MCQ 50 marks

1. **D.** 14.1 cm

Explanation: Half-separation a = 20 cm; at a distance x on the perpendicular bisector, $F \propto \frac{x}{(a^2+x^2)^{\frac{3}{2}}}$

$\frac{dF}{dx} = 0 \Rightarrow x = \frac{a}{\sqrt{2}} = \frac{d}{2\sqrt{2}}$

$x = \frac{40}{2\sqrt{2}} = 14.1$ cm

2. **C.** 2

Explanation: After touching, each ball carries $\frac{q_1+q_2}{2}$

$\frac{(q_1+q_2)^2}{4} = 1.125 q_1 q_2$; let $x = \frac{q_1}{q_2}$

$(x+1)^2 = 4.5x \Rightarrow x^2 - 2.5x + 1 = 0$

$x = 2$ or $\frac{1}{2}$; the ratio of the larger to the smaller is 2

3. **C.** $3 \times 10^6\ \text{NC}^{-1}$

Explanation: $E = \frac{kq}{r^2} = \frac{9\times10^9\times3\times10^{-5}}{(0.3)^2} = 3 \times 10^6\ \text{NC}^{-1}$

4. **D.** $1.5 \times 10^8\ \text{NC}^{-1}$

Explanation: At the midpoint the two fields point in opposite directions

$E = \frac{k(20-5)\times10^{-6}}{(0.03)^2} = 1.5 \times 10^8\ \text{NC}^{-1}$ (towards the 5 μC charge)

5. **B.** 1.6×10^{-14} N

Explanation: Charge of an alpha particle = $2e = 3.2 \times 10^{-19}$ C

$F = qE = 3.2 \times 10^{-19} \times 5 \times 10^4 = 1.6 \times 10^{-14}$ N

6. **A.** 4.8×10^{-19} C

Explanation: Charge is quantized: q = ne, where n is an integer

$\frac{4.8\times10^{-19}}{1.6\times10^{-19}} = 3$ (an integer), so this charge is possible

7. **C.** $\frac{25}{81}$

Explanation: Effective distance = $(d - t) + t\sqrt{K} = 6 + 4 \times 3 = 18$ cm

$\frac{F}{F_0} = \left(\frac{10}{18}\right)^2 = \frac{25}{81}$

8. **C.** $-\frac{1}{2\sqrt{2}}$

Explanation: Let the side be l. The resultant of the forces on q due to the two Q charges is $\sqrt{2}\frac{kQq}{l^2}$ (along the diagonal)

The force due to the q at the opposite corner is $\frac{kq^2}{(\sqrt{2}l)^2} = \frac{kq^2}{2l^2}$ (along the same line)

For zero net force: $\sqrt{2}Q + \frac{q}{2} = 0$

$\therefore \frac{Q}{q} = -\frac{1}{2\sqrt{2}}$

9. **C.** 1.36 cm

Explanation: The electric attraction must balance the weight: $\frac{kq_1q_2}{x^2} = mg$

$x^2 = \frac{9\times10^9\times8\times10^{-9}\times5\times10^{-9}}{0.2\times10^{-3}\times9.8}$

$x = 0.0136$ m $= 1.36$ cm

10. **C.** $1.02 \times 10^{-7}\ \text{NC}^{-1}$

Explanation: $eE = m_p g$

$E = \frac{1.67\times10^{-27}\times9.8}{1.6\times10^{-19}} = 1.02 \times 10^{-7}\ \text{NC}^{-1}$

11. **A.** $226\ \text{Nm}^2\text{C}^{-1}$

Explanation: By symmetry, the total flux is divided equally among the six faces

$\phi = \frac{q}{6\epsilon_0} = \frac{1.2\times10^{-8}}{6\times8.854\times10^{-12}} = 226\ \text{Nm}^2\text{C}^{-1}$

12. **B.** $0.064\ \text{Nm}^2\text{C}^{-1}$

Explanation: An angle of 30° with the surface means θ = 60° with the normal

$\phi = EA\cos\theta = 2000 \times (8 \times 10^{-3})^2 \times \cos 60°$

$= 0.064\ \text{Nm}^2\text{C}^{-1}$

13. **C.** $3.39 \times 10^5\ \text{Nm}^2\text{C}^{-1}$

Explanation: The flux does not depend on the radius

$\phi = \frac{q}{\epsilon_0} = \frac{3\times10^{-6}}{8.854\times10^{-12}} = 3.39 \times 10^5\ \text{Nm}^2\text{C}^{-1}$

14. **D.** 5 cm

Explanation: The charges are of opposite sign, so the point lies outside them, on the side of the smaller charge

$\frac{2}{x^2} = \frac{50}{(x+20)^2} \Rightarrow \frac{x+20}{x} = 5$

$x = 5$ cm

15. **B.** 3.98×10^{-7} C

Explanation: $q = \epsilon_0\phi = 8.854 \times 10^{-12} \times 4.5 \times 10^4 = 3.98 \times 10^{-7}$ C

16. **C.** 50 V

Explanation: $q\frac{V}{d} = mg \Rightarrow V \propto \frac{m}{q}$
With half the radius, $m' = \frac{m}{8}$ and $q' = 2q$
$V' = 800 \times \frac{1}{8} \times \frac{1}{2} = 50\,V$

17. **A.** 5 : 1
Explanation: $R = 125^{\frac{1}{3}} r = 5r$, $Q = 125q$
$\frac{\sigma_B}{\sigma_s} = \frac{125}{5^2} = 5$

18. **C.** $2 \times 10^4\,NC^{-1}$, 0
Explanation: Between the plates: $E = \frac{\sigma}{2\epsilon_0} + \frac{\sigma}{2\epsilon_0} = \frac{\sigma}{\epsilon_0} = \frac{1.77\times10^{-7}}{8.854\times10^{-12}} = 2 \times 10^4\,NC^{-1}$
Outside: the two fields are equal and opposite, so the field is 0

19. **B.** 6 cm
Explanation: $\frac{10}{x} = \frac{40}{30-x}$
$300 - 10x = 40x \Rightarrow x = 6\,cm$

20. **B.** 106.7 V
Explanation: Large drop: $R = 4r$, $Q = 64q$, $V_B = 16 \times 10 = 160\,V$
$C \propto$ radius: $C_1 \propto 4r$, $C_2 \propto 2r$
$V = \frac{Q}{C_1+C_2} = \frac{C_1 V_B}{C_1+C_2} = \frac{4\times160}{6}$
$V = 106.7\,V$

21. **D.** 4
Explanation: $K = \frac{F_0}{F_m} = \frac{60}{15} = 4$

22. **A.** 270 V
Explanation: Inside the sphere, $V = \frac{kQ}{2R^3}(3R^2 - r^2)$; at the centre, $V = \frac{3kQ}{2R}$
$V = 1.5 \times \frac{9\times10^9\times2\times10^{-9}}{0.1} = 1.5 \times 180 = 270\,V$

23. **B.** 4 : 1
Explanation: Distances from the centre: $r_A = 0.75\,m$, $r_B = 1.5\,m$
$\frac{E_A}{E_B} = \left(\frac{r_B}{r_A}\right)^2 = \left(\frac{1.5}{0.75}\right)^2 = 4$

24. **A.** 79.7 nC
Explanation: $q = \epsilon_0\Phi = 8.854 \times 10^{-12} \times 9000 = 7.97 \times 10^{-8}\,C = 79.7\,nC$

25. **D.** 3.6×10^{11} V
Explanation: The potential inside a conducting sphere equals the potential at its surface
$V = \frac{9\times10^9\times12}{0.3} = 3.6 \times 10^{11}\,V$

26. **D.** 0
Explanation: For the equilibrium of an end charge: $\frac{kQq}{\left(\frac{d}{2}\right)^2} + \frac{kQ^2}{d^2} = 0 \Rightarrow q = -\frac{Q}{4}$
$U = \frac{kQ^2}{d} + 2 \times \frac{2kQq}{d} = \frac{kQ^2}{d} + \frac{4kQ}{d}\left(-\frac{Q}{4}\right)$
$U = \frac{kQ^2}{d} - \frac{kQ^2}{d} = 0$

27. **D.** $0.0894\,ms^{-1}$
Explanation: $qV = \frac{1}{2}mv^2$
$v = \sqrt{\frac{2\times20\times10^{-9}\times400}{2\times10^{-3}}} = \sqrt{8\times10^{-3}} = 0.0894\,ms^{-1}$

28. **C.** 6×10^{-3} C
Explanation: $W = qV$
$q = \frac{0.15}{25} = 6 \times 10^{-3}\,C$

29. **B.** x = 2
Explanation: $E = -\frac{dV}{dx} = -(6x - 3x^2)$
$6x - 3x^2 = 0 \Rightarrow x = 0, 2$

30. **A.** $-6\hat{i} + 2\hat{j} + 3\hat{k}$
Explanation: $\vec{E} = -\left(\frac{\partial V}{\partial x}\hat{i} + \frac{\partial V}{\partial y}\hat{j} + \frac{\partial V}{\partial z}\hat{k}\right)$
$= -[6x\hat{i} - 2z\hat{j} + (1-2y)\hat{k}]$
At (1, 2, 1): $\vec{E} = -[6\hat{i} - 2\hat{j} - 3\hat{k}] = -6\hat{i} + 2\hat{j} + 3\hat{k}$

31. **A.** $5\,NC^{-1}$, **uniform**
Explanation: $\vec{E} = -3\hat{i} - 4\hat{j}$ (independent of position, so uniform)
$|\vec{E}| = \sqrt{9+16} = 5\,NC^{-1}$

32. **D.** −10 V
Explanation: $V = -\int \vec{E} \cdot d\vec{r} = -(10x - 20y)$
At (3, 1): $V = -(30 - 20) = -10\,V$

33. **C.** 2
Explanation: $\frac{2kp}{x^3} = 16 \times \frac{kp}{y^3}$
$\frac{y^3}{x^3} = 8 \Rightarrow \frac{y}{x} = 2$

34. **A.** 2 m
Explanation: $\cos^2\theta = \frac{1}{r^2-3}$ and $\cos^2\theta \le 1$
$r^2 - 3 \ge 1 \Rightarrow r \ge 2\,m$

35. **B.** 1.99 s
Explanation: $T = 2\pi\sqrt{\frac{I}{pE}} = 2\pi\sqrt{\frac{2\times10^{-6}}{2\times10^{-7}\times100}}$
$= 2\pi \times 0.3162 = 1.99\,s$

36. **A.** 2×10^{-6} Nm
Explanation: $p = 5 \times 10^{-9} \times 2 \times 10^{-3} = 10^{-11}\,Cm$

$\tau = pE \sin 30° = 10^{-11} \times 4 \times 10^5 \times 0.5 = 2 \times 10^{-6}$ Nm

37. **A.** 6.72×10^{-3} J

Explanation: $W = pE(\cos 0° - \cos 180°) = 2pE$

$= 2 \times 4 \times 10^{-6} \times 12 \times 10^{-3} \times 7 \times 10^4 = 6.72 \times 10^{-3}$ J

38. **D.** 1.6×10^{-5} J

Explanation: $U = \frac{Q^2}{2C} = \frac{(40 \times 10^{-9})^2}{2 \times 50 \times 10^{-12}} = 1.6 \times 10^{-5}$ J

39. **B.** $\frac{8}{9}$

Explanation: $U \propto V^2 \Rightarrow U_2 = \frac{U_1}{9}$

Decrease $= U_1 - \frac{U_1}{9} = \frac{8}{9}U_1$

40. **A.** 0.06 J

Explanation: $C_s = \frac{4 \times 12}{16} = 3\ \mu F$

$Q = 3 \times 10^{-6} \times 400 = 1.2 \times 10^{-3}$ C

$U_{12} = \frac{Q^2}{2C} = \frac{(1.2 \times 10^{-3})^2}{2 \times 12 \times 10^{-6}} = 0.06$ J

41. **B.** 12 μF, 216 μC

Explanation: $C_p = 8 + 4 = 12\ \mu F$

$Q = 12 \times 18 = 216\ \mu C$

42. **A.** 12 μF

Explanation: $\frac{1}{C_3} = \frac{1}{1.2} - \frac{1}{2} - \frac{1}{4}$

$= 0.8333 - 0.75 = 0.0833$

$C_3 = 12\ \mu F$

43. **D.** Q

Explanation: In a series combination every capacitor carries the same charge

So the charge on each capacitor = Q

44. **C.** 16 V

Explanation: $C_s = \frac{2 \times 8}{10} = 1.6\ \mu F$, $Q = 1.6 \times 20 = 32\ \mu C$

$V_2 = \frac{32}{2} = 16$ V

45. **B.** 9

Explanation: $C_p = 3C$, $C_s = \frac{C}{3}$

$\frac{C_p}{C_s} = 9$

46. **D.** 4

Explanation: The battery is disconnected, so Q is constant

$U = \frac{Q^2}{2C}$, $C' = KC \Rightarrow U' = \frac{U}{K}$

$\frac{U}{K} = \frac{U}{4} \Rightarrow K = 4$

47. **A. Field unchanged,** $K = 3$

Explanation: The battery stays connected, so V is constant and $E = \frac{V}{d}$ is unchanged

$Q = CV = KC_0V \Rightarrow K = 3$

48. **B.** 2

Explanation: The two parts are in parallel:

$C = \frac{\epsilon_0 A}{2d} + \frac{3\epsilon_0 A}{2d}$

$C = \frac{\epsilon_0 A}{d} \times \frac{1+3}{2} = 2C_0$

49. **B.** $8C_0$

Explanation: When n plates are connected alternately, $(n - 1)$ capacitors are in parallel

$C = (9 - 1)C_0 = 8C_0$

50. **D.** 1.11×10^{-6} J

Explanation: $C = \frac{\epsilon_0 \pi r^2}{d} = \frac{8.854 \times 10^{-12} \times \pi \times 0.01}{0.005} = 5.56 \times 10^{-11}$ F

$U = \frac{1}{2}CV^2 = \frac{1}{2} \times 5.56 \times 10^{-11} \times 4 \times 10^4 = 1.11 \times 10^{-6}$ J