2015 Question 8

(i) **Define electric field strength.**

\[ E = \text{force per unit charge} \]

(ii) **Draw a labelled diagram of a gold leaf electroscope.**

A = insulated joint, B = metal case

Marking scheme:
- Metal cap attached to gold leaves
- Metal case (and glass window)
- Both the cap and the leaves are insulated from the case

(iii) **Describe how it can be given a negative charge by induction.**

- Positively charged rod
- Bring rod close to cap
- Earth cap
- Remove earth (and then remove rod)

(iv) **Explain, with the aid of a labelled diagram, how point discharge occurs.**

- Diagram with concentration of charge at point
- Air/gas near the point is ionised (by large electric field)
- Opposite charges neutralise the charge at the point

(v) **Describe an experiment to demonstrate point discharge.**

- Apparatus
- Charge pointed conductor
- Observe point discharge / ionic wind using e.g. candle

(vi) **What is the electric field strength at a point 4 cm from the surface of the dome?**

\[ d = 24 \text{ cm} = 0.24 \text{ m} \]
\[ E = \frac{Q}{4\pi\varepsilon d^2} \]
\[ E = 5.9 \times 10^5 \text{ N C}^{-1} \text{ away from the centre of the dome} \]
2014 Question 9
(i) **Explain the underlined terms.**
   Capacitance is the ratio of charge (on a capacitor) to the potential difference across it.
   An electric field is a region (of space) where electrostatic forces are experienced / forces experienced by charged particles
(ii) **Describe an experiment to demonstrate an electric field pattern.**
    High voltage
    Connected to two plates
    In oil and semolina
    Semolina forms electric field pattern
(iii) **Calculate the charge on each plate**
    \[ C = \frac{Q}{V} \]
    \[ Q = 72 \, \mu C \]
(iv) **Calculate the energy stored in the capacitor.**
    \[ E = \frac{1}{2}CV^2 \]
    \[ E = 216 \, \mu J \]
(v) **Calculate the new capacitance.**
    \[ 4 \, \mu F \]
(vi) **State two differences between a capacitor and a battery.**
    Capacitor discharges faster than a battery / capacitor stores (electrostatic) potential energy while a battery stores chemical energy / battery gives a constant current / battery stores more energy
(vii) **Touchscreens also contain two polarising filters. What is meant by polarisation of light?**
    Vibration of a wave is in one plane
(viii) **Give one application of capacitors, other than in touchscreens.**
    e.g. flash of a camera / tuning circuits / defibrillator

2013 Question 12 (c)
(i) **Define the unit of charge, the coulomb.**
    The coulomb is the amount of charge that passes when one Amp flows for one second.
(ii) **State Coulomb’s law**
    Coulomb’s Law states that the force between two point charges is proportional to the product of the charges and inversely proportional to the square of the distance between them.
(iii) **Calculate the force of repulsion between two small spheres when they are held 8 cm apart in a vacuum.**
    \[ F = \frac{1}{4\pi\varepsilon} \frac{Q_1Q_2}{d^2} \]
    \[ F = 12.64 \, N \]
(iv) **Copy the diagram above and show on it the electric field generated by the charges.**
    Curved deviation of the field lines on interaction
    Correct direction of field
(v) **Mark on your diagram a place where the electric field strength is zero.**
    Neutral/null point marked halfway between charges
2011 Question 9

(a)
(i) **State Coulomb’s law**
   The force between two charges is proportional to the product of the charges and inversely proportional to the square of the distance between them.

(ii) **What is the new force, in terms of \( F \), between the spherical conductors?**

   \[
   F = \frac{Q(3Q)}{4\pi \varepsilon d^2}
   \]

   \[
   F' = \frac{2Q(2Q)}{4\pi \varepsilon d^2}
   \]

   \[
   F' = \frac{4}{4\pi \varepsilon d^2} \left(\frac{4\pi \varepsilon d^2 F}{3}\right)
   \]

   \[
   F' = \frac{4}{3} F
   \]

(b)
(i) **Draw a labelled diagram of an electroscope.**

A = insulated joint, B = metal case

(ii) **Why should the frame of an electroscope be earthed?**

   If the frame was charged it would affect the degree of deflection of the leaf.

(iii) **Describe how to charge an electroscope by induction.**

   1. Bring a charged rod near the electroscope (the positive and negative charges become separated on it).
   2. Keeping the charged rod in place, earth the cap by touching it with your finger.
   3. Some of the negative charge on the metal flows through you to earth.
   4. Remove your finger, then and only then remove the rod.
   5. The conductor will now be positively charged.

(c)
(i) **How does a full-body metal-foil suit protect an operator when working on high voltage power lines?**

   All charges will reside on the outside of the conducting suit because the suit blocks out external electrical fields so he won’t get shocked.

   (You did need to make reference to electric fields to get full marks here, even though it wasn’t specifically mentioned in the syllabus, which I thought was nasty).

(ii) **Describe an experiment to investigate the principle by which the operator is protected.**

   1. Charge the conductor (a metal can will do fine).
   2. Using a proof plane, touch the inside of the can and bring it up to the GLE. Notice that there is no deflection.
   3. Touch the proof plane off the outside of the can and bring it up to the GLE. Notice that there is a deflection.
   4. Conclusion: charge resides on outside only
2010 Question 12 (d)

(i) Define electric field strength and give its unit of measurement.
   Electric field strength is defined as force per unit charge.
   Its unit is the N C$^{-1}$

(ii) Copy the diagram into your answerbook and show on it the direction of the electric field at point P.

(iii) Calculate the electric field strength at P.
   The electric field strength at P is the sum of the electric fields acting on P from the other two charges.
   The electric field strength is towards the left in both cases (attracted to the negative charge and repelled from the positive charge). Because they are both in the same direction the individual field strengths can simply be added together.

\[
E = \frac{q_1}{4\pi \varepsilon d^2} + \frac{q_2}{4\pi \varepsilon d^2}
\]

\[
E = \frac{2 \times 10^{-6}}{4\pi \varepsilon (0.1)^2} + \frac{5 \times 10^{-6}}{4\pi \varepsilon (0.15)^2}
\]

\[
E_{\text{total}} = 3.77 \times 10^6 \text{ N C}^{-1}
\]

(iv) Under what circumstances will point discharge occur?
   Large electric field strength / potential at a point / high charge density at a point.

2009 Question 9

(i) Define potential difference
   Potential difference is the work done in moving unit charge from one place to another.

(ii) Define capacitance
   The capacitance of a conductor is the ratio of the charge on the conductor to its potential.

(iii) A capacitor stores energy.
   Describe an experiment to demonstrate that a capacitor stores energy.
   1. Set up as shown.
   2. Close the switch to charge the capacitor.
   3. Remove the battery and connect the terminals together to ‘short’ the circuit.
   4. The bulb will flash as the capacitor discharges, showing that it stores energy.

   The ability of a capacitor to store energy is the basis of a defibrillator. During a heart attack the chambers of the heart fail to pump blood because their muscle fibres contract and relax randomly.
   To save the victim, the heart muscle must be shocked to re-establish its normal rhythm.
   A defibrillator is used to shock the heart muscle.
   A 64 μF capacitor in a defibrillator is charged to a potential difference of 2500 V.
   The capacitor is discharged through electrodes attached to the chest of a heart attack victim.

(iv) Calculate the charge stored on each plate of the capacitor.
   \[q = CV \quad \Box \quad q = (64 \times 10^{-6})(2500) \quad \Box \quad q = 0.16 \text{ C}\]

(v) Calculate the energy stored in the capacitor.
   \[E = \frac{1}{2} CV^2 = \frac{1}{2} (64 \times 10^{-6})(2500)^2 = 200 \text{ J}\]

(vi) Calculate the average current that flows through the victim when the capacitor discharges in a time of 10 ms.
   \[I = \frac{q}{t} = (64 \times 10^{-6})/(10 \times 10^{-3}) = 16 \text{ A}\]

(vii) Calculate the average power generated as the capacitor discharges.
   \[P = \frac{W}{t} = (200)/(10 \times 10^{-3}) = 20000 \text{ W}\]
2008 Question 12 (d)
(i) Define capacitance.
   The capacitance of a conductor is the ratio of the charge on the conductor to its potential.
(ii) Describe how an electroscope can be charged by induction.
   1. Bring a charged rod near the electroscope (the positive and negative charges become separated on it).
   2. Keeping the charged rod in place, earth the cap by touching it with your finger.
      Some of the negative charge on the metal flows through you to earth.
   3. Remove your finger, then and only then remove the rod.
   4. The conductor will now be positively charged.
(iii) How would you demonstrate that the capacitance of a parallel plate capacitor depends on the distance between its plates?
      Connect the two parallel plates to a digital multi-meter (DMM) set to read capacitance. Note the capacitance.
      Increase the distance between them – note that the capacitance decreases.

2007 Question 8
(i) Define electric field strength and give its unit of measurement.
   Electric field strength at a point is the force per unit charge at that point.
   The unit is the N C⁻¹
(ii) Describe how an electric field pattern may be demonstrated in the laboratory.
   Apparatus: oil, metal plates, container, semolina, H.T.
   Arrange: correct arrangement
   Procedure: switch on power
   Observation: semolina particles line up to show field pattern.
(iii) The dome of a Van de Graff generator is charged.
(iv) The dome has a diameter of 30 cm and its charge is 4 C.
     A 5 μC point charge is placed 7 cm from the surface of the dome.
     Calculate the electric field strength at a point 7 cm from the dome.
     The key here is to note that d corresponds to the distance from the charge to the centre of the dome, i.e.
     0.07 + 0.15 (radius of the dome) = 0.22 m
     \[ E = \frac{1 \times 4}{4 \pi (8.9 \times 10^{-12}) (0.22)^2} \]
     Answer: \( E = 7.39 \times 10^{11} \text{ N C}^{-1} \)
(v) Calculate the electrostatic force exerted on the 5 μC point charge.
     \( F = E q \)
     \( F = (7.39 \times 10^{11}) (5 \times 10^{-6}) \) or \( F = 3.69 \times 10^6 \text{ N} \)
(vi) All the charge resides on the surface of a Van de Graff generator’s dome. Explain why.
     Like charges repel and the charges are a maximum distance apart on the outside surface of dome.
(vii) Describe an experiment to demonstrate that total charge resides on the outside of a conductor.
     Apparatus: metal can, gold leaf electroscope, proof plane.
     Procedure: charge metal can and use proof plane to test inside and outside.
     Observation: leaves on g.l.e. deflect for outside sample only.
     Conclusion: charge resides on outside only.
(viii) Give an application of this effect.
     Electrostatic shielding / co-axial cable / TV (signal) cable / to protect persons or equipment, enclose
     them in hollow conductors /Faraday cages (there is no electric field inside a closed conductor), etc.
2006 Question 12 (b)

(i) List the factors that affect the capacitance of a parallel plate capacitor.
Common area of plates, distance apart, permittivity of dielectric between plates.

(ii) The plates of an air filled parallel plate capacitor have a common area of 40 cm\(^2\) and are 1 cm apart.
The capacitor is connected to a 12 V d.c. supply. Calculate the capacitance of the capacitor.
\[ C = \varepsilon_A/d \]
\[ C = [(8.85 \times 10^{-12})(40 \times 10^{-4})] / (0.01) \]
\[ C = 3.54 \times 10^{-12} \text{ F} \]

(iii) Calculate the magnitude of the charge on each plate.
\[ Q = C \times V \]
\[ Q = (3.54 \times 10^{-12})(12) = 4.2(5) \times 10^{-11} \text{ C} \]

(iv) What is the net charge on the capacitor?
zero

(v) Give a use for a capacitor.
blocks d.c. /smoothing /tuning circuits / timing circuits / flash guns for cameras.

2005 Question 10

(i) Define electric field strength.
Electric field strength is defined as force per unit charge.

(ii) State Coulomb’s law of force between electric charges.
The force between two charges is proportional to the product of the charges and inversely proportional to the square of the distance between them.

(iii) Why is Coulomb’s law an example of an inverse square law?
Force is inversely proportional to distance squared.

(iv) Give two differences between the gravitational force and the electrostatic force between two electrons.
  Gravitational force is much smaller than the electrostatic force.
  Gravitational force is attractive, electrostatic force (between two electrons) is repulsive.

(v) Describe an experiment to show an electric field pattern.
High voltage and two metal plates /electrodes
Semolina and oil in container
Connect a (high) voltage to the plates in container
Semolina lines up in the field

(vi) Calculate the electric field strength at the point B, which is 10 mm from an electron.
\[ E = Q/4\pi\varepsilon d^2 \]
\[ = (1.6 \times 10^{-19})/4\pi(8.9 \times 10^{-12})(0.01)^2 \]
\[ E = 1.4 \times 10^{-5} \text{ N C}^{-1} \]

(vii) What is the direction of the electric field strength at B?
Towards the electron / to the right

(viii) A charge of 5 μC is placed at B. Calculate the electrostatic force exerted on this charge.
\[ F = Eq \text{ or } F = (1.4 \times 10^{-5})(5 \times 10^{-6}) \]
\[ = 7.2 \times 10^{-11} \text{ N} \]
Towards the electron
2004 Question 8

(i) **Define potential difference.**
   The potential difference (p.d.) between two points is the work done in bringing a charge of 1 Coulomb from one point to the other.

(ii) **Define capacitance.**
   The capacitance of a conductor is the ratio of the charge on the conductor to its potential.

(iii) **Describe an experiment to demonstrate that a capacitor can store energy.**
   1. Set up as shown.
   2. Close the switch to charge the capacitor.
   3. Remove the battery and connect the terminals together to ‘short’ the circuit.
   4. The bulb will flash as the capacitor discharges, showing that it stores energy.

(iv) **Calculate the potential difference across the resistor and hence the potential difference across the capacitor when the current is 80 μA.**
   \[ V = IR \]
   \[ V \text{ (across 47 kΩ resistor)} = (80 \times 10^{-6} \times 47 \times 10^3) = 3.76 \text{ V} \]
   \[ V \text{ (across the capacitor)} = 6 - 3.76 = 2.24 \text{ V} \]

(v) **Calculate the charge on the capacitor at this instant.**
   \[ C = \frac{Q}{V} \]
   \[ Q = CV = (50 \times 10^{-6}) \times (2.24) = 1.12 \times 10^{-4} \text{ C} \]

(vi) **Calculate the energy stored in the capacitor when it is fully charged.**
   \[ E = \frac{1}{2} CV^2 = \frac{1}{2} (50 \times 10^{-6})(6)^2 = 9 \times 10^{-4} \text{ J} \]

(vii) **Describe what happens in the circuit when the 6 V d.c. supply is replaced with a 6 V a.c. supply.**
   The current will flow continually.

2003 Question 12 (c)

(i) **State Coulomb’s law of force between electric charges.**
   Coulomb’s Law states that the force between two point charges is proportional to the product of the charges and inversely proportional to the square of the distance between them.

(ii) **Define electric field strength and give its unit.**
   Electric field strength at a point is the force per unit charge at that point.
   The unit of electric field strength is the Newton per Coulomb (NC⁻¹).

(iii) **How would you demonstrate an electric field pattern?**
   Oil and semolina or seeds
   High tension / high voltage
   Lines of semolina show field

(iv) **The diagram shows a negative charge – Q at a point X.**
    Copy the diagram and show on it the direction of the electric field strength at Y.
    Arrow towards X
2002 Question 11

(a) Why is a lightning conductor made of copper?
   It is a good conductor.

(b) What is meant by electric field strength?
   Electric field strength is defined as force per unit charge.

(c) Why do the ions near the lightning conductor accelerate?
   They experience a large force.

(d) How does the presence of ions in the air cause the air to be more conducting?
   The ions act as charge carriers.

(e) How do the charged clouds become neutralised?
   Electrons flow to or from the ground through the air.

(f) What are the two ways in which a lightning conductor prevents a building from being damaged by lightning?
   Neutralises charged clouds
   It conducts charges to earth.

(g) Why are raised umbrellas and golf clubs not recommended during thunderstorms?
   Because they act as lightning conductors.

(h) Explain why pointed surfaces should be avoided when using high voltage electrical equipment.
   Sparking is more likely to occur from these points due to point discharge.