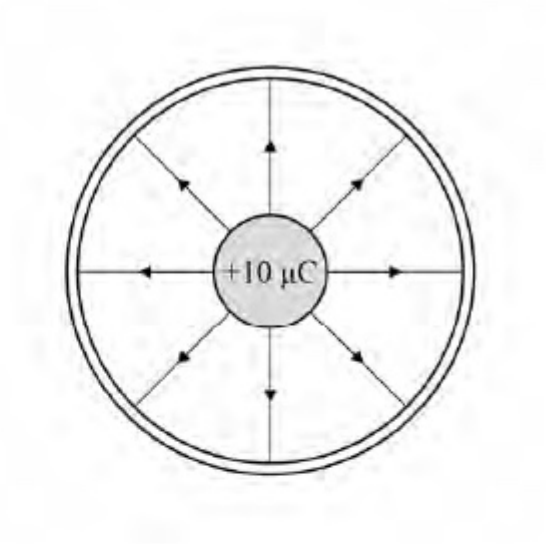
9. A conducting sphere holding a charge of +10 μC is placed centrally inside a second uncharged conducting sphere.

Which diagram shows the electric field lines for the system?

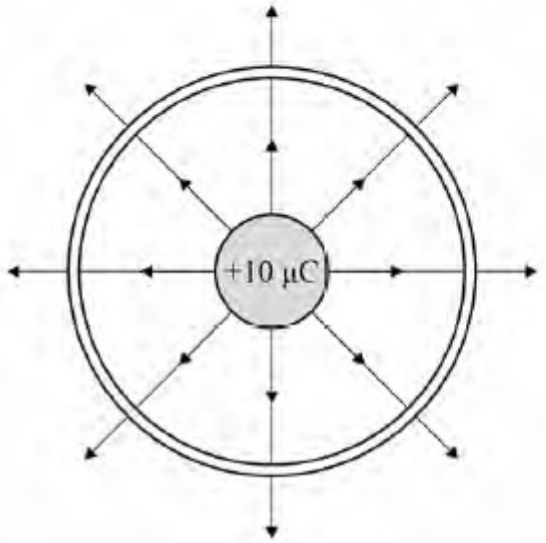
A



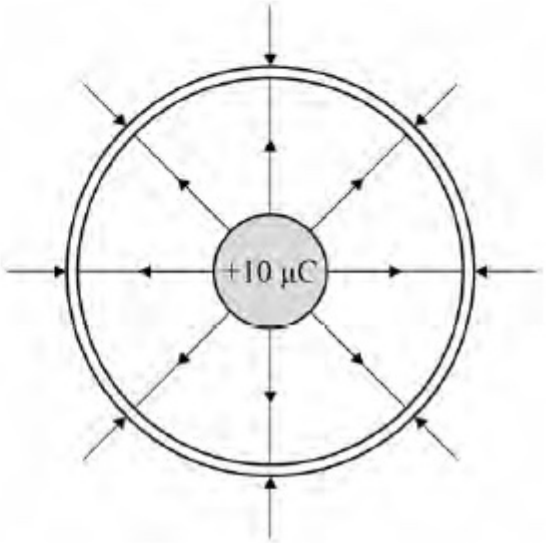
B



C



D



A ☐

B ☐

C ☒

D ☐

+ve charge ∴ radial field lines point outwards

uncharged conducting sphere becomes charged, acts as a positively charged sphere

∴ lines in the same direction

(Total 1 mark)

10. The ionisation potential for the atoms of a gas is V. Electrons of mass m and charge e travelling at a speed v can just cause ionisation of atoms in the gas.

What is V?

Meant to be a lowercase 'v'

A $\frac{eV}{2m}$ ○

B $\frac{2eV}{m}$ ○

C $\sqrt{\frac{eV}{2m}}$ ○

D $\sqrt{\frac{2eV}{m}}$ ●

$V = \frac{E_K}{Q}$ ← Work done on atoms by electrons

$V = \frac{\frac{1}{2}mv^2}{e}$

$2eV = mv^2$

$v = \sqrt{\frac{2eV}{m}}$

(Total 1 mark)

11. An electric field acts into the plane of the paper. An electron enters the field at 90° to the field lines.

The force on the electron is

A zero. ○

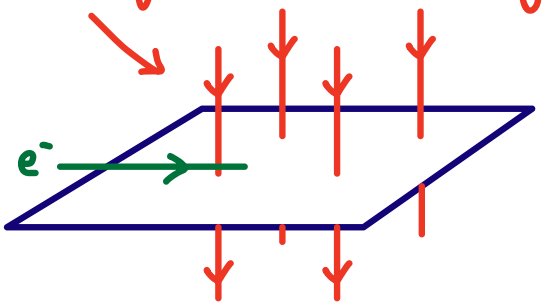
B along the direction of the field. ○

C at 90° to the field. ○

D opposite to the direction of the field. ●

(Total 1 mark)

Direction = force on a +ve charge



∴ force on -ve electron must be opposite i.e. up out of paper

12. A positive charge of 2.0×10^{-4} C is placed in an electric field at a point where the potential is +500 V.

What is the potential energy of the system?

A 1.0×10^{-1} J ●

B 1.0×10^{-1} J C^{-1} ○

C 4.0×10^{-7} J ○

D 4.0×10^{-7} J C^{-1} ○

$E_p = QV$

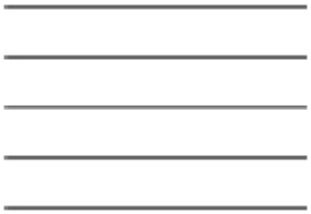
$= 2.0 \times 10^{-4} \times 500$

$= 1.0 \times 10^{-1}$ J

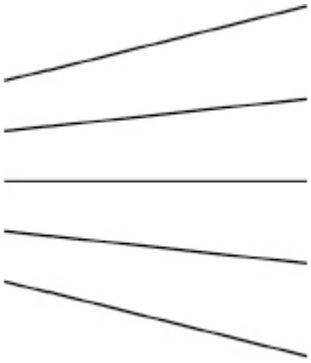
(Total 1 mark)

13. Which diagram shows lines of equipotential in steps of equal potential difference near an isolated point charge?

A



B



C

D

A ⬭

B ⬭

C ⬭

D ⬬

$V \propto \frac{1}{r}$ ∴ must be parallel, concentric circles that get more spaced out

(Total 1 mark)

14. Two fixed charges of magnitude $+Q$ and $+3Q$ repel each other with a force F. An additional charge of $-2Q$ is given to each charge.

What are the magnitude and the direction of the force between the charges?

	Magnitude of force	Direction of force	
A	$\frac{F}{3}$	repulsive	○
B	$5F$	attractive	○
C	$5F$	repulsive	○
D	$\frac{F}{3}$	attractive	●

$F \propto Q_1 Q_2$

$F_1 = +Q \cdot +3Q = 3Q^2$

$F_2 = -Q \cdot +Q = -Q^2$

$F_2 = -\frac{F_1}{3}$

(Total 1 mark)

15. At a distance L from a fixed point charge, the electric field strength is E and the electric potential is V.

What are the electric field strength and the electric potential at a distance $3L$ from the charge?

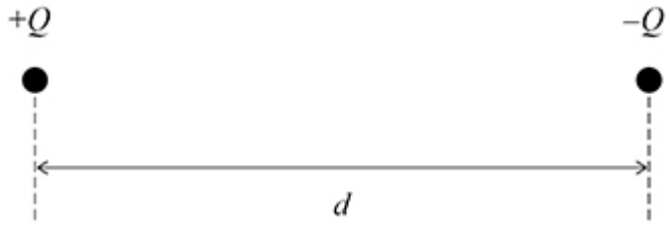
	Electric field strength	Electric potential	
A	$\frac{E}{3}$	$\frac{V}{9}$	○
B	$\frac{E}{3}$	$\frac{V}{3}$	○
C	$\frac{E}{9}$	$\frac{V}{3}$	●
D	$\frac{E}{9}$	$\frac{V}{9}$	○

(Total 1 mark)

$E \propto \frac{1}{r^2} \quad \therefore \frac{E}{3^2} = \frac{E}{9}$

$V \propto \frac{1}{r} \quad \therefore \frac{V}{3}$

16. The diagram shows a particle with charge $+Q$ and a particle with charge $-Q$ separated by a distance d.
The particles exert a force F on each other.



An additional charge of $+2Q$ is then given to each particle and their separation is increased to $2d$.

What is the force that now acts between the particles?

$F \propto Q_1 Q / d^2$

$F_1 = +Q \cdot -Q / d^2 = -Q^2/d^2$

$F_2 = +3Q \cdot +Q / 2d^2 = +\frac{3Q^2}{4d^2}$

A an attractive force of $\frac{9}{2}F$ ○

B an attractive force of $\frac{9}{4}F$ ○

C a repulsive force of $\frac{3}{2}F$ ○

D a repulsive force of $\frac{3}{4}F$ ●

(Total 1 mark)

17. Two protons are separated by distance r.
The electrostatic force between the two protons is **X** times the gravitational force between them.

What is the best estimate for **X**?

$F_g = \frac{6.67 \times 10^{-11} \times (10^{-27})^2}{r^2} \approx \frac{10^{-65}}{r^2}$

$F_E = \frac{(10^{-19})^2}{4\pi \times 10 \times 10 \times 10^{-12} \, r^2} = \frac{10^{-28}}{r^2}$ (4π, 8.85)

A 10^{20} ○

B 10^{28} ○

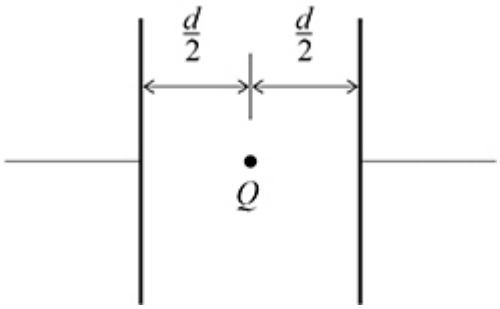
C 10^{36} ●

D 10^{42} ○

(Total 1 mark)

$F_E / F_g = 10^{-28} / 10^{-65} \approx 10^{37}$ (very rough)

18. Two parallel metal plates separated by a distance d have a potential difference V across them. A particle with charge Q is placed midway between the plates.



What is the magnitude of the electrostatic force acting on the particle?

A zero ○

B $\frac{QV}{2d}$ ○

C $\frac{QV}{d}$ ●

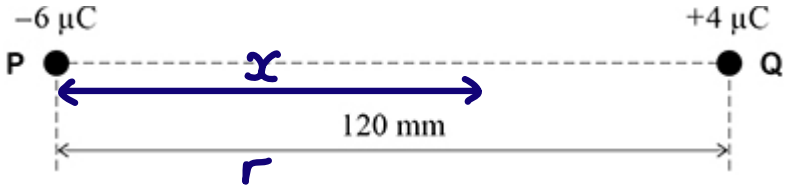
D $\frac{2QV}{d}$ ○

$F = EQ \qquad E = \frac{V}{d}$

$F = \frac{VQ}{d}$

(Total 1 mark)

19. Two charged particles **P** and **Q** are separated by a distance of 120 mm.
X is a point on the line between **P** and **Q** where the electric potential is zero.



What is the distance from **P** to **X**?

$V \propto \frac{Q}{r} \qquad V_P + V_Q = 0 \qquad V_P = -V_Q$

A 40 mm ○

B 48 mm ○

C 60 mm ○

D 72 mm ●

$\frac{Q_P}{x} = \frac{-Q_Q}{r-x}$

$Q_P r - Q_P x = -Q_Q x$

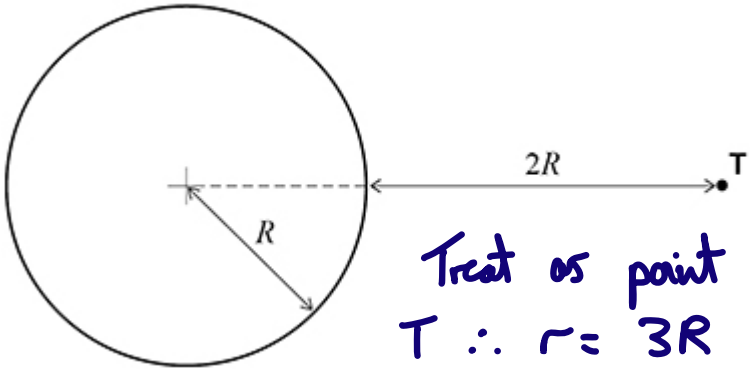
$x(Q_P - Q_Q) = Q_P . r$

$x = \frac{-6 \times 120}{-6-4}$

$= \frac{720}{10} = 72 \text{ mm}$

(Total 1 mark)

20. An isolated spherical conductor is charged.
The conductor has a radius R and an electric potential V. The electric field strength at its surface is E.



Treat as point charge at T ∴ r = 3R

Point **T** is a distance $2R$ from the surface.

What are the electric field strength and electric potential at **T**?

	Electric field strength	Electric potential
A	~~$\frac{E}{2}$~~	~~$\frac{V}{4}$~~
B	~~$\frac{E}{3}$~~	~~$\frac{V}{9}$~~
C	~~$\frac{E}{4}$~~	~~$\frac{V}{2}$~~
D	$\frac{E}{9}$	$\frac{V}{3}$

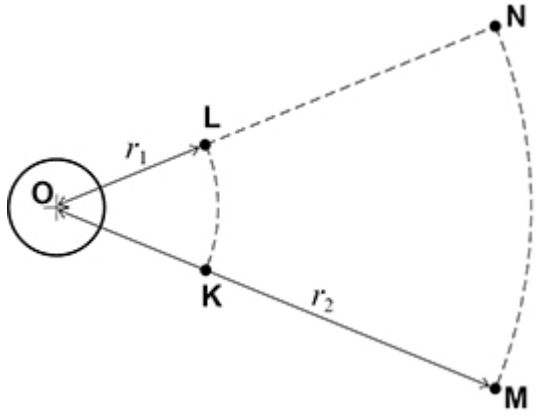
○ ○ ○ ●

$E \propto \frac{1}{r^2}$ ∴ $\frac{E}{3^2} = \frac{E}{9}$

$V \propto \frac{1}{r}$ ∴ $\frac{V}{3}$

(Total 1 mark)

21. **O** is the centre of a negatively charged sphere.



M and N lie on an equipotential

K and **L** are two points at a distance r_1 from **O**.
M and **N** are two points at a distance r_2 from **O**.

Which statement is true?

A The work done moving an electron from **M** to **K** is the same as that done moving an electron from **K** to **L**.

B The work done moving a positron from **K** to **M** is the same as that done moving an electron from **K** to **M**.

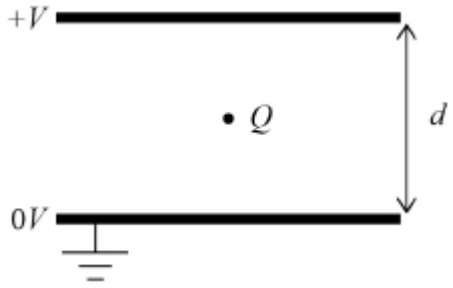
C No work is done moving an electron from **M** to **N**.

D No work is done moving a positron from **L** to **N**.

$\Delta W = Q\Delta V$ but $\Delta V = 0$

(Total 1 mark)

22. A small object of mass m has a charge Q. The object remains stationary in an evacuated space between two horizontal plates. The plates are separated by a distance d and the potential difference between the plates is V.



What is V?

A $\frac{mQg}{d}$

B $\frac{mdg}{Q}$

C $\frac{mQ}{d}$

D $\frac{md}{Q}$

$V = \frac{E_p}{Q} = \frac{mgh}{Q}$ $h = d$

$V = \frac{mgd}{Q}$

(Total 1 mark)

23. 1.5 mJ of work is done when a charge of 30 μC is moved between two points, **M** and **N**, in an electric field.

What is the potential difference between **M** and **N**?

A 20 mV ○

B 20 V ○

C 45 V ○

D 50 V ●

$\Delta V = \frac{\Delta W}{Q} = \frac{1.5 \times 10^{-3}}{30 \times 10^{-6}}$

$= 50V$

(Total 1 mark)

24. A parallel-plate capacitor is fully charged and then disconnected from the power supply. A dielectric is then inserted between the plates.

Which row correctly identifies the charge on the plates and the electric field strength between the plates?

	Charge	Electric field strength	
A	Stays the same	Increases	○
B	Increases	Decreases	○
C	Increases	Increases	○
D	Stays the same	Decreases	●

(Total 1 mark)

Dielectric reduces the electric field between the two charged plates, but does not change the charge.