ANSWERS

Chapter 1

1.1 6×10^{-3} N (repulsive)

1.2 (a) 12 cm
(b) 0.2 N (attractive)

1.3 2.4×10^{39}. This is the ratio of electric force to the gravitational force (at the same distance) between an electron and a proton.

1.5 Charge is not created or destroyed. It is merely transferred from one body to another.

1.6 Zero N

1.8 (a) 5.4×10^{6} N C^{-1} along OB
(b) 8.1×10^{-3} N along OA

1.9 Total charge is zero. Dipole moment = 7.5×10^{-8} C m along *z*-axis.

1.10 10^{-4} N m

1.11 (a) 2×10^{12}, from wool to polythene.
(b) Yes, but of a negligible amount (= 2×10^{-18} kg in the example).

1.12 (a) 1.5×10^{-2} N
(b) 0.24 N

1.13 5.7×10^{-3} N

1.14 Charges 1 and 2 are negative, charge 3 is positive. Particle 3 has the highest charge to mass ratio.

1.15 25.98 N m^2/C

1.16 Zero. The number of lines entering the cube is the same as the number of lines leaving the cube.

1.17 (a) 0.07 μC
(b) No, only that the net charge inside is zero.

1.18 2.2×10^{5} N m^2/C

1.19 1.9×10^{5} N m^2/C

1.20 (a) -10^{3} N m^2/C; because the charge enclosed is the same in the two cases.
(b) –8.8 nC

1.21 –6.67 nC

1.22 (a) 1.45×10^{-3} C
(b) 1.6×10^{8} Nm^2/C

1.23 10 μC/m

1.24 (a) Zero, (b) Zero, (c) 1.9 N/C

1.25 9.81×10^{-4} mm.

1.26 Only (c) is right; the rest cannot represent electrostatic field lines, (a) is wrong because field lines must be normal to a conductor, (b) is wrong because field lines cannot start from a negative charge, (d) is wrong because field lines cannot intersect each other, (e) is wrong because electrostatic field lines cannot form closed loops.

1.27 The force is 10^{-2} N in the negative z-direction, that is, in the direction of decreasing electric field. You can check that this is also the direction of decreasing potential energy of the dipole; torque is zero.

1.28 (a) *Hint:* Choose a Gaussian surface lying wholly within the conductor and enclosing the cavity.

(b) Gauss's law on the same surface as in (a) shows that q must induce $-q$ on the inner surface of the conductor.

(c) Enclose the instrument fully by a metallic surface.

1.29 *Hint:* Consider the conductor with the hole filled up. Then the field just outside is $(\sigma/\varepsilon_0)\ \hat{\mathbf{n}}$ and is zero inside. View this field as a superposition of the field due to the filled up hole plus the field due to the rest of the charged conductor. Inside the conductor, these fields are equal and opposite. Outside they are equal both in magnitude and direction. Hence, the field due to the rest of the conductor is $\left(\dfrac{\sigma}{2\varepsilon_0}\right)\hat{\mathbf{n}}$.

1.31 p;uud; n;udd.

1.32 (a) *Hint:* Prove it by contradiction. Suppose the equilibrium is stable; then the test charge displaced slightly in any direction will experience a restoring force towards the null-point. That is, all field lines near the null point should be directed inwards towards the null-point. That is, there is a net inward flux of electric field through a closed surface around the null-point. But by Gauss's law, the flux of electric field through a surface, not enclosing any charge, must be zero. Hence, the equilibrium cannot be stable.

(b) The mid-point of the line joining the two charges is a null-point. Displace a test charge from the null-point slightly along the line. There is a restoring force. But displace it, say, normal to the line. You will see that the net force takes it away from the null-point. Remember, stability of equilibrium needs restoring force in all directions.

1.34 1.6 cm

Chapter 2

2.1 10 cm, 40 cm away from the positive charge on the side of the negative charge.

2.2 2.7×10^{6} V

2.3 (a) The plane normal to AB and passing through its mid-point has zero potential everywhere.

(b) Normal to the plane in the direction AB.

2.4 (a) Zero

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(b) 10^5 N C^{-1}

(c) 4.4×10^4 N C^{-1}

2.5 96 pF

2.6 (a) 3 pF

(b) 40 V

2.7 (a) 9 pF

(b) 2×10^{-10} C, 3×10^{-10} C, 4×10^{-10} C

2.8 18 pF, 1.8×10^{-9} C

2.9 (a) $V = 100$ V, $C = 108$ pF, $Q = 1.08 \times 10^{-8}$ C

(b) $Q = 1.8 \times 10^{-9}$ C, $C = 108$ pF, $V = 16.6$ V

2.10 1.5×10^{-8} J

2.11 6×10^{-6} J

2.12 1.2 J; the point R is irrelevant to the answer.

2.13 Potential = $4q/(\sqrt{3}\,\pi\,\varepsilon_0\, b)$; field is zero, as expected by symmetry.

2.14 (a) 2.4×10^5 V; 4.0×10^5 Vm^{-1} from charge 2.5 μC to 1.5 μC.

(b) 2.0×10^5 V; 6.6×10^5 Vm^{-1} in the direction that makes an angle of about 69° to the line joining charge 2.5 μC to 1.5 μC.

2.15 (a) $-q/(4\pi r_1^2)$, $(Q+q)/(4\pi r_2^2)$

(b) By Gauss's law, the net charge on the inner surface enclosing the cavity (not having any charge) must be zero. For a cavity of arbitrary shape, this is not enough to claim that the electric field inside must be zero. The cavity may have positive and negative charges with total charge zero. To dispose of this possibility, take a closed loop, part of which is inside the cavity along a field line and the rest inside the conductor. Since field inside the conductor is zero, this gives a net work done by the field in carrying a test charge over a closed loop. We know this is impossible for an electrostatic field. Hence, there are no field lines inside the cavity (i.e., no field), and no charge on the inner surface of the conductor, whatever be its shape.

2.17 $\lambda/(2\pi\varepsilon_0 r)$, where r is the distance of the point from the common axis of the cylinders. The field is radial, perpendicular to the axis.

2.18 (a) –27.2 eV

(b) 13.6 eV

(c) –13.6 eV, 13.6 eV. Note in the latter choice the total energy of the hydrogen atom is zero.

2.19 –19.2 eV; the zero of potential energy is taken to be at infinity.

2.20 The ratio of electric field of the first to the second is (b/a). A flat portion may be equated to a spherical surface of large radius, and a pointed portion to one of small radius.

2.21 (a) On the axis of the dipole, potential is $(\pm\, 1/4\pi\varepsilon_0)\; p/(x^2 - a^2)$ where $p = 2qa$ is the magnitude of the dipole moment; the + sign when the point is closer to q and the – sign when it is closer to $-q$. Normal to the axis, at points $(x, y, 0)$, potential is zero.

(b) The dependence on r is $1/r^2$ type.

(c) Zero. No, because work done by electrostatic field between two points is independent of the path connecting the two points.

2.22 For large r, quadrupole potential goes like $1/r^3$, dipole potential goes like $1/r^2$, monopole potential goes like $1/r$.

2.23 Eighteen 1 μF capacitors arranged in 6 parallel rows, each row consisting of 3 capacitors in series.

2.24 1130 km^2

2.25 Equivalent capacitance

$Q_1 = 10^{-8}$ C, $V_1 = 100$ V ; $Q_2 = Q_3 = 10^{-8}$ C

$V_2 = V_3 = 50$ V

$Q_4 = 2.55 \times 10^{-8}$ C, $V_4 = 200$ V

2.26 (a) 2.55×10^{-6} J

(b) $u = 0.113$ J m^{-3}, $u = (½)\ \varepsilon_0 E^2$

2.27 2.67×10^{-2} J

2.28 *Hint:* Suppose we increase the separation of the plates by Δx. Work done (by external agency) = $F\,\Delta x$. This goes to increase the potential energy of the capacitor by $u\,a\,\Delta x$ where u is energy density. Therefore, $F = u\,a$ which is easily seen to be $(1/2)\ QE$, using $u = (1/2)\ \varepsilon_0\ E^2$. The physical origin of the factor 1/2 in the force formula lies in the fact that just outside the conductor, field is E, and inside it is zero. So, the average value $E/2$ contributes to the force.

2.30 (a) 5.5×10^{-9} F

(b) 4.5×10^2 V

(c) 1.3×10^{-11} F

2.31 (a) No, because charge distributions on the spheres will not be uniform.

(b) No.

(c) Not necessarily. (True only if the field line is a straight line.) The field line gives the direction of acceleration, not that of velocity, in general.

(d) Zero, no matter what the shape of the complete orbit.

(e) No, potential is continuous.

(f) A single conductor is a capacitor with one of the 'plates' at infinity.

(g) A water molecule has permanent dipole moment. However, detailed explanation of the value of dielectric constant requires microscopic theory and is beyond the scope of the book.

2.32 1.2×10^{-10} F, 2.9×10^4 V

2.33 19 cm^2

2.34 (a) Planes parallel to x-y plane.

(b) Same as in (a), except that planes differing by a fixed potential get closer as field increases.

(c) Concentric spheres centred at the origin.

(d) A periodically varying shape near the grid which gradually reaches the shape of planes parallel to the grid at far distances.

2.35 30 cm

2.36 *Hint:* By Gauss's law, field between the sphere and the shell is determined by q_1 alone. Hence, potential difference between the sphere and the shell is independent of q_2. If q_1 is positive, this potential difference is always positive.

2.37 (a) Our body and the ground form an equipotential surface. As we step out into the open, the original equipotential surfaces of open air change, keeping our head and the ground at the same potential.

(b) Yes. The steady discharging current in the atmosphere charges up the aluminium sheet gradually and raises its voltage to an extent depending on the capacitance of the capacitor (formed by the sheet, slab and the ground).

(c) The atmosphere is continually being charged by thunderstorms and lightning all over the globe and discharged through regions of ordinary weather. The two opposing currents are, on an average, in equilibrium.

(d) Light energy involved in lightning; heat and sound energy in the accompanying thunder.

Chapter 3

3.1 30 A

3.2 17 Ω, 8.5 V

3.3 (a) 6 Ω

(b) 2 V, 4 V, 6 V

3.4 (a) (20/19) Ω

(b) 10A, 5 A, 4A; 19A

3.5 1027 °C

3.6 2.0×10^{-7} Ωm

3.7 0.0039 $°C^{-1}$

3.8 867 °C

3.9 Current in branch AB = (4/17) A,
in BC = (6/17) A, in CD = (–4/17) A,
in AD = (6/17) A, in BD. = (–2/17) A, total current = (10/17) A.

3.10 (a) X = 8.2 Ω; to minimise resistance of the connection which are not accounted for in the bridge formula.

(b) 60.5 cm from A.

(c) The galvanometer will show no current.

3.11 11.5 V; the series resistor limits the current drawn from the external source. In its absence, the current will be dangerously high.

3.12 2.25 V

3.13 2.7×10^4 s (7.5 h)

3.14 Take the radius of the earth = 6.37×10^6 m and obtain total charge of the globe. Divide it by current to obtain time = 283 s. Still this method gives you only an estimate; it is not strictly correct. Why?

3.15 (a) 1.4 A, 11.9 V

(b) 0.005 A; impossible because a starter motor requires large current (~ 100 A) for a few seconds.

3.16 The mass (or weight) ratio of copper to aluminium wire is (1.72/2.63) × (8.9/2.7) ≅ 2.2. Since aluminium is lighter, it is preferred for long suspensions of cables.

3.17 Ohm's law is valid to a high accuracy; the resistivity of the alloy manganin is nearly independent of temperature.

2015-16(20/01/2015)