Chapter 13

1. a. **10 V**
   b. 15 ms: **−10 V**, 20 ms: **0 V**
   c. **20 V**
   d. **20 ms**
   e. **2 cycles**

2. a. **200 μA**
   b. 1 μs: **200 μA**, 7 μs: **−200 µA**
   c. **400 μA**
   d. **4 μs**
   e. **2.5 cycles**

3. a. **40 mV**
   b. 1.5 ms: **−40 mV**, 5:1 ms: **−40 mV**
   c. **80 mV**
   d. **2 ms**
   e. **3.5 cycles**

4. a. **high**
   b. **5 cycles**
   c. T = **5 μs**
   d. $f = \frac{1}{T} = \frac{1}{5\ \mu\text{s}}$ = **200 kHz**
   e. **16 mV**
   f. **32 mV**

5. a. $T = \frac{1}{f} = \frac{1}{200\ \text{Hz}}$ = **5 ms**
   b. $T = \frac{1}{f} = \frac{1}{40\ \text{MHz}}$ = **25 ns**
   c. $T = \frac{1}{f} = \frac{1}{20\ \text{kHz}}$ = **50 μs**
   d. $T = \frac{1}{f} = \frac{1}{1\,\text{Hz}}$ = **1 s**

6. a. $f = \frac{1}{T} = \frac{1}{1\text{s}}$ = **1 Hz**
   b. $f = \frac{1}{T} = \frac{1}{\frac{1}{16}\text{s}}$ = **16 Hz**
   c. $f = \frac{1}{T} = \frac{1}{40\ \text{ms}}$ = **25 Hz**
   d. $f = \frac{1}{T} = \frac{1}{25\ \mu\text{s}}$ = **40 kHz**

7. $T = \dfrac{1}{1\text{ kHz}} = 1\text{ ms}, 5(1\text{ ms}) = \mathbf{5\ ms}$

8. $T = \dfrac{24\text{ ms}}{80\text{ cycles}} = \mathbf{0.3\ ms}$

9. $f = \dfrac{42\text{ cycles}}{6\text{ s}} = \mathbf{7\ Hz}$

10. a. $V_{peak} = (2.5\text{ div.})(50\text{ mV/div}) = \mathbf{125\ mV}$

    b. $T = (3.2\text{ div.})(10\ \mu\text{s/div.}) = \mathbf{32\ \mu s}$

    c. $f = \dfrac{1}{T} = \dfrac{1}{32\ \mu\text{s}} = \mathbf{31.25\ kHz}$

11. a. Peak = 2.8 div.(10 mV/div.) = **28 mV**
    b. Peak-to-peak = 2(28 mV) = **56 mV**
    c. T = 2 div.(5 μs/div.) = **10 μs**
    d. **5 cycles**

12. a. Radians = $\left(\dfrac{\pi}{180°}\right)40° = \mathbf{0.22\pi\ rad}$

    b. Radians = $\left(\dfrac{\pi}{180°}\right)60° = \mathbf{\dfrac{\pi}{3}\ rad}$

    c. Radians = $\left(\dfrac{\pi}{180°}\right)135° = \mathbf{0.75\pi\ rad}$

    d. Radians = $\left(\dfrac{\pi}{180°}\right)170° = \mathbf{0.94\pi\ rad}$

13. a. Degrees = $\left(\dfrac{180°}{\pi}\right)\left(\dfrac{\pi}{3}\right) = \mathbf{60°}$

    b. Degrees = $\left(\dfrac{180°}{\pi}\right)1.2\pi = \mathbf{216°}$

    c. Degrees = $\left(\dfrac{180°}{\pi}\right)\dfrac{1}{10}\pi = \mathbf{18°}$

    d. Degrees = $\left(\dfrac{180°}{\pi}\right)0.6\ \pi = \mathbf{108°}$

14. a. $\omega = \dfrac{2\pi}{T} = \dfrac{2\pi}{1.8\text{ s}} = \mathbf{3.49\ rad/s}$

    b. $\omega = \dfrac{2\pi}{0.3\times10^{-3}\text{ s}} = \mathbf{20.94\times10^{3}\ rad/s}$

c. $\omega = \dfrac{2\pi}{8\times10^{-6}\text{ s}} = \mathbf{785.4 \times 10^3\ rad/s}$

d. $\omega = \dfrac{2\pi}{4\times10^{-6}\text{ s}} = \mathbf{1.57 \times 10^6\ rad/s}$

15. a. $\omega = 2\pi f = 2\pi(100\text{ Hz}) = \mathbf{628.32\ rad/s}$
b. $\omega = 2\pi f = 2\pi(0.25\text{ kHz}) = \mathbf{1.57 \times 10^3\ rad/s}$
c. $\omega = 2\pi f = 2\pi(2\text{ kHz}) = \mathbf{12.56 \times 10^3\ rad/s}$
d. $\omega = 2\pi f = 2\pi(0.004\text{ MHz}) = \mathbf{25.13 \times 10^3\ rad/s}$

16. a. $\omega = 2\pi f = \dfrac{2\pi}{T} \Rightarrow f = \dfrac{\omega}{2\pi}$

$T = \dfrac{2\pi}{\omega} = \dfrac{1}{f}$

$f = \dfrac{\omega}{2\pi} = \dfrac{754\text{ rad/s}}{2\pi} = \mathbf{120\ Hz,\ } \boldsymbol{T} \mathbf{= 8.33\ ms}$

b. $f = \dfrac{\omega}{2\pi} = \dfrac{12\text{ rad/s}}{2\pi} = \mathbf{1.91\ Hz,\ } \boldsymbol{T} \mathbf{= 523.6\ ms}$

c. $f = \dfrac{\omega}{2\pi} = \dfrac{6000\text{ rad/s}}{2\pi} = \mathbf{954.93\ Hz,\ } \boldsymbol{T} \mathbf{= 1.05\ ms}$

d. $f = \dfrac{\omega}{2\pi} = \dfrac{0.16\text{ rad/s}}{2\pi} = \mathbf{25.46 \times 10^{-3}\ Hz,\ } \boldsymbol{T} \mathbf{= 39.28\ ms}$

17. $(60°)\left(\dfrac{\pi}{180°}\right) = \dfrac{\pi}{3}$ radians

$t = \dfrac{\theta}{\omega} = \dfrac{\pi/3\text{ rad}}{2\pi f} = \dfrac{\pi/3\text{ rad}}{2\pi(60\text{ Hz})} = \dfrac{1}{(6)(60)} = \dfrac{1}{360} = \mathbf{2.78\ ms}$

18. $(30°)\left(\dfrac{\pi}{180°}\right) = \dfrac{\pi}{6},\ \alpha = \omega t \Rightarrow \omega = \dfrac{\alpha}{t} = \dfrac{\pi/6}{5\times10^{-3}\text{ s}} = \mathbf{104.7\ rad/s}$

19. a. Amplitude = **20**, $f = \dfrac{\omega}{2\pi} = \dfrac{377\text{ rad/s}}{2\pi} = \mathbf{60\ Hz}$
b. Amplitude = **12**, $f = \mathbf{120\ Hz}$
c. Amplitude = $\mathbf{10^6}$, $f = \dfrac{\omega}{2\pi} = \dfrac{10{,}000\text{ rad/s}}{2\pi} = \mathbf{1591.55\ Hz}$
d. Amplitude = **8**, $f = \dfrac{\omega}{2\pi} = \dfrac{10{,}058\text{ rad/s}}{2\pi} = \mathbf{1.6\ kHz}$

20. –

21. –

22. $T = \dfrac{2\pi}{\omega} = \dfrac{2\pi}{157} = 40 \text{ ms}, \ \dfrac{1}{2} \text{ cycle} = \mathbf{20 \text{ ms}}$

23. $i = 0.5 \sin 72° = 0.5(0.9511) = \mathbf{0.48 \text{ A}}$

24. $1.2\pi\left(\dfrac{180°}{\pi}\right) = 216°$

$v = 20 \sin 216° = 20(-0.588) = \mathbf{-11.76 \text{ V}}$

25. $6 \times 10^{-3} = 30 \times 10^{-3} \sin \alpha$

$0.2 = \sin \alpha$

$\alpha = \sin^{-1} 0.2 = \mathbf{11.54°}$ and $180° - 11.54° = \mathbf{168.46°}$

26. $v = V_m \sin \alpha$

$40 = V_m \sin 30° = V_m (0.5)$

$\therefore V_m = \dfrac{40}{0.5} = \mathbf{80 \text{ V}}$

$\dfrac{30°}{360°} = \dfrac{1 \text{ ms}}{T}$

$T = 1 \text{ ms}\left(\dfrac{360}{30}\right) = \mathbf{12 \text{ ms}}$

$f = \dfrac{1}{T} = \dfrac{1}{12 \times 10^{-3} \text{ s}} = \mathbf{83.33 \text{ Hz}}$

$\omega = 2\pi f = (2\pi)(83.33 \text{ Hz}) = \mathbf{523.58 \text{ rad/s}}$

and $v = \mathbf{80 \sin 523.58}t$

27. –

28. –

29. a. $v = \mathbf{6 \times 10^{-3} \sin (2\pi \, 2000}t \mathbf{+ 30°)}$

b. $i = \mathbf{20 \times 10^{-3} \sin(2\pi \, 60}t \mathbf{- 60°)}$

30. a. $v = \mathbf{120 \times 10^{-6} \sin(2\pi \, 1000}t \mathbf{- 80°)}$

31. $v = \mathbf{12 \times 10^{-3} \sin(2\pi \, 2000}t \mathbf{+ 135°)}$

32. $v = \mathbf{8 \times 10^{-3} \sin(2\pi \, 500}t \mathbf{+ \pi/6)}$

33. $\boldsymbol{v}$ **leads** $\boldsymbol{i}$ **by 90°**

34. $\boldsymbol{i}$ **leads** $\boldsymbol{v}$ **by 40°**

35. $v = 2 \sin (\omega t - \underbrace{30° + 90°}_{+60°})$

$i = 5 \sin(\omega t + 60°)$

} **in phase**

36. $v = 4 \sin(\omega t + 90° + 90° + 180° = 4 \sin \omega t$

$i = \sin(\omega t + 10° + 180°) = \sin(\omega t + 190°)$

} $\boldsymbol{i}$ **leads** $\boldsymbol{v}$ **by 190°**

37. $T = \frac{1}{f} = \frac{1}{1000\ \text{Hz}} = 1\ \text{ms}$

$$t_1 = \frac{120°}{180°}\left(\frac{T}{2}\right) = \frac{2}{3}\left(\frac{1\ \text{ms}}{2}\right) = \mathbf{\frac{1}{3}\ ms}$$

38. $\omega = 2\pi f = \frac{2\pi}{T}$

$$T = \frac{2\pi}{\omega} = \frac{2\pi}{50{,}000\ \text{rad/s}} = 125.66\ \mu\text{s}$$

$$t_1 = \left(\frac{40°}{360°}\right)(T) = \left(\frac{40°}{360°}\right)(125.66\ \mu\text{s})$$

$$= \mathbf{13.96\ \mu s}$$

39. $T = 1\ \text{ms}$

t_{peak} @ 30°

$$t_{peak} = \frac{30°}{360°}(T) = \mathbf{\frac{1}{12}\ ms}$$

40. a. $T = (8\ \cancel{\text{div.}})(1\ \text{ms}/\cancel{\text{div.}}) = \mathbf{8\ ms}$ (both waveforms)

b. $f = \frac{1}{T} = \frac{1}{8\ \text{ms}} = \mathbf{125\ Hz\ (both)}$

c. Peak = (2.5 div)(0.5 V/div.) = 1.25 V

$V_{rms} = 0.707(1.25\ \text{V}) = \mathbf{0.884\ V}$

d. Phase shift = 4.6 div., T = 8 div.

$\theta = \frac{4.6\ \text{div.}}{8\ \text{div.}} \times 360° = \mathbf{207°}$ ***i* leads *e***

or ***e* leads *i* by 153°**

41. $$G = \frac{0 + (6\ \text{V})(5\ \text{ms}) + (3\ \text{V})(10\ \text{ms}) - (3\ \text{V})(10\ \text{ms})}{30\ \text{ms}}$$

$$= \frac{30\ \text{V} + 30\ \text{V} - 30\ \text{V}}{30} = \mathbf{1\ V}$$

42. $$G = \frac{\frac{1}{2}(1\ \mu\text{V})(10\ \cancel{\mu\text{s}}) + (5\ \mu\text{V})(10\ \cancel{\mu\text{s}}) - (2\ \mu\text{V})(10\ \cancel{\mu\text{s}}) + 2\left(\frac{1}{2}(4\ \mu\text{V})(5\ \cancel{\mu\text{s}})\right) - \frac{1}{2}(2\ \mu\text{V})(10\ \cancel{\mu\text{s}})}{40\ \cancel{\mu\text{s}}}$$

$$= \frac{5\ \mu\text{V} + 50\ \mu\text{V} - 20\ \mu\text{V} + 20\ \mu\text{V} - 10\ \mu\text{V}}{40} = \frac{45\ \mu\text{V}}{40}$$

$$= \mathbf{1.125\ \mu V}$$

43. $$G = \frac{-(6\text{ mV})(1\text{ ms}) + (8\text{ mV})(\frac{1}{2}\text{ ms}) + (6\text{ mV})(3\text{ ms}) - \frac{1}{2}(2\text{ mV})(5\text{ ms})}{14\text{ ms}}$$
$$= \frac{-6\text{ mV} + 4\text{ mV} + 18\text{ mV} - 5\text{ mV}}{14} = \frac{+22\text{ mV} - 11\text{ mV}}{14} = \frac{11\text{ mV}}{14}$$
$$= \mathbf{0.786\ mV}$$

44. $$G = \frac{0 + \frac{1}{2}(30\text{ mA})(3\text{ ms}) - \frac{1}{2}(20\text{ mA})(2\text{ ms})}{7\text{ ms}}$$
$$= \frac{45\text{ mA} - 20\text{ mA}}{7} = \mathbf{3.57\ mA}$$

45. a. 0 V

b. $$G = \frac{(4\text{ V})(5\text{ ms}) + \frac{1}{2}(8\text{ V})(5\text{ ms}) - (8\text{ V})(5\text{ ms}) + (4\text{ V})(5\text{ ms}) + \frac{1}{2}(8\text{ V})(5\text{ ms}) - (8\text{ V})(5\text{ ms})}{25\text{ ms}}$$
$$= \frac{20\text{ V} + 20\text{ V} - 40\text{ V} + 20\text{ V} + 20\text{ V} - 40\text{ V}}{25}$$
$$= \mathbf{0\ V}$$

c. The same

46. $$\text{Area} = \frac{1}{2}(\pi r^2) = \frac{1}{2}\pi(20\text{ mA})^2 = 628.32\ \mu\text{A}$$
$$G = \frac{628.32\ \mu\text{A}}{d} = \frac{628.32\ \mu\text{A}}{40\text{ mA}} = 15.71\text{ mA}$$
$$G = \frac{(15.71\text{ mA})(\pi) - (5\text{ mA})(\pi)}{2\pi}$$
$$= \mathbf{5.36\ mA}$$

47. a. $T = (2\text{ div.})(0.2\text{ ms/div}) = \mathbf{0.4\ ms}$

b. $$f = \frac{1}{T} = \frac{1}{0.4\text{ ms}} = \mathbf{2.5\ kHz}$$

c. Average = $(-2.5\text{ div.})(10\text{ mV/div.}) = \mathbf{-25\ mV}$

48. a. $T = (4\text{ div.})(10\ \mu\text{s/div.}) = \mathbf{40\ \mu s}$

b. $$f = \frac{1}{T} = \frac{1}{40\ \mu\text{s}} = \mathbf{25\ kHz}$$

c. $$G = \frac{(2.5\text{ div.})(1.5\text{ div.}) + (1\text{ div.})(0.5\text{ div.}) + (1\text{ div.})(0.6\text{ div.}) + (2.5\text{ div.})(0.4\text{ div.}) + (1\text{ div.})(1\text{ div.})}{4\text{ div.}}$$
$$= \frac{3.75\text{ div.} + 0.5\text{ div.} + 0.6\text{ div.} + 1\text{ div.} + 1\text{ div.}}{4}$$

$$= \frac{6.85 \text{ div.}}{4} = 1.713 \text{ div.}$$

$1.713 \cancel{\text{div.}}(10 \text{ mV}/\cancel{\text{div.}}) = \mathbf{17.13\ mV}$

49. a. $V_{rms} = 0.7071(120 \text{ V}) = \mathbf{84.85\ V}$
b. $I_{rms} = 0.7071(6 \text{ mA}) = \mathbf{4.24\ mA}$
c. $V_{rms} = 0.7071(8\ \mu\text{V}) = \mathbf{5.66\ \mu V}$

50. a. $\upsilon = \mathbf{6.79 \sin 377}t$
b. $i = \mathbf{70.7 \times 10^{-3} \sin 377}t$
c. $\upsilon = \mathbf{2.83 \times 10^{3} \sin 377}t$

51. $$V_{rms} = \sqrt{\frac{(2 \text{ V})^2(4 \text{ s}) + (-2 \text{ V})^2(1 \text{ s}) + (-1 \text{ V})^2(4\text{s})}{12 \text{ s}}} = \sqrt{\frac{16 \text{ V}^2\text{s} + 4 \text{ V}^2\text{s} + 4 \text{ V}^2\text{s}}{12 \text{ s}}}$$
$$= \sqrt{\frac{24 \text{ V}^2 \cancel{\text{s}}}{12 \cancel{\text{s}}}} = \sqrt{2 \text{ V}^2}$$
$$= \mathbf{1.414\ V}$$

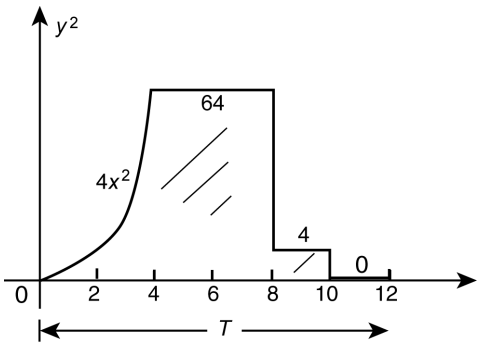
52. $$V_{rms} = \sqrt{\frac{(3 \text{ V})^2(2 \text{ s}) + (2 \text{ V})^2(2 \text{ s}) + (1 \text{ V})^2(2\text{s}) + (-1 \text{ V})^2(2 \text{ s}) + (-3 \text{ V})^2(2 \text{ s}) + (1 \text{ V})^2(2\text{s})}{12 \text{ s}}}$$
$$= \sqrt{\frac{50}{12} \text{ V}^2} = \sqrt{4.167 \text{ V}^2} = \mathbf{2.04\ V}$$

53. $$G = \frac{(8 \text{ V})(4 \text{ ms}) - (8 \text{ V})(4 \text{ ms})}{8 \text{ ms}} = \frac{0}{8 \text{ ms}} = \mathbf{0\ V}$$
$$V_{rms} = \sqrt{\frac{(8 \text{ V})^2(4 \text{ ms}) + (-8 \text{ V})^2(4 \text{ ms})}{8 \text{ ms}}} = \mathbf{8\ V}$$

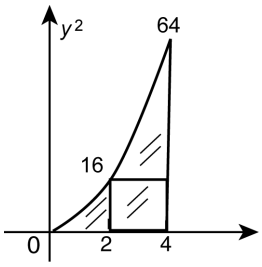
54. a. $T = (4 \text{ div.})(10\ \mu\text{s/div.}) = \mathbf{40\ \mu s}$
$$f = \frac{1}{T} = \frac{1}{40\ \mu\text{s}} = \mathbf{25\ kHz}$$
Av. = (1 div.)(20 mV/div.) = **20 mV**
Peak = (2 div.)(20 mV/div.) = **40 mV**
$$\text{rms} = \sqrt{V_0^2 + \frac{V_{max}^2}{2}} = \sqrt{(20 \text{ mV})^2 + \frac{(40 \text{ mV})^2}{2}} = \mathbf{34.64\ mV}$$

b. $T = (2 \text{ div.})(50\ \mu\text{s}) = \mathbf{100\ \mu s}$
$$f = \frac{1}{T} = \frac{1}{100\ \mu\text{s}} = \mathbf{10\ kHz}$$
Av. = (−1.5 div.)(0.2 V/div.) = **−0.3 V**
Peak = (1.5 div.)(0.2 V/div.) = **0.3 mV**
$$\text{rms} = \sqrt{V_0^2 + \frac{V_{max}^2}{2}} = \sqrt{(.3 \text{ V})^2 + \frac{(.3 \text{ V})^2}{2}} = \mathbf{367.42\ mV}$$

55. a.



b.



$$A_1 = \frac{1}{2}(2)(16) + (2)(16) + \frac{1}{2}(2)(48) = 96$$

Area = 96 + (4)(64) + (2)(4) = 96 + 256 + 8 = **360**

c. $\text{rms} = \sqrt{\frac{360}{12}} = \sqrt{30} = \mathbf{5.48}$

d. $G = \frac{\frac{1}{2}(4)(8) + 4(8) - 2(2)}{12} = \frac{16 + 32 - 4}{12} = \mathbf{3.67}$

e. rms ≅ **1.5 (average value)**

56. a. $V_{dc} = IR = (4\text{ mA})(2\text{ k}\Omega) = 8\text{ V}$
Meter indication = 2.22(8 V) = **17.76 V**

b. $V_{\text{rms}} = 0.707(16\text{ V}) = \mathbf{11.31\ V}$