MCQ 50 marks

1. **C.** $3.6 \times 10^4\ \text{NC}^{-1}$

Explanation: The field of the +q at x = 1 points in the −x direction and that of the −q at x = 2 points in the +x direction, so the contributions alternate in sign

$|E| = kq\left[1 - \frac{1}{4} + \frac{1}{16} - \cdots\right]$ (geometric series, $r = -\frac{1}{4}$)

$= kq \times \frac{1}{1+\frac{1}{4}} = \frac{4kq}{5}$

$= 0.8 \times 9 \times 10^9 \times 5 \times 10^{-6} = 3.6 \times 10^4\ \text{NC}^{-1}$

2. **B.** 90 N

Explanation: By Coulomb's law, $F = \frac{kq_1q_2}{r^2}$

$= \frac{9\times10^9\times(0.2)^2}{(2000)^2}$

$= \frac{3.6\times10^8}{4\times10^6} = 90\ \text{N}$

3. **D.** −2.25 μC

Explanation: For the equilibrium of an end charge, the net force on it must be zero:

$\frac{k(9)q}{\left(\frac{d}{2}\right)^2} + \frac{k(9)(9)}{d^2} = 0$

$4q = -9 \Rightarrow q = -2.25\ \mu\text{C}$

4. **B.** 1.17×10^{-8} C

Explanation: From the geometry, $\sin\theta = \frac{0.025}{1} \Rightarrow \tan\theta \approx 0.02501$

$F_e = mg\tan\theta = 2 \times 10^{-3} \times 9.8 \times 0.02501 = 4.9 \times 10^{-4}$ N

Since $\frac{kq^2}{r^2} = F_e$, we get $q = r\sqrt{\frac{F_e}{k}}$

$q = 0.05 \times \sqrt{\frac{4.9\times10^{-4}}{9\times10^9}} = 1.17 \times 10^{-8}$ C

5. **D.** 36

Explanation: $\frac{F'}{F} = \frac{1}{K} \times 3^2 = \frac{9}{K}$

$\frac{9}{K} = \frac{1}{4} \Rightarrow K = 36$

6. **C.** 0.5 m

Explanation: At the null point the two fields are equal in magnitude: $\frac{kQ}{x^2} = \frac{k(9Q)}{(2-x)^2}$

$\frac{2-x}{x} = 3 \Rightarrow x = 0.5$ m

7. **B.** 10

Explanation: At equilibrium the electric force balances the weight: $qE = mg \Rightarrow q = \frac{4.9\times10^{-15}\times9.8}{3\times10^4} = 1.6 \times 10^{-18}$ C

$n = \frac{1.6\times10^{-18}}{1.6\times10^{-19}} = 10$

8. **D.** $\frac{3}{4}$

Explanation: $F \propto q(Q-q)$; the force is maximum when $q = \frac{Q}{2}$, so $F_{max} \propto \frac{Q^2}{4}$

For $q = \frac{Q}{4}$: $F \propto \frac{Q}{4} \cdot \frac{3Q}{4} = \frac{3Q^2}{16}$

$\frac{F}{F_{max}} = \frac{\frac{3}{16}}{\frac{1}{4}} = \frac{3}{4}$

9. **A.** 4

Explanation: Conservation of volume gives $\frac{4}{3}\pi R^3 = 8 \times \frac{4}{3}\pi r^3 \Rightarrow R = 2r$, and the total charge is Q = 8q

Energy of a charged sphere: $U = \frac{kQ^2}{2R}$

Large drop: $U_B = \frac{k(8q)^2}{2(2r)} = 32 \times \frac{kq^2}{2r}$

Total of the small drops: $U_S = 8 \times \frac{kq^2}{2r}$

$\frac{U_B}{U_S} = \frac{32}{8} = 4$

10. **C.** 2.73×10^{-19} kg

Explanation: Number of electrons lost, $n = \frac{4.8\times10^{-8}}{1.6\times10^{-19}} = 3 \times 10^{11}$

Decrease in mass $= nm_e = 3 \times 10^{11} \times 9.1 \times 10^{-31} = 2.73 \times 10^{-19}$ kg

11. **A.** 10^{-4} C

Explanation: $\frac{k(q)(4q)}{r^2} = F \Rightarrow 4q^2 = \frac{40\times9}{9\times10^9} = 4 \times 10^{-8}$

$q = 10^{-4}$ C

12. **B.** $5 \times 10^4\ \text{NC}^{-1}$

Explanation: $E_1 = E_2 = \frac{9\times10^9\times2\times10^{-6}}{(0.6)^2} = 5 \times 10^4\ \text{NC}^{-1}$

The angle between the two fields is 120°

$E = \sqrt{E_1^2 + E_2^2 + 2E_1E_2\cos 120°} = E_1 = 5 \times 10^4\ \text{NC}^{-1}$ (parallel to the base)

13. **B.** $20\ \text{Nm}^2\text{C}^{-1}$

Explanation: Total flux $= \frac{q}{\epsilon_0} = \frac{2.125\times10^{-9}}{8.854\times10^{-12}} = 240\ \text{Nm}^2\text{C}^{-1}$

Flux through each face $= \frac{240}{6} = 40$

By symmetry, the flux through a half-face is $\frac{40}{2} = 20\ \text{Nm}^2\text{C}^{-1}$

14. **A.** $50\ \text{Nm}^2\text{C}^{-1}$

Explanation: Four cubes arranged around the edge enclose the charge completely
So the flux through each cube is $\phi = \frac{q}{4\epsilon_0}$
$= \frac{1.771\times10^{-9}}{4\times8.854\times10^{-12}} = 50\,\text{Nm}^2\text{C}^{-1}$

15. **A.** $4.52 \times 10^6\,\text{Nm}^2\text{C}^{-1}$
Explanation: By Gauss's law, $\phi = \frac{q_{enc}}{\epsilon_0}$
$\phi = \frac{40\times10^{-6}}{8.854\times10^{-12}} = 4.52 \times 10^6\,\text{Nm}^2\text{C}^{-1}$

16. **A.** 0
Explanation: Total enclosed charge = +q − q = 0
$\phi = \frac{0}{\epsilon_0} = 0$

17. **B.** $1.2 \times 10^5\,\text{NC}^{-1}$
Explanation: $E = \frac{2k\lambda}{r} = \frac{2\times9\times10^9\times2\times10^{-6}}{0.3} = 1.2 \times 10^5\,\text{NC}^{-1}$

18. **A.** 2.3×10^{-18} J
Explanation: $U = \frac{ke^2}{r} = \frac{9\times10^9\times(1.6\times10^{-19})^2}{10^{-10}} = 2.3 \times 10^{-18}$ J (positive, because the force is repulsive)

19. **B.** $5 \times 10^5\,\text{NC}^{-1}$
Explanation: $E = \frac{\sigma}{2\epsilon_0} = \frac{8.854\times10^{-6}}{2\times8.854\times10^{-12}} = 5 \times 10^5\,\text{NC}^{-1}$

20. **B.** 0.21 V
Explanation: The point is 0.1 m from A and 0.3 m from B
$V = 9 \times 10^9 \left(\frac{5\times10^{-12}}{0.1} - \frac{8\times10^{-12}}{0.3}\right)$
$= 0.21$ V

21. **C.** 0.826 m
Explanation: $Q_1 = \frac{V_1 r_1}{k} = \frac{9\times0.2}{9\times10^9} = 2 \times 10^{-10}$ C
$Q_2 = \frac{4\times0.3}{9\times10^9} = 1.33 \times 10^{-10}$ C
$x = \frac{d}{1+\sqrt{\frac{Q_2}{Q_1}}} = \frac{1.5}{1+\sqrt{0.667}}$
$= 0.826$ m

22. **D.** 509 V
Explanation: Distance from the centre to a corner, $r = \frac{0.2\sqrt{2}}{2} = 0.1414$ m
$V = \frac{4kq}{r} = \frac{4\times9\times10^9\times2\times10^{-9}}{0.1414} = 509$ V

23. **C.** 928 V
Explanation: The midpoint is 0.1 m from the charges at the two ends of the side and $0.1\sqrt{3}$ m from the opposite vertex
$V = 9 \times 10^9 \times 4 \times 10^{-9} \left(\frac{2}{0.1} + \frac{1}{0.1732}\right)$
$= 36 \times 25.77 = 928$ V

24. **C. Constant for $r \le R$; $V \propto \frac{1}{r}$ for $r > R$**
Explanation: Inside, E = 0, so the potential is constant and equal to the potential at the surface
Outside, $V = \frac{kQ}{r}$ (a rectangular hyperbola)

25. **C.** 4 : 3
Explanation: $\sigma \propto \frac{Q}{r^2}$
$\frac{\sigma_1}{\sigma_2} = \frac{16}{27} \times \left(\frac{6}{4}\right)^2 = \frac{16}{27} \times \frac{9}{4} = \frac{4}{3}$

26. **C.** 1.8×10^{12} V
Explanation: The potential inside a conducting sphere equals the potential at its surface
Total charge = $8 \times 5 = 40$ C
$V = \frac{9\times10^9\times40}{0.2} = 1.8 \times 10^{12}$ V

27. **A.** 1.2 J
Explanation: $W = kq_1q_2\left(\frac{1}{r_2} - \frac{1}{r_1}\right)$
$= 9 \times 10^9 \times 20 \times 10^{-12}\left(\frac{1}{0.1} - \frac{1}{0.3}\right)$
$= 0.18 \times 6.667 = 1.2$ J

28. **B.** $1.2 \times 10^7\,\text{ms}^{-1}$
Explanation: The work done on the electron equals its kinetic energy gained: $eV = \frac{1}{2}mv^2$
$v = \sqrt{\frac{2\times1.6\times10^{-19}\times405}{9\times10^{-31}}} = \sqrt{1.44 \times 10^{14}} = 1.2 \times 10^7\,\text{ms}^{-1}$

29. **B.** 6×10^{11} W
Explanation: $W = qV = 25 \times 1.2 \times 10^9 = 3 \times 10^{10}$ J
$P = \frac{W}{t} = \frac{3\times10^{10}}{0.05} = 6 \times 10^{11}$ W

30. **A.** 102 pV
Explanation: From $s = \frac{1}{2}at^2$: $a = \frac{2\times0.3}{(0.1)^2} = 60\,\text{ms}^{-2}$
$E = \frac{ma}{e}$, so $V = Ed = \frac{mas}{e}$
$V = \frac{9.1\times10^{-31}\times60\times0.3}{1.6\times10^{-19}} = 1.02 \times 10^{-10}$ V

31. **D.** $\sqrt{29}$
Explanation: $\vec{E} = -(2x\hat{i} - 4y\hat{j} + 3\hat{k}) = -2\hat{i} + 4\hat{j} - 3\hat{k}$
$|\vec{E}| = \sqrt{4 + 16 + 9} = \sqrt{29}$

32. **D.** −3 V

Explanation: $V_B - V_A = -\int_1^2 \frac{8}{x^3}dx =$
$-8\left[-\frac{1}{2x^2}\right]_1^2$
$= 4\left[\frac{1}{x^2}\right]_1^2 = 4\left(\frac{1}{4} - 1\right) = -3$ V

33. **D.** 1.08×10^5 NC^{-1}
Explanation: $p = q(2l) = 8 \times 10^{-6} \times 0.006 = 4.8 \times 10^{-8}$ Cm
On the axis: $E = \frac{2kp}{r^3} = \frac{2\times9\times10^9\times4.8\times10^{-8}}{(0.2)^3}$
$= 1.08 \times 10^5$ NC^{-1}

34. **D.** 60°
Explanation: $\frac{kp\sqrt{1+3\cos^2\theta}}{r^3} = \frac{kp\cos\theta}{r^2}$
$1 + 3\cos^2\theta = r^2\cos^2\theta \Rightarrow \cos^2\theta = \frac{1}{r^2-3}$
$\cos^2\theta = \frac{1}{7-3} = \frac{1}{4} \Rightarrow \theta = 60°$

35. **C.** 7.5×10^4 V
Explanation: The distance from the positive charge is 0.08 m and from the negative charge is 0.12 m
$V = 9 \times 10^9 \times 2 \times 10^{-6}\left(\frac{1}{0.08} - \frac{1}{0.12}\right)$
$= 18000 \times 4.167 = 7.5 \times 10^4$ V

36. **B.** $\sqrt{3}$ qa
Explanation: Treating +2q as two charges of +q gives two dipoles of moment qa each, with an angle of 60° between them
$p = \sqrt{(qa)^2 + (qa)^2 + 2(qa)^2\cos 60°} = \sqrt{3}$ qa

37. **C.** 15 C
Explanation: $U = \frac{Q^2}{2C} \Rightarrow \frac{(Q+3)^2}{Q^2} = 1.44$
$\frac{Q+3}{Q} = 1.2 \Rightarrow 0.2Q = 3$
$Q = 15$ C

38. **C.** 2.5×10^{-9} J
Explanation: $p = 50 \times 10^{-9} \times 20 \times 10^{-6} = 10^{-12}$ Cm
$W = pE(\cos 0° - \cos 60°) = 10^{-12} \times 5000 \times 0.5$
$= 2.5 \times 10^{-9}$ J

39. **D.** 1.85 cm
Explanation: Exact value: $E = \frac{2kpr}{(r^2-l^2)^2}$;
approximate value: $E_0 = \frac{2kp}{r^3}$
$\frac{2kpr}{(r^2-l^2)^2} = 2 \times \frac{2kp}{r^3} \Rightarrow r^4 = 2(r^2 - l^2)^2$
$r^2 = \sqrt{2}(r^2 - l^2) \Rightarrow r^2 = \frac{\sqrt{2}}{\sqrt{2}-1}l^2 = 3.414l^2$
$l = 1$ cm $\Rightarrow r = \sqrt{3.414} = 1.85$ cm

40. **A.** 56.4 μC
Explanation: $\Delta Q = C\Delta V = 4.7 \times (21 - 9)$
$= 56.4$ μC

41. **B.** 0.36 J
Explanation: $C_s = \frac{3\times6}{3+6} = 2$ μF
$U = \frac{1}{2}C_sV^2 = \frac{1}{2} \times 2 \times 10^{-6} \times 600^2 = 0.36$ J

42. **A.** 6 μF
Explanation: Series part: $\frac{6\times3}{9} = 2$ μF
$C = 2 + 4 = 6$ μF

43. **A.** $\frac{18}{11}$ μF
Explanation: $\frac{1}{C_s} = \frac{1}{3} + \frac{1}{6} + \frac{1}{9} = \frac{6+3+2}{18} = \frac{11}{18}$
$C_s = \frac{18}{11} \approx 1.64$ μF

44. **D.** 300 μC
Explanation: $C_s = \frac{10\times15}{25} = 6$ μF
In series, each capacitor carries the same charge: $Q = 6 \times 50 = 300$ μC

45. **A.** $\frac{U}{2}$
Explanation: Charge is conserved and $C' = 2C$
$U' = \frac{Q^2}{2(2C)} = \frac{U}{2}$

46. **D. It is doubled**
Explanation: Q remains constant and $C' = \frac{C}{2}$
$U' = \frac{Q^2}{2C'} = 2U$

47. **C.** 4.5
Explanation: $C \propto K \Rightarrow K = \frac{36}{8} = 4.5$

48. **A.** 39.8 Jm^{-3}
Explanation: $u = \frac{1}{2}\epsilon_0E^2 = \frac{1}{2} \times 8.854 \times 10^{-12} \times 9 \times 10^{12} = 39.8$ Jm^{-3}

49. **D.** 1.27×10^{-6} J
Explanation: $C = \frac{\epsilon_0A}{d} = \frac{8.854\times10^{-12}\times0.2}{10^{-4}} =$
1.77×10^{-8} F
$U = \frac{1}{2}CV^2 = \frac{1}{2} \times 1.77 \times 10^{-8} \times 144$
$= 1.27 \times 10^{-6}$ J

50. **B.** 0
Explanation: By Gauss's law, $\oint \vec{E} \cdot d\vec{A} = \frac{q_{enc}}{\varepsilon_0}$
Here, all the charge of a charged hollow conductor lies on its outer surface
So, the charge enclosed by a Gaussian surface inside is $q_{enc} = 0$
Therefore, the field at any point inside is $E = 0$