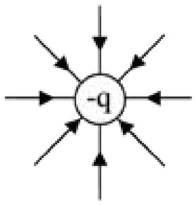
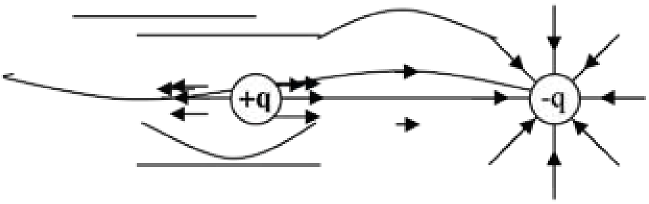
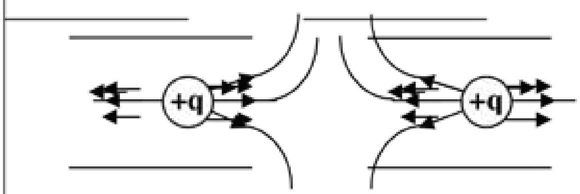
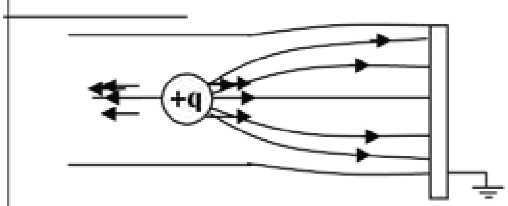
Electrical Fundamentals

Set 14: Electrical Charges and Fields

14.1	(a)	
	(b)	
	(c)	
	(d)	
14.2		As the car moves and its rubber tyres rub against the ground static charge accumulates around the car shell. The car is effectively isolated from the ground as rubber is an insulator however when you touch it, you provide the charge with a path to Earth which it readily accepts and you may feel a small shock.
14.3	(a)	$q = 1000 \times e = 100 \times 1.6 \times 10^{-19}$ C $= 1.6 \times 10^{-16}$ C

	(b)	$F = 9 \times 10^9 \dfrac{q_1 q_2}{d^2} = 9 \times 10^9 \dfrac{(1.6 \times 10^{-16}\ C)(-1.6 \times 10^{-16}\ C)}{(0.01 \times 10^{-3}\ m)^2} = -2.3 \times 10^{-12}\ N$ negative forces are attractive forces
	(c)	see diagram 1b). above
14.4		0.7 pC is equivalent to a $\text{number of electrons} = \dfrac{q}{e} = \dfrac{0.7 \times 10^{-12}\ C}{1.6 \times 10^{-19}\ C} = 4.4 \times 10^6$ so, if 7 x 10^6 electrons are suddenly released into the chip, thereby more than doubling the existing number, the relatively huge repelling force exerted on these electrons will cause chaos.
14.5	(a)	Electrostatic attraction due to opposite charges being on the L plate and the window – the L plate will definitely be charged and the window probably uncharged.
	(b)	Friction between the rubbing of the L plate on clothing – electrons will be transferred from one of these materials to the other, leaving them each with an equal but opposite charge.
	(c)	Metallic surfaces since the charge would not remain concentrated in one point (metals are good conductors) and they would begin evenly distributing themselves over the surface. Also, any surface which has a similar charge to the L plate already on it, since like charges repel.
	(d)	No since the L plate is plastic and static charge will occur only at the point of rubbing where it will be more concentrated. It is unlikely that all parts of the L plate are rubbed exactly the same.
14.6		$I = \dfrac{q}{t} = \dfrac{2 \times 10^{-9}\ C}{1 \times 10^{-6}\ s} = 2.0 \times 10^{-3}\ \text{A or } 2.0\ \text{mA}$
14.7	(a)	q = I x t = 2 A x (4 h x 3600 s) = 2.88 x 10^4 C
	(b)	$\text{number of electrons} = \dfrac{q}{e} = \dfrac{2.88 \times 10^4\ C}{1.6 \times 10^{-19}\ C} = 1.8 \times 10^{23}$
14.8	(a)	q = I x t = 4 A x 90 s = 360 C
	(b)	since voltage is work done per unit charge, then W = V x q = 240 V x 360 C = 86 400 J (or 86.4 kJ)
14.9		When taking the coffee cups out of the stacks in the carton you charge them electrically. Since polystyrene is an insulator the charge is retained and since they are set out close together there is an electrostatic force between them. Whether this is attractive or repulsive makes no difference, there will be some movement since the cups have little mass and therefore little inertia to overcome the force.
14.10	(a)	$F = 9 \times 10^9 \dfrac{q_1 q_2}{d^2}$ since the charges are the same, then $q = \sqrt{\dfrac{F d^2}{9 \times 10^9}} = \sqrt{\dfrac{0.5\ N \times (0.8 \times 10^{-3}\ m)^2}{9 \times 10^9}}$ gives q = 5.96 x 10^{-9} C (or 5.96 nC)

	(b)	This equation applies to point charges and the articles of clothing cannot really be considered as such.
14.11	(a)	In order for the oil drop to be attracted towards the upper plate (thereby opposing the gravitational pull acting upon it), it must be oppositely charged to that plate. So, the oil drop will be negatively charged.
	(b)	The force must be exactly balanced by the gravitational force, so $F_{elec} = 2 \times 10^{-3}$ N
	(c)	If F_{elec} is greater than F_{grav} then there will be an upward resultant force and the oil drop will move toward the upper plate.
	(d)	$\text{number of electrons} = \frac{q}{e} = \frac{6.4 \times 10^{-18}\ \text{C}}{1.6 \times 10^{-19}\ \text{C}} = 40$
	(e)	$F = 9 \times 10^{9} \frac{q_1 q_2}{d^2} = 9 \times 10^{9} \frac{6.4 \times 10^{-18}\ \text{C} \times 6.4 \times 10^{-18}\ \text{C}}{(0.02 \times 10^{-3}\ \text{m})^2} = 9.22 \times 10^{-22}\ \text{N}$ positive forces are repulsive forces
	(f)	Any suggestion that involves friction charging the oil drop as it enters the gap between the plates, e.g. inserting it through a syringe.
14.12	(a)	Current follows the path of "least resistance" and that is to a conductor on the ground. The air is ionised and the spark or ionised flash represents that current path. Air, even humid air, is not a good conductor of electricity. Typical values: the electric field for a spark is of the order of 10^6 V m^{-1} so the difference in voltage between the ends would be of the order of 10^9 V, assuming a cloud to Earth distance of about 1000 m.
	(b)	The cause is friction between particles which constitute the clouds with each other and other air particles. Since the cloud is an isolated system, the charge and hence the voltage (since q is proportional to V) accumulates.
	(c)	$E = P \times t = 100$ W x (3 months x 30 days x 24 h x 3600 s) = 7.8×10^8 J
	(d)	$q = \frac{W}{V} = \frac{7.8 \times 10^8\ \text{J}}{10^9\ \text{V}} = 0.78\ \text{C}$
	(e)	$I = \frac{q}{t} = \frac{0.78\ \text{C}}{50 \times 10^{-6}\ \text{s}} = 15\,600\ \text{A or } 15.6\ \text{kA}$