Chapter 2

1. –

2. a. $F = k\dfrac{Q_1Q_2}{r^2} = \dfrac{(9\times10^9)(1\text{ C})(2\text{ C})}{(1\text{ m})^2} = \mathbf{18\times10^9\ N}$

   b. $F = k\dfrac{Q_1Q_2}{r^2} = \dfrac{(9\times10^9)(1\text{ C})(2\text{ C})}{(3\text{ m})^2} = \mathbf{2\times10^9\ N}$

   c. $F = k\dfrac{Q_1Q_2}{r^2} = \dfrac{(9\times10^9)(1\text{ C})(2\text{ C})}{(10\text{ m})^2} = \mathbf{0.18\times10^9\ N}$

   d. Exponentially, $\dfrac{r_3}{r_1} = \dfrac{10\text{ m}}{1\text{ m}} = \mathbf{10}$ while $\dfrac{F_1}{F_2} = \dfrac{18\times10^9\text{ N}}{0.18\times10^9\text{ N}} = \mathbf{100}$

3. a. r = 1 ft:

   $$1\text{ ft}\left[\frac{12\text{ in.}}{1\text{ ft}}\right]\left[\frac{1\text{ m}}{39.37\text{ in.}}\right] = 0.305\text{ m}$$

   $$F = \frac{kQ_1Q_2}{r^2} = \frac{(9\times10^9)(8\times10^{-6}\text{ C})(40\times10^{-6}\text{ C})}{(0.305\text{ m})^2} = \frac{2880\times10^{-3}}{93\times10^{-3}}$$

   $= \mathbf{30.97\ N}$

   b. r =10 ft:

   $$10\text{ ft}\left[\frac{12\text{ in.}}{1\text{ ft}}\right]\left[\frac{1\text{ m}}{39.37\text{ in.}}\right] = 3.05\text{ m}$$

   $$F = \frac{kQ_1Q_2}{r^2} = \frac{2880\times10^{-3}}{(3.05\text{ m})^2} = \frac{2880\times10^{-3}}{9.30} = \mathbf{0.31\ N}$$

   c. r = 100 yds:

   $$100\text{ yds}\left[\frac{3\text{ ft}}{1\text{ yd}}\right]\left[\frac{12\text{ in.}}{1\text{ ft}}\right]\left[\frac{1\text{ m}}{39.37\text{ in.}}\right] = 91.4\text{ m}$$

   $$F = \frac{kQ_1Q_2}{r^2} = \frac{2880\times10^{-3}}{(91.4\text{ m})^2} = \frac{2880\times10^{-3}}{8.35\times10^3}$$

   $= \mathbf{345\ \mu N}$

4. –

5. $Q_1 = Q_2 = Q;\ F_1 = \dfrac{kQ^2}{r_1^2} \Rightarrow Q^2 = \dfrac{F_1r_1^2}{k};\ F_2 = \dfrac{kQ^2}{r_2^2} = \dfrac{k}{r_2^2}\left[\dfrac{F_1r_1^2}{k}\right]$ and $F_2 = \dfrac{\mathbf{r_1^2}}{\mathbf{r_2^2}}\boldsymbol{F_1}$

6. $F = \dfrac{kQ_1Q_2}{r^2} \Rightarrow r = \sqrt{\dfrac{kQ_1Q_2}{F}} = \sqrt{\dfrac{(9\times10^9)(20\times10^{-6})^2}{3.6\times10^4}}$ = **10 mm**

7. $F = \dfrac{kQ_1Q_2}{r^2} \Rightarrow 1.8 = \dfrac{kQ_1Q_2}{(2\text{ m})^2} \Rightarrow kQ_1Q_2 = 4(1.8) = 7.2$

   a. $F = \dfrac{kQ_1Q_2}{r^2} = \dfrac{7.2}{(10)^2}$ = **72 mN**

   b. $Q_1/Q_2 = 1/2 \Rightarrow Q_2 = 2Q_1$

   $7.2 = kQ_1Q_2 = (9 \times 10^9)(Q_1)(2Q_1) = 9 \times 10^9 \left(2Q_1^2\right)$

   $\dfrac{7.2}{18\times10^9} = Q_1^2 \Rightarrow Q_1 = \sqrt{\dfrac{7.2}{18\times10^9}}$ = **20 μC**

   $Q_2 = 2Q_1 = 2(2 \times 10^{-5}\text{ C})$ = **40 μC**

8. $V = \dfrac{W}{Q} = \dfrac{1.2\text{ J}}{20\text{ mC}}$ = **120 V**

9. $W = VQ = (60\text{ V})(8\text{ mC})$ = **0.48 J**

10. $Q = \dfrac{W}{V} = \dfrac{200\ \mu\text{J}}{20\text{ mV}} = 10\text{ mC}$

11. $Q = \dfrac{W}{V} = \dfrac{620\text{ mJ}}{9\text{ V}}$ = **68.9 mC**

12. a. $W = QV = (1 \times 10^{12}\text{ electrons})(40\text{ V})$ = **40×10^{12} eV**

    b. $40 \times 10^{12}\ \text{eV}\left[\dfrac{1\text{ C}}{6.242 \times 10^{18}\ \text{electrons}}\right]$ = **6.41 μJ**

13. $I = \dfrac{Q}{t} = \dfrac{96\text{ mC}}{8.4\text{ s}}$ = **11.43 mA**

14. $I = \dfrac{Q}{t} = \dfrac{312\text{ C}}{(2)(60\text{ s})}$ = **2.60 A**

15. $Q = It = (40\text{ mA})(1.2)(60\text{ s})$ = **2.88 C**

16. $Q = It = (250\text{ mA})(1.2)(60\text{ s})$ = **18.0 C**

17. $t = \dfrac{Q}{I} = \dfrac{6\text{ mC}}{2\text{ mA}}$ = **3 s**

18. 21.847×10^{18} ~~electrons~~ $\left[\frac{1\text{ C}}{6.242\times10^{18}\ \text{~~electrons~~}}\right] = 3.5$ C

$I = \frac{Q}{t} = \frac{3.5\text{ C}}{12\text{ s}} = 0.29$ A

19. 5 min = (5)(60 s) = 300 s

$Q = It$ = (4 mA)(300 s) = 1.2 C

$1.2\ \cancel{C}\left[\frac{6.242\times10^{18}\text{ electrons}}{1\ \cancel{C}}\right] =$ **7.49×10^{18} electrons**

20. $I = \frac{Q}{t} = \frac{86\text{ C}}{(1.2)(60\text{ s})} = 1.194$ A > 1 A **(yes)**

21. 0.84×10^{16} ~~electrons~~ $\left[\frac{1\text{ C}}{6.242\times10^{18}\ \text{~~electrons~~}}\right] = 1.346$ mC

$I = \frac{Q}{t} = \frac{1.346\text{ mC}}{60\text{ ms}} =$ **22.43 mA**

22. a. $Q = It$ = (2 mA)(0.01 μs) = 2×10^{-11} C

$2 \times 10^{-11}\ \cancel{C}\left[\frac{6.242\times10^{18}\ \text{~~electrons~~}}{1\ \cancel{C}}\right]\left[\frac{1\ \cancel{¢}}{\text{~~electron~~}}\right]$

$= 1.25 \times 10^{8}\ ¢ = \$1.25 \times 10^{6} =$ **1.25 million**

b. $Q = It$ = (100 μA)(1.5 ns) = 1.5×10^{-13} C

$1.5 \times 10^{-13}\ \cancel{C}\left[\frac{6.242\times10^{18}\ \text{~~electrons~~}}{1\ \cancel{C}}\right]\left[\frac{\$1}{\text{~~electron~~}}\right] =$ **0.94 million**

(a) > (b)

23. $Q = It = (200 \times 10^{-3}\text{ A})(30\text{ s}) = 6$ C

$V = \frac{W}{Q} = \frac{40\text{ J}}{6\text{ C}} =$ **6.67 V**

24. $Q = It = \left[\frac{420\text{ C}}{\cancel{\text{min}}}\right](0.5\ \cancel{\text{min}}) = 210$ C

$V = \frac{W}{Q} = \frac{742\text{ J}}{210\text{ C}} =$ **3.53 V**

25. $Q = \frac{W}{V} = \frac{0.4\text{ J}}{12\text{ V}} = 33.33$ mC

$I = \frac{Q}{t} = \frac{33.33\text{ mC}}{5 \times 10^{-3}\text{ s}} =$ **6.67 A**

26. $I = \dfrac{\text{Ah rating}}{t(\text{hours})} = \dfrac{180\text{ Ah}}{40\text{ h}} = \mathbf{4.5\ A}$

27. Ah = (0.8 A)(75 h) = **60.0 Ah**

28. $t(\text{hours}) = \dfrac{\text{Ah rating}}{I} = \dfrac{80\text{ Ah}}{1.28\text{ A}} = \mathbf{62.5\ h}$

29. 40 Ah(for 1 h): $W_1 = VQ = V{\cdot}I{\cdot}t = (12\text{ V})(40\text{ A})(1\text{ h}\cancel{)}\left[\dfrac{60\text{ min}}{1\text{ h}}\right]\left[\dfrac{60\text{ s}}{1\text{ min}}\right] = 1.728\times10^{6}\text{ J}$

60 Ah(for 1 h): $W_2 = (12\text{ V})(60\text{ A})(1\text{ h}\cancel{)}\left[\dfrac{60\text{ min}}{1\text{ h}}\right]\left[\dfrac{60\text{ s}}{1\text{ min}}\right] = 2.592\times10^{6}\text{ J}$

Ratio $W_2/W_1 = 1.5$ or 50% more energy available with 60 Ah rating.

For 60 s discharge: $40\text{ Ah} = It = I\left[60\text{ s}\cancel{\right]}\left[\dfrac{1\text{ min}}{60\text{ s}}\right]\left[\dfrac{1\text{ h}}{60\text{ min}}\right] = I(16.67\times10^{-3}\text{ h})$

$$\text{and } I = \frac{40\text{ Ah}}{16.67\times10^{-3}\text{ h}} = \mathbf{2400\ A}$$

$60\text{ Ah} = It = I\left[60\text{ s}\cancel{\right]}\left[\dfrac{1\text{ min}}{60\text{ s}}\right]\left[\dfrac{1\text{ h}}{60\text{ min}}\right] = I(16.67\times10^{-3}\text{ h})$

$$\text{and } I = \frac{60\text{ Ah}}{16.67\times10^{-3}\text{ h}} = \mathbf{3600\ A}$$

$I_2/I_1 = 1.5$ or 50 % more starting current available at 60 Ah

30. 0.75(18 Ah) = 13.5 Ah $\Rightarrow\cong$ **250 mA**

31. (18 Ah − 15.5 Ah)/18 Ah × 100% = **13.89%**

32. At 100 mA, discharge time ≅ 120 H; At 25 mA, discharge time ≅ 425 h;
≅ **300 h more at 25 mA**

33. $I = \dfrac{3\text{ Ah}}{6.0\text{ h}} = 500\text{ mA}$

$Q = It = (500\text{ mA})(6\text{ h}\cancel{)}\left[\dfrac{60\text{ min}}{1\text{ h}}\right]\left[\dfrac{60\text{ s}}{1\text{ min}}\right] = 10.80\text{ kC}$

$W = QV = (10.8\text{ kC})(12\text{ V}) \cong \mathbf{129.6\ kJ}$

34. –

35. –

36. –

37. a. $0.5 \text{ in} \left[\frac{2.54 \text{ cm}}{1 \text{ in}} \right] = 1.27 \text{ cm}$

$1.27 \text{ cm} \left[\frac{30 \text{ kV}}{\text{cm}} \right] = \mathbf{38.1\ kV}$

b. $1.27 \text{ cm} \left[\frac{270 \text{ kV}}{\text{cm}} \right] = \mathbf{342.9\ kV}$

c. 342.9 kV:38.1 kV = **9:1**

38. –

39. –

40. –

41. –