1.

| | | |
|---|---|---|
| (a) 12 μs | (d) 3.5 Gbits | (g) 39 pA |
| (b) 750 mJ | (e) 6.5 nm | (h) 49 kΩ |
| (c) 1.13 kΩ | (f) 13.56 MHz | (i) 11.73 pA |

2. (a) 1 MW (e) 33 μJ (i) 32 mm
(b) 12.35 mm (f) 5.33 nW
(c) 47. kW (g) 1 ns
(d) 5.46 mA (h) 5.555 MW

3. (a) $(400\ \text{Hp})\left(\dfrac{745.7\ \text{W}}{1\ \text{hp}}\right)$ = 298.3 kW

(b) $12\ \text{ft} = (12\ \text{ft})\left(\dfrac{12\ \text{in}}{1\ \text{ft}}\right)\left(\dfrac{2.54\ \text{cm}}{1\ \text{in}}\right)\left(\dfrac{1\ \text{m}}{100\ \text{cm}}\right) = 3.658\ \text{m}$

(c) 2.54 cm = 25.4 mm

(d) $(67\ \text{Btu})\left(\dfrac{1055\ \text{J}}{1\ \text{Btu}}\right)$ = 70.69 kJ

(e) $285.4\ \ 10^{-15}$ s = 285.4 fs

4. (15 V)(0.1 A) = 1.5 W = 1.5 J/s.

3 hrs running at this power level equates to a transfer of energy equal to

(1.5 J/s)(3 hr)(60 min/ hr)(60 s/ min) = 16.2 kJ

5. Motor power = 175 Hp

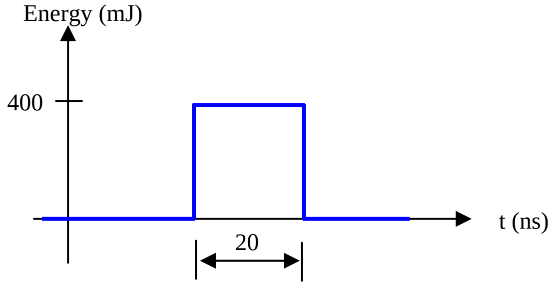
(a) With 100% efficient mechanical to electrical power conversion,
(175 Hp)[1 W/ (1/745.7 Hp)] = 130.5 kW

(b) Running for 3 hours,
Energy = $(130.5\times10^3$ W)(3 hr)(60 min/hr)(60 s/min) = 1.409 GJ

(c) A single battery has 430 kW-hr capacity. We require
(130.5 kW)(3 hr) = 391.5 kW-hr therefore one battery is sufficient.

6. The 400-mJ pulse lasts 20 ns.

(a) To compute the peak power, we assume the pulse shape is square:



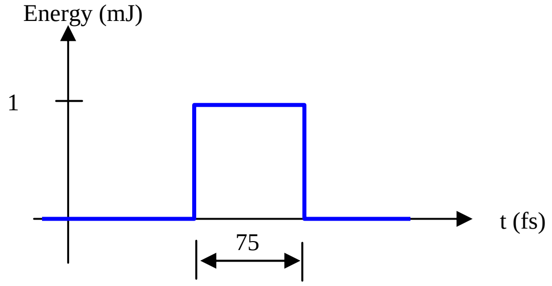

Then $P = 400\times10^{-3}/20\times10^{-9} = 20$ MW.

(b) At 20 pulses per second, the average power is

$P_{avg}$ = (20 pulses)(400 mJ/pulse)/(1 s) = 8 W.

7. The 1-mJ pulse lasts 75 fs.

(a) To compute the peak power, we assume the pulse shape is square:

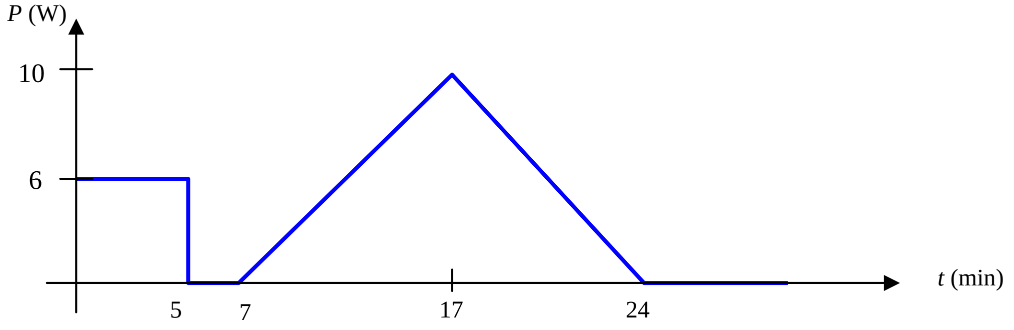



Then $P = 1\times10^{-3}/75\times10^{-15} = 13.33$ GW.

(b) At 100 pulses per second, the average power is

$P_{avg}$ = (100 pulses)(1 mJ/pulse)/(1 s) = 100 mW.

8. The power drawn from the battery is (not quite drawn to scale):




(a) Total energy (in J) expended is
[6(5) + 0(2) + 0.5(10)(10) + 0.5(10)(7)]60 = 6.9 kJ.

(b) The average power in Btu/hr is
(6900 J/24 min)(60 min/1 hr)(1 Btu/1055 J) = 16.35 Btu/hr.

9. The total energy transferred during the first 8 hr is given by

(10 W)(8 hr)(60 min/ hr)(60 s/ min) = 288 kJ

The total energy transferred during the last five minutes is given by

$$\int_0^{300\text{ s}} \left[ -\frac{10}{300}t + 10 \right] dt = -\frac{10}{600}t^2 + 10t \Big|_0^{300} = 1.5\text{ kJ}$$

(a) The total energy transferred is 288 + 1.5 = 289.5 kJ

(b) The energy transferred in the last five minutes is 1.5 kJ

10. Total charge $q = 18t^2 - 2t^4$ C.

(a) $q(2\text{ s}) = 40$ C.

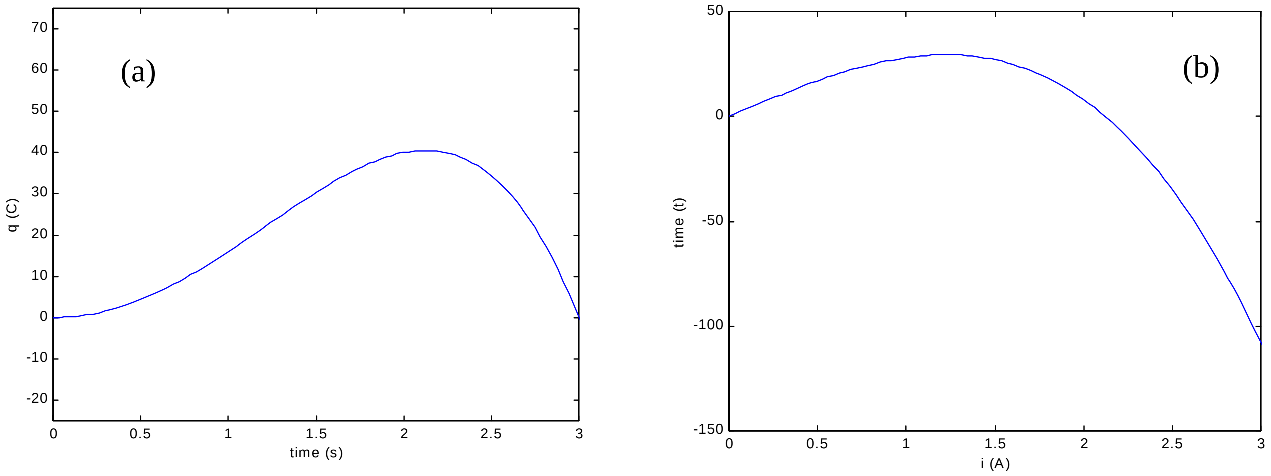
(b) To find the maximum charge within $0 \le t \le 3$ s, we need to take the first and second derivitives:

$dq/dt = 36t - 8t^3 = 0$, leading to roots at 0, ± 2.121 s
$d^2q/dt^2 = 36 - 24t^2$

substituting $t = 2.121$ s into the expression for $d^2q/dt^2$, we obtain a value of –14.9, so that this root represents a maximum.
Thus, we find a maximum charge $q = 40.5$ C at $t = 2.121$ s.

(c) The rate of charge accumulation at $t = 8$ s is
$dq/dt|_{t = 0.8} = 36(0.8) - 8(0.8)^3 = 24.7$ C/s.

(d) See Fig. (a) and (b).



11. Referring to Fig. 2.6*c*,

$$i_1(t) \;=\; \begin{cases} -2+3e^{-5t} \text{ A}, & t<0 \\ -2+3e^{3t} \text{ A}, & t>0 \end{cases}$$

Thus,

(a) $i_1(-0.2)$ = 6.155 A

(b) $i_1$ (0.2) = 3.466 A

(c) To determine the instants at which $i_1 = 0$, we must consider $t < 0$ and $t > 0$ separately:

for $t < 0$, $- 2 + 3e^{-5t} = 0$ leads to $t$ = -0.2 ln (2/3) = +0.0811 s (impossible)

for $t > 0$, $-2 + 3e^{3t} = 0$ leads to $t$ = (1/3) ln (2/3) = –0.135 s (impossible)

Therefore, the current is *never* negative.

(d) The total charge passed left to right in the interval $–0.8 < t < 0.1$ s is

$$q(t) = \int_{-0.8}^{0.1} i_1(t)\,dt$$

$$= \int_{-0.8}^{0}\left[-2+3e^{-5t}\right]dt \quad + \quad \int_{0}^{0.1}\left[-2+3e^{3t}\right]dt$$

$$= \left(-2t-\frac{3}{5}e^{-5t}\right)\Bigg|_{-0.8}^{0} \quad + \quad \left(-2t+e^{3t}\right)\Big|_{0}^{0.1}$$

= 33.91 C

12. Referring to Fig. 2.28,

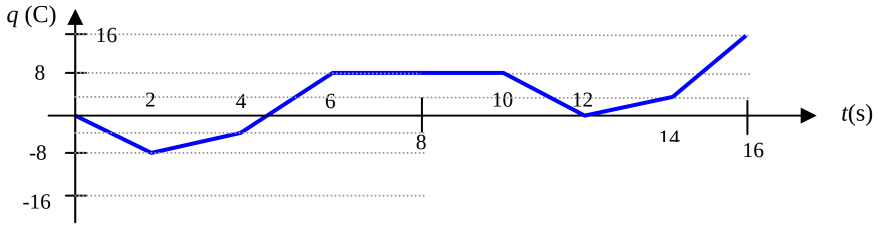
(a) The average current over one period (10 s) is

$i_{avg}$ = [-4(2) + 2(2) + 6(2) + 0(4)]/10 = 800 mA

(b) The total charge transferred over the interval 1 < $t$ < 12 s is

$$q_{\text{total}} = \int_1^{12} i(t)dt = -4(1) + 2(2) + 6(2) + 0(4) - 4(2) = 4\text{ C}$$

(c) See Fig. below



13. (a) $V_{BA} = -\dfrac{2 \text{ pJ}}{-1.602\times10^{-19} \text{ C}} = 12.48 \text{ MV}$

(b) $V_{ED} = \dfrac{0}{-1.602\times10^{-19} \text{ C}} = 0$

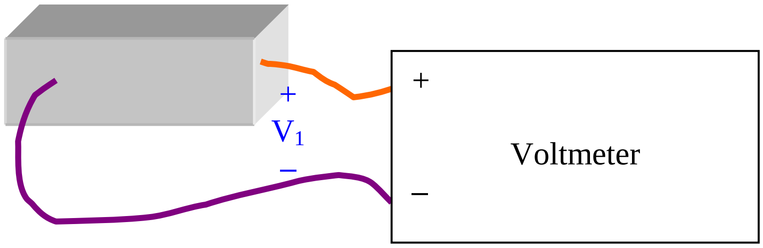
(c) $V_{DC} = -\dfrac{3 \text{ pJ}}{1.602\times10^{-19} \text{ C}} = -18.73 \text{ MV}$

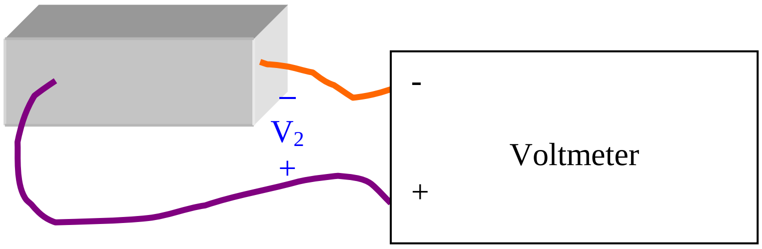
(d) It takes – 3 pJ to move $+1.602\text{x}10^{-19}$ C from D to C.
It takes 2 pJ to move $-1.602\text{x}10^{-19}$ C from B to C, or –2 pJ to move $+1.602\text{x}10^{-19}$ C from B to C, or +2 pJ to move $+1.602\text{x}10^{-19}$ C from C to B.

Thus, it requires –3 pJ + 2 pJ = –1 pJ to move $+1.602\text{x}10^{-19}$ C from D to C to B.

Hence, $V_{DB} = \dfrac{-1 \text{ pJ}}{1.602\times10^{-19} \text{ C}} = -6.242 \text{ MV}.$

14.




From the diagram, we see that $V_2 = –V_1 = +2.86$ V.

15. (a) $P_{abs}$ = (+3.2 V)(-2 mA) = –6.4 mW (or +6.4 mW *supplied*)

(b) $P_{abs}$ = (+6 V)(-20 A) = –120 W (or +120 W *supplied*)

(d) $P_{abs}$ = (+6 V)(2 $i_x$) = (+6 V)[(2)(5 A)] = +60 W

(e) $P_{abs} = (4 \sin 1000t \text{ V})(-8 \cos 1000t \text{ mA})\Big|_{t = 2 \text{ ms}} = +12.11 \text{ W}$

16. $i = 3te^{-100t}$ mA and $v = [6 - 600t]\, e^{-100t}$ mV

(a) The power absorbed at $t$ = 5 ms is

$$P_{\text{abs}} = \left[(6 - 600t)e^{-100t} \cdot 3te^{-100t}\right]_{t=5ms} \quad \mu\text{W}$$

$$= 0.01655\ \mu\text{W} \quad = \quad 16.55\ \text{nW}$$

(b) The energy delivered over the interval $0 < t < \infty$ is

$$\int_0^\infty P_{abs}\, dt \quad = \quad \int_0^\infty 3t(6 - 600t)e^{-200t}\, dt \qquad \mu\text{J}$$

Making use of the relationship

$$\int_0^\infty x^n\, e^{-ax}\, dx \quad = \quad \frac{n!}{a^{n+1}}$$ where n is a positive integer and a > 0,

we find the energy delivered to be

$$= 18/(200)^2 \quad - \quad 1800/(200)^3$$

$$= 0$$

17. (a) $P_{abs} = (40i)(3e^{-100t})\big|_{t = 8 \text{ ms}} = 360\left[e^{-100t}\right]^2_{t=8ms} = 72.68$ W

(b) $P_{abs} = \left(0.2\dfrac{di}{dt}\right)i = -180\left[e^{-100t}\right]^2_{t=8ms} = -36.34$ W

(c) $P_{abs} = \left(30\int_0^t i\,dt + 20\right)\left(3e^{-100t}\right)\Big|_{t=8ms}$

$$= \left(90e^{-100t}\int_0^t 3e^{-100t'}dt' + 60e^{-100t}\right)\Big|_{t=8ms} = 27.63 \text{ W}$$

18. (a) The short-circuit current is the value of the current at V = 0.

Reading from the graph, this corresponds to approximately 3.0 A.

(b) The open-circuit voltage is the value of the voltage at I = 0.

Reading from the graph, this corresponds to roughly 0.4875 V, estimating the curve as hitting the x-axis 1 mm behind the 0.5 V mark.

(c) We see that the maximum current corresponds to zero voltage, and likewise, the maximum voltage occurs at zero current. The maximum power point, therefore, occurs somewhere between these two points. By trial and error,

$P_{max}$ is roughly (375 mV)(2.5 A) = 938 mW, or just under 1 W.

19. (a) $P|_{\text{first 2 hours}} = (5\text{ V})(0.001\text{ A}) = 5\text{ mW}$

$P|_{\text{next 30 minutes}} = (?\text{ V})(0\text{ A}) = 0\text{ mW}$

$P|_{\text{last 2 hours}} = (2\text{ V})(-0.001\text{ A}) = -2\text{ mW}$

(b) Energy = (5 V)(0.001 A)(2 hr)(60 min/ hr)(60 s/ min) = 36 J

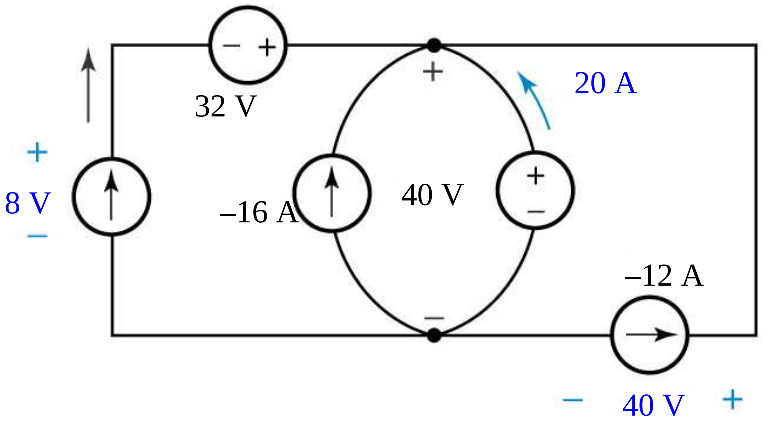
(c) 36 – (2)(0.001)(60)(60) = 21.6 J

20. Note that in the table below, only the –4-A source and the –3-A source are actually "absorbing" power; the remaining sources are supplying power to the circuit.

| **Source** | **Absorbed Power** | **Absorbed Power** |
|---|---|---|
| 2 V source | (2 V)(-2 A) | - 4 W |
| 8 V source | (8 V)(-2 A) | - 16 W |
| -4 A source | (10 V)[-(-4 A)] | 40 W |
| 10 V source | (10 V)(-5 A) | - 50 W |
| -3 A source | (10 V)[-(-3 A)] | 30 W |

The 5 power quantities sum to –4 – 16 + 40 – 50 + 30 = 0, as demanded from conservation of energy.

21.




$P_{8V\ supplied}$ = (8)(8) = 64 W (source of energy)

$P_{32V\ supplied}$ = (32)(8) = 256 W (source of energy)

$P_{-16A\ supplied}$ = (40)(–16) = –640 W

$P_{40V\ supplied}$ = (40)(20) = 800 W (source of energy)

$P_{-12A\ supplied}$ = (40)( –12) = –480 W

Check: $\sum$ supplied power = 64 + 256 – 640 + 800 – 480 = 0 (ok)

22. We are told that $V_x = 1$ V, and from Fig. 2.33 we see that the current flowing through the dependent source (and hence through each element of the circuit) is $5V_x = 5$ A. We will compute *absorbed* power by using the current flowing *into* the positive reference terminal of the appropriate voltage (passive sign convention), and we will compute *supplied* power by using the current flowing *out of* the positive reference terminal of the appropriate voltage.

(a) The power absorbed by element "A" = (9 V)(5 A) = 45 W

(b) The power supplied by the 1-V source = (1 V)(5 A) = 5 W, and
the power supplied by the dependent source = (8 V)(5 A) = 40 W

(c) The sum of the supplied power = 5 + 40 = 45 W
The sum of the absorbed power is 45 W, so

yes, the sum of the power supplied = the sum of the power absorbed, as we expect from the principle of conservation of energy.

23. We are asked to determine the voltage $v_s$, which is identical to the voltage labeled $v_1$. The only remaining reference to $v_1$ is in the expression for the current flowing through the dependent source, $5v_1$.

This current is equal to $-i_2$.
Thus,

$$5\, v_1 = -i_2 = -\, 5 \text{ mA}$$

Therefore $v_1 = -1$ mV

and so $v_s = v_1 = -1$ mV

24. The voltage across the dependent source = $v_2 = –2i_x = –2(–0.001) = 2$ mV.

25. The battery delivers an energy of 460.8 W-hr over a period of 8 hrs.

(a) The power delivered to the headlight is therefore (460.8 W-hr)/(8 hr) = 57.6 W

(b) The current through the headlight is equal to the power it absorbs from the battery divided by the voltage at which the power is supplied, or

$I$ = (57.6 W)/(12 V) = 4.8 A

26. The supply voltage is 110 V, and the maximum dissipated power is 500 W. The fuses are specified in terms of current, so we need to determine the maximum current that can flow through the fuse.

$$P = V\,I \qquad \text{therefore } I_{\text{max}} = P_{\text{max}}/V \;= (500\text{ W})/(110\text{ V}) \;= 4.545\text{ A}$$

If we choose the 5-A fuse, it will allow up to (110 V)(5 A) = 550 W of power to be delivered to the application (we must assume here that the fuse absorbs zero power, a reasonable assumption in practice). This exceeds the specified maximum power.

If we choose the 4.5-A fuse instead, we will have a maximum current of 4.5 A. This leads to a maximum power of (110)(4.5) = 495 W delivered to the application.

Although 495 W is less than the maximum power allowed, this fuse will provide adequate protection for the application circuitry. If a fault occurs and the application circuitry attempts to draw too much power, 1000 W for example, the fuse will blow, no current will flow, and the application circuitry will be protected. However, if the application circuitry tries to draw its maximum rated power (500 W), the fuse will also blow. In practice, most equipment will not draw its maximum rated power continuously—although to be safe, we typically assume that it will.

27. (a) $i_{max}$ = 5/ 900 = 5.556 mA

$i_{min}$ = 5/ 1100 = 4.545 mA

(b) $p = v^2 / R$ so

$p_{min}$ = 25/ 1100 = 22.73 mW

$p_{max}$ = 25/ 900 = 27.78 mW

28. $p = i^2 R$, so
$p_{min} = (0.002)^2\ (446.5) = 1.786$ mW and (more relevant to our discussion)
$p_{max} = (0.002)^2\ (493.5) = 1.974$ mW

1.974 mW would be a correct answer, although power ratings are typically expressed as integers, so 2 mW might be more appropriate.

29. (a) $P_{abs} = i^2R = [20e^{-12t}]^2 \, (1200)\ \mu W$

$= [20e^{-1.2}]^2 \, (1200)\ \mu W$

$= 43.54$ mW

(b) $P_{abs} = v^2/R = [40 \cos 20t]^2 / 1200$ W

$= [40 \cos 2]^2 / 1200$ W

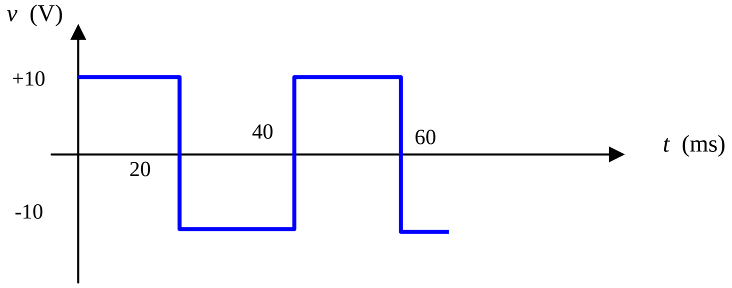
*keep in mind we are using radians*

$= 230.9$ mW

(c) $P_{abs} = v\,i = 8t^{1.5}$ W

$= 253.0$ mW

30. It's probably best to begin this problem by sketching the voltage waveform:




(a) $v_{\max} = +10$ V

(b) $v_{avg} = [(+10)(20\times10^{-3}) + (-10)(20\times10^{-3})]/(40\times10^{-3}) \quad = \quad 0$

(c) $i_{avg} = v_{avg} / R \quad = \quad 0$

(d) $$p_{abs}\big|_{\max} = \frac{v_{\max}^2}{R} = (10)^2 / 50 = 2 \text{ W}$$

(e) $$p_{abs}\big|_{avg} = \frac{1}{40}\left[\frac{(+10)^2}{R}\cdot 20 + \frac{(-10)^2}{R}\cdot 20\right] = 2 \text{ W}$$

31. Since we are informed that the same current must flow through each component, we begin by defining a current *I* flowing out of the positive reference terminal of the voltage source.

The power supplied by the voltage source is $V_s I$.
The power absorbed by resistor $R_1$ is $I^2R_1$.
The power absorbed by resistor $R_2$ is $I^2R_2$.

Since we know that the total power supplied is equal to the total power absorbed, we may write:

$$V_s I = I^2R_1 + I^2R_2$$

or

$$V_s = I R_1 + I R_2$$
$$V_s = I (R_1 + R_2)$$

By Ohm's law,

$$I = V_{R_2} / R_2$$

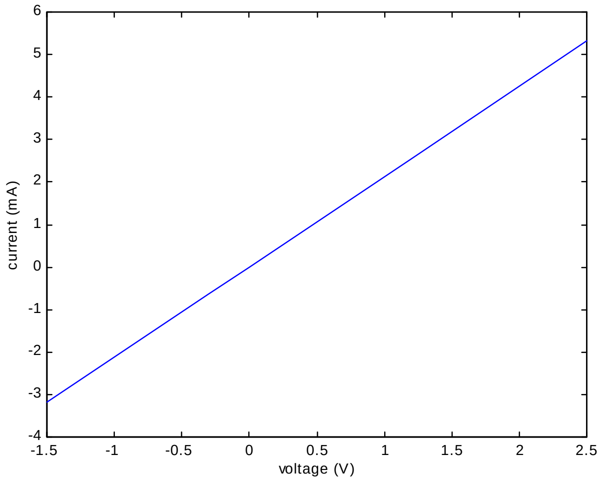
so that

$$V_s = \frac{V_{R_2}}{R_2}(R_1 + R_2)$$

Solving for $V_{R_2}$ we find

$$V_{R_2} = V_s \frac{R_2}{(R_1 + R_2)} \qquad Q.E.D.$$

32. (a)

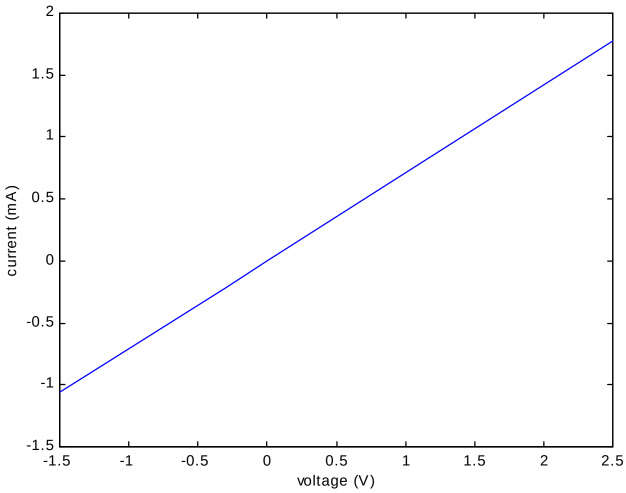



(b) We see from our answer to part (a) that this device has a reasonably linear characteristic (a not unreasonable degree of experimental error is evident in the data). Thus, we choose to estimate the resistance using the two extreme points:

$$R_{\text{eff}} = [(2.5 - (-1.5)]/[5.23 - (-3.19)] \text{ k}\Omega \quad = 475\ \Omega$$

Using the last two points instead, we find $R_{\text{eff}}$ = 469 Ω, so that we can state with some certainty at least that a reasonable estimate of the resistance is approximately 470 Ω.

(c)



33. Top Left Circuit: $I$ = (5/10) mA = 0.5 mA, and $P_{10k} = V^2/10$ mW = 2.5 mW

Top Right Circuit: $I$ = -(5/10) mA = -0.5 mA, and $P_{10k} = V^2/10$ mW = 2.5 mW

Bottom Left Circuit: $I$ = (-5/10) mA = -0.5 mA, and $P_{10k} = V^2/10$ mW = 2.5 mW

Bottom Right Circuit: $I$ = -(-5/10) mA = 0.5 mA, and $P_{10k} = V^2/10$ mW = 2.5 mW

34. The voltage $v_{out}$ is given by

$$v_{out} = -10^{-3} v_\pi (1000)$$

$$= - v_\pi$$

Since $v_\pi = v_s = 0.01 \cos 1000t$ V, we find that

$$v_{out} = - v_\pi = -0.01 \cos 1000t \quad \text{V}$$

35. $v_{out} = -v_{\pi} = -v_S = -2\sin 5t$ V

$v_{out}$ ($t$ = 0) = 0 V

$v_{out}$ ($t$ = 0.324 s) = -2sin (1.57) = -2 V

(use care to employ radian mode on your calculator or convert 1.57 radians to degrees)

36. 18 AWG wire has a resistance of 6.39 Ω / 1000 ft.

Thus, we require 1000 (53) / 6.39 = 8294 ft of wire.
(Or 1.57 miles. Or, 2.53 km).

37. We need to create a 470-Ω resistor from 28 AWG wire, knowing that the ambient temperature is 108°F, or 42.22°C.

Referring to Table 2.3, 28 AWG wire is 65.3 mΩ/ft at 20°C, and using the equation provided we compute

$$R_2/R_1 = (234.5 + T_2)/(234.5 + T_1) = (234.5 + 42.22)/(234.5 + 20) = 1.087$$

We thus find that 28 AWG wire is (1.087)(65.3) = 71.0 mΩ/ft.

Thus, to repair the transmitter we will need

(470 Ω)/(71.0 × 10-3 Ω/ft) = 6620 ft (1.25 miles, or 2.02 km).

Note: This seems like a lot of wire to be washing up on shore. We may find we don't have enough. In that case, perhaps we should take our cue from Eq. [6], and try to squash a piece of the wire flat so that it has a very small cross-sectional area…..

38. We are given that the conductivity $\sigma$ of copper is $5.8\times10^7$ S/m.

(a) 50 ft of #18 (18 AWG) copper wire, which has a diameter of 1.024 mm, will have a resistance of $l/(\sigma A)$ ohms, where A = the cross-sectional area and $l$ = 50 ft.

Converting the dimensional quantities to meters,

$l$ = (50 ft)(12 in/ft)(2.54 cm/in)(1 m/100 cm) = 15.24 m

and

$r$ = 0.5(1.024 mm)(1 m/1000 mm) = $5.12\times10^{-4}$ m

so that

$A = \pi r^2 = \pi(5.12\times10^{-4}\text{ m})^2 = 8.236\times10^{-7}\text{ m}^2$

Thus, $R = (15.24\text{ m})/[(5.8\times10^7)(8.236\times10^{-7})] = 319.0\text{ m}\Omega$

(b) We assume that the conductivity value specified also holds true at 50°C.

The cross-sectional area of the foil is

$A = (33\ \mu\text{m})(500\ \mu\text{m})(1\text{ m}/10^6\ \mu\text{m})(1\text{ m}/10^6\ \mu\text{m}) = 1.65\times10^{-8}\text{ m}^2$

So that

$R = (15\text{ cm})(1\text{ m}/100\text{ cm})/[(5.8\times10^7)(1.65\times10^{-8})] = 156.7\text{ m}\Omega$

A 3-A current flowing through this copper in the direction specified would lead to the dissipation of

$$I^2R = (3)^2\,(156.7)\text{ mW} = 1.410\text{ W}$$

39. Since $R = \rho \ell / A$, it follows that $\rho = R A / \ell$.
From Table 2.4, we see that 28 AWG soft copper wire (cross-sectional area = 0.0804 $mm^2$) is 65.3 Ω per 1000 ft. Thus,

$R = 65.3\ \Omega$.

$\ell$ = (1000 ft)(12 in/ft)(2.54 cm/in)(10 mm/cm) = 304,800 mm.

$A = 0.0804\ mm^2$.

Thus, $\rho = (65.3)(0.0804)/304800 = 17.23\ \mu\Omega/\ mm$

or

$\rho\ =\ 1.723\ \mu\Omega\cdot cm$

which is in fact consistent with the representative data for copper in Table 2.3.

40. (a) From the text,

(1) Zener diodes,
(2) Fuses, and
(3) Incandescent (as opposed to fluorescent) light bulbs

This last one requires a few facts to be put together. We have stated that temperature can affect resistance—in other words, if the temperature changes during operation, the resistance will not remain constant and hence nonlinear behavior will be observed. Most discrete resistors are rated for up to a specific power in order to ensure that temperature variation during operation will not significantly change the resistance value. Light bulbs, however, become rather warm when operating and can experience a significant change in resistance.

(b) The energy is dissipated by the resistor, converted to heat which is transferred to the air surrounding the resistor. The resistor is unable to store the energy itself.

41. The quoted resistivity $\rho$ of B33 copper is 1.7654 μΩ·cm.
$A = \pi r^2 = \pi(10^{-3})^2 = 10^{-6}\pi\ \text{m}^2$. $\ell$ = 100 m.

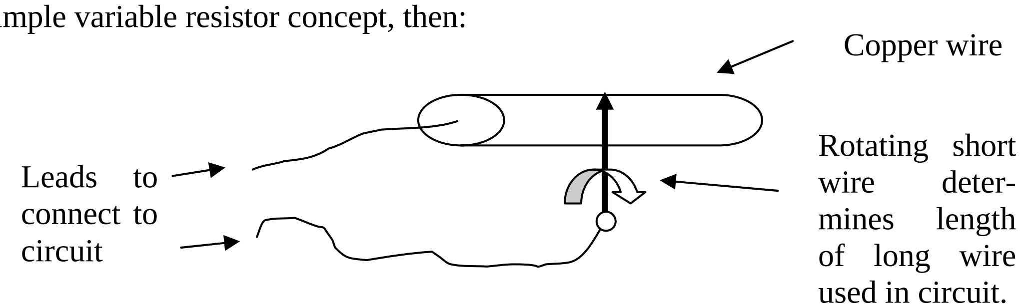
Thus, $R = \rho\ell / A = \dfrac{\left(1.7654\times10^{-6}\,\Omega\text{cm}\right)\left(1\text{ m}/100\text{ cm}\right)\left(100\text{ m}\right)}{10^{-6}\pi} = 0.5619\ \Omega$

And $P = I^2R = (1.5)^2\,(0.5619) = 1.264$ W.

42. We know that for any wire of cross-sectional area A and length $\ell$, the resistance is given by R = $\rho\ \ell$ / A.

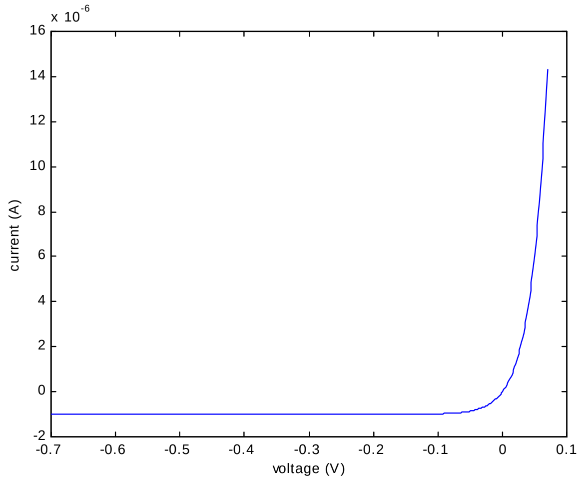
If we keep $\rho$ fixed by choosing a material, and A fixed by choosing a wire gauge (e.g. 28 AWG), changing $\ell$ will change the resistance of our "device."

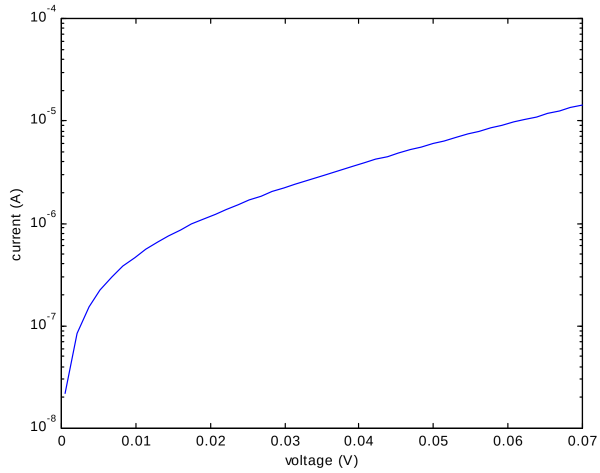
A simple variable resistor concept, then:




But this is somewhat impractical, as the leads may turn out to have almost the same resistance unless we have a very long wire, which can also be impractical. One improvement would be to replace the copper wire shown with a coil of insulated copper wire. A small amount of insulation would then need to be removed from where the moveable wire touches the coil so that electrical connection could be made.

43. (a) We need to plot the negative and positive voltage ranges separately, as the positive voltage range is, after all, exponential!




(b) To determine the resistance of the device at $V$ = 550 mV, we compute the corresponding current:

$$I = 10^{-9}\,[e^{39(0.55)} - 1] \;=\; 2.068 \text{ A}$$

Thus, $R$(0.55 V) = 0.55/2.068 = 266 mΩ

(c) $R$ = 1 Ω corresponds to $V = I$. Thus, we need to solve the transcendental equation

$$I = 10^{-9}\,[e^{39I} - 1]$$

Using a scientific calculator or the tried-and-true trial and error approach, we find that

$$I = 514.3 \text{ mA}$$

44. We require a 10-Ω resistor, and are told it is for a portable application, implying that size, weight or both would be important to consider when selecting a wire gauge. We have 10,000 ft of each of the gauges listed in Table 2.3 with which to work. Quick inspection of the values listed eliminates 2, 4 and 6 AWG wire as their respective resistances are too low for only 10,000 ft of wire.

Using 12-AWG wire would require (10 Ω) / (1.59 mΩ/ft) = 6290 ft.
Using 28-AWG wire, the narrowest available, would require

$$(10\ \Omega) / (65.3\ \text{m}\Omega/\text{ft}) = 153\ \text{ft}.$$

Would the 28-AWG wire weight less? Again referring to Table 2.3, we see that the cross-sectional area of 28-AWG wire is 0.0804 $\text{mm}^2$, and that of 12-AWG wire is 3.31 $\text{mm}^2$. The volume of 12-AWG wire required is therefore 6345900 $\text{mm}^3$, and that of 28-AWG wire required is only 3750 $\text{mm}^3$.

The best (but not the only) choice for a portable application is clear: 28-AWG wire!

45. Our target is a 100-Ω resistor. We see from the plot that at $N_D = 10^{15}$ cm$^{-3}$, $\mu_n \sim 2\text{x}10^3$ cm$^2$/V-s, yielding a resistivity of 3.121 Ω-cm.

At $N_D = 10^{18}$ cm$^{-3}$, $\mu_n \sim 230$ cm$^2$/ V-s, yielding a resistivity of 0.02714 Ω-cm.

Thus, we see that the lower doping level clearly provides material with higher resistivity, requiring less of the available area on the silicon wafer.

Since $R = \rho L/A$, where we know $R = 100\ \Omega$ and $\rho = 3.121\ \Omega$-cm for a phosphorus concentration of $10^{15}$ cm$^{-3}$, we need only define the resistor geometry to complete the design.

We choose a geometry as shown in the figure; our contact area is arbitrarily chosen as 100 μm by 250 μm, so that only the length L remains to be specified. Solving,

$$L = \frac{R}{\rho}A = \frac{(100\ \Omega)(100\ \mu\text{m})(250\ \mu\text{m})}{(3.121\ \Omega\ \text{cm})(10^4\ \ \mu\text{m/cm})} = \ 80.1\ \mu\text{m}$$

Design summary (one possibility): $N_D = 10^{15}$ cm$^{-3}$
$L$ = 80.1 μm
Contact width = 100 μm

(Note: this is somewhat atypical; in the semiconductor industry contacts are typically made to the top and/or bottom surface of a wafer. So, there's more than one solution based on geometry as well as doping level.)