1. (a) 45 mW

(b) 2 nJ

(c) 100 ps

(d) 39.212 fs

(e) 3 Ω

(f) 18 km

(g) 2.5 Tb

(h) 100 exaatoms/m^3

2. (a) 1.23 ps

(b) 1 μm

(c) 1.4 K

(d) 32 nm

(e) 13.56 MHz

(f) 2.021 millimoles

(g) 130 ml

(h) 100 m

3. (a) 1.212 V

(b) 100 mA

(c) 1 zs

(d) 33.9997 zs

(e) 13.1 fs

(f) 10 Ms

(g) 10 µs

(h) 1 s

4. (a) 10^{21} m

(b) 10^{18} m

(c) 10^{15} m

(d) 10^{12} m

(e) 10^{9} m

(f) 10^{6} m

5. (a) 373.15 K

(b) 255.37 K

(c) 0 K

(d) 149.1 kW

(e) 914.4 mm

(f) 1.609 km

6. (a) 373.15 K

(b) 273.15 K

(c) 4.2 K

(d) 112 kW

(e) 528 kJ

(f) 100 W (100 J/s is also acceptable)

7. (a) $P = 550\text{ mJ}/\ 15\text{ ns} = \boxed{36.67\text{ MW}}$

(b) $P_{avg} = (550\text{ mJ/pulse})(100\text{ pulses/s}) = 55\text{ J/s} = \boxed{55\text{ W}}$

8. (a) 500×10^{-6} J/50×10^{-15} s = 10 GJ/s = **10 GW**

(b) (500×10^{-6} J/pulse)(80×10^{6} pulses/s) = 40 kJ/s = **40 kW**

9. Energy = (40 hp)(1 W/ 1/745.7 hp)(3 h)(60 min/h)(60 s/ min) = 322.1 MJ

10. $(20\text{ hp})(745.7\text{ W/hp})/[(500\text{ W/m}^2)(0.1)] = \boxed{298\text{ m}^2}$

11. (a) (100 pW/device)(N devices) = 1 W. Solving, N = 10^{10} devices

(b) Total area = (1 μm^2/ 5 devices)(10^{10} devices) = 2000 mm^2

(roughly 45 mm on a side, or less than two inches by two inches, so yes).

12. (a) 20×10^3 Wh/ 100 W = 200 h

So, in one day we remain at the \$0.05/kWh rate.

(0.100 kW)(N 100 W bulbs)(\$0.05/kWh)(7 days)(24 h/day) = \$10

Solving, N = 11.9

Fractional bulbs are not realistic so rounding down, 11 bulbs maximum.

(b) Daily cost = (1980)(\$0.10/kWh)(24 h) + (20 kW)(\$0.05/kWh)(24 h) = \$4776

13. Between 9 pm and 6 am corresponds to 9 hrs at \$0.033 per kWh.
Thus, the daily cost is (0.033)(2.5)(9) + (0.057)(2.5)(24 – 9) = \$2.88

Consequently, 30 days will cost \$86.40

14. $$\frac{(9\times10^9 \text{ person})(100 \text{ W/person})}{(800 \text{ W/m}^2)(0.1)} = \boxed{11.25\times10^9 \text{ m}^2}$$

15. $q(t) = 5e^{-t/2}$ C

$dq/dt = -(5/2)\, e^{-t/2}$ C/s $=$ $\boxed{-2.5e^{-t/2}\text{ A}}$

16. $q = i \cdot t = (10^{-9}\text{ A})(60\text{ s}) = \boxed{60\text{ nC}}$

17. (a) # electrons = -10^{13} C/(-1.602×10^{-19} C/electron) = 6.242×10^{31} electrons

(b) $$\left[\frac{6.242\times10^{31}\ \text{electrons}}{\pi\left(\frac{1\ \text{cm}}{2}\right)^2}\right]\left(\frac{100\ \text{cm}}{1\ \text{m}}\right)^2 = 7.948\times10^{35}\ \text{electrons/m}^2$$

(c) current = (10^6 electons/s)(-1.602×10^{-19} C/electron) = 160.2 fA

18. $q(t) = 9 - 10t$ C

(a) $q(0) =$ 9 C

(b) $q(1) =$ –1 C

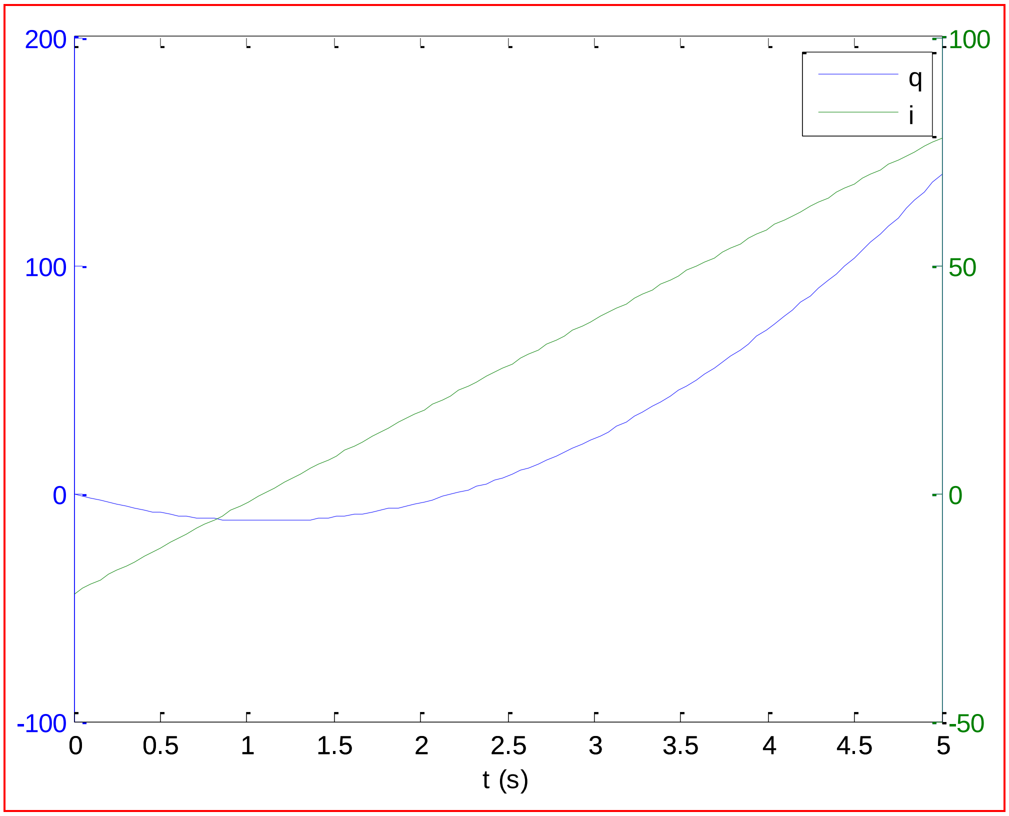
(c) $i(t) = dq/dt =$ –10 A, regardless of value of t

19. (a) $q = 10t^2 - 22t$

$i = dq/dt = 20t - 22 = 0$

Solving, t = 1.1 s

(b)



20. i(t) = 114sin 100πt A

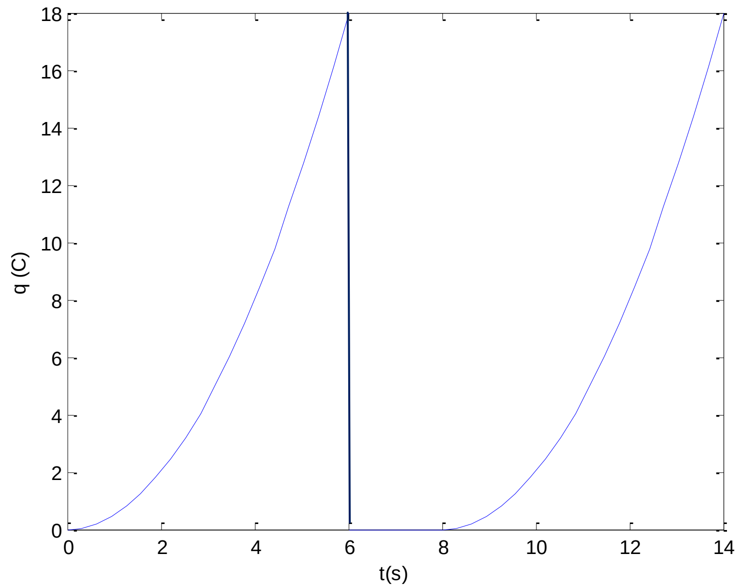
(a) This function is zero whenever 100πt = πn, n = 1, 2, …
or when t = 0.01n.
Therefore, the current drops to zero **201 times** (t = 0, t = 0.01, … t = 2) in the interval.

(b) $q = \int_0^1 i dt = 114\int_0^1 \sin 100\pi t = -\frac{114}{100\pi}\cos 100\pi t\Big|_0^1 = \boxed{0\ \text{C net}}$

21. (a) Define $i_{avg} = \dfrac{1}{T}\int_0^T i(t)dt = \dfrac{1}{8}\int_0^8 tdt = $ 2.25 A

(b) $q(t) = \int_0^t i(t')dt' = \int_0^t t'dt'$ =

$500t^2$ mC, $0 \le t < 6$
0, $6 \le t < 8$
$500(t - 8)^2$ mC, $8 \le t < 14$



22. (a) $i_{avg} = \dfrac{(3)(1)+(-1)(1)+(1)(1)+(0)(1)}{4} = \boxed{750\text{ mA}}$

(b) $i_{avg} = \dfrac{(3)(1)+(-1)(1)+(1)(1)}{3} = \boxed{1\text{ A}}$

(c) $$q(t) = \int i(t)dt = \boxed{\begin{cases} 3t + q(0) = 3t + 1\text{ C}, & 0 \le t \le 1\text{ s} \\ -t + q(1) = -t + 4\text{ C}, & 1 \le t \le 2\text{ s} \\ t + q(2) = t + 2\text{ C}, & 2 \le t \le 3\text{ s} \\ q(3) = 5\text{ C}, & 3 \le t \le 4\text{ s} \end{cases}}$$

23. A to C = 5 pJ. B to C = 3 pJ. Thus, A to B = 2 pJ.
A to D = 8 pJ so C to D = 3 pJ

(a) $V_{CB} = 3\times10^{-12}/{-1.602\times10^{-19}}$ = **–18.73 MV**

(b) $V_{DB} = (3 + 3)\times10^{-12}/{-1.602\times10^{-19}}$ = **–37.45 MV**

(c) $V_{BA} = 2\times10^{-12}/{-1.602\times10^{-19}}$ = **–12.48 MV**

24. $v_x = 10^{-3}$ J/ -1.602×10^{-19} C = $\boxed{-6.24\times10^{15}\text{ V}}$

$v_y = -v_x$ = $\boxed{+6.24\times10^{15}\text{ V}}$

25. (a) Voltage is defined as the potential difference between two points, hence two wires are needed (one to each ‘point’).

(b) The reading will be the negative of the value displayed previously.

26. (a) $P_{abs} = (+6)(+10^{-12}) = \boxed{6\text{ pW}}$

(b) $P_{abs} = (+1)(+10\times10^{-3}) = \boxed{10\text{ mW}}$

(c) $P_{abs} = (+10)(-2) = \boxed{-20\text{ W}}$

27. (a) $P_{abs} = (2)(-1) = \boxed{-2\ \text{W}}$

(b) $P_{abs} = (-16e^{-t})(0.008e^{-t}) = \boxed{-47.09\ \text{mW}}$

(c) $P_{abs} = (2)(-10^{-3})(0.1) = \boxed{-200\ \mu\text{W}}$

28. $P_{abs} = v_p(1)$

(a) $(+1)(1) =$ **1 W**

(b) $(-1)(1) =$ **–1 W**

(c) $(2 + 5\cos 5t)(1) = (2 + 5\cos 5)(1) =$ **3.418 W**

(d) $(4e^{-2t})(1) = (4e^{-2})(1) =$ **541.3 mW**

(e) A negative value for absorbed power indicates the element is actually supplying power to whatever it is connected to.

29. $P_{supplied} = (2)(2) = \boxed{4\text{ W}}$

30. (a) Short circuit corresponds to zero voltage, hence i_{sc} = 3.0 A.

(b) Open circuit corresponds to zero current, hence v_{oc} = 500 mV.

(c) $P_{max} \approx (0.375)(2.5)$ = 938 mW (near the knee of curve)

31. Looking at sources left to right,

$P_{supplied}$ =

(2)(2)	= 4 W;
(8)(2)	= 16 W;
(10(-4)	= -40 W;
(10)(5)	= 50 W;
(10)(-3)	= -30 W

Note these sum to zero, as expected.

32. The remaining power is leaving the laser as heat, due to losses in the system. Conservation of energy requires that the total output energy, regardless of form(s), equal the total input energy.

33. (a) $V_R = 10$ V, $V_x = 2$ V

$P_{abs} =$

(2)(-10) = –20 W;

(10)(10) = 100 W;

(8)(-10) = –80 W

(b) element A is a passive element, as it is absorbing positive power

34. (a) V_R = 10 0 V, V_x = 92 V

$P_{Vx(supplied)} = (92)(5V_x) = (92)(5)(92)$ = 42.32 kW
$P_{VR(supplied)} = (100)(-5V_x) = -100(5)(92)$ = -46.00 kW
$P_{5Vx(supplied)} = (8)(5V_x) = (8)(5)(92)$ = 3.68 W

(b) 42.32 – 46 + 3.68 = 0

35. $i_2 = -3v_1$ therefore $v_1 = -100/3$ mV = **–33.33 mV**

36. First, it cannot dissipate more than 100 W and hence imax = 100/12 = 8.33 A

It must also allow at least 12 W or imin = 12/12 = 1 A

10 A is too large; 1 A is just on the board and likely to blow at minimum power operation, so 4 A is the optimum choice among the values available.

37. $(-2i_x)(-i_x) = 1$

Solving, $i_x = 707$ mA

38. (a) $10^{-3}/4.7\times10^{3}$ = $\boxed{210 \text{ nA}}$

(b) $10/4.7\times10^{3}$ = $\boxed{2.1 \text{ mA}}$

(c) $4e^{-t}/4.7\times10^{3}$ = $\boxed{850e^{-t}\ \mu\text{A}}$

(d) $100\cos5t / 4.7\times10^{3}$ = $\boxed{21\cos5t \text{ mA}}$

(e) $\left|\frac{-7}{4.7\times10^{3}}\right|$ = $\boxed{1.5 \text{ mA}}$

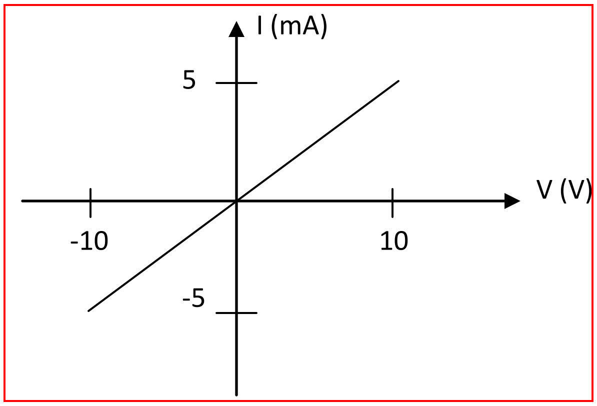
39. (a) $(1980)(0.001) = \boxed{1.98\ \text{V}}$;
$(2420)(0.001) = \boxed{2.42\ \text{V}}$

(b) $(1980)(4\times10^{-3}\sin 44t) = \boxed{7.92\ \sin 44t\ \text{V}}$;
$(2420)(4\times10^{-3}\sin 44t) = \boxed{9.68\ \sin 44t\ \text{V}}$

40. $I = V/R$; $I_{min} = V_{min}/R = -10/2000 = -5$ mA

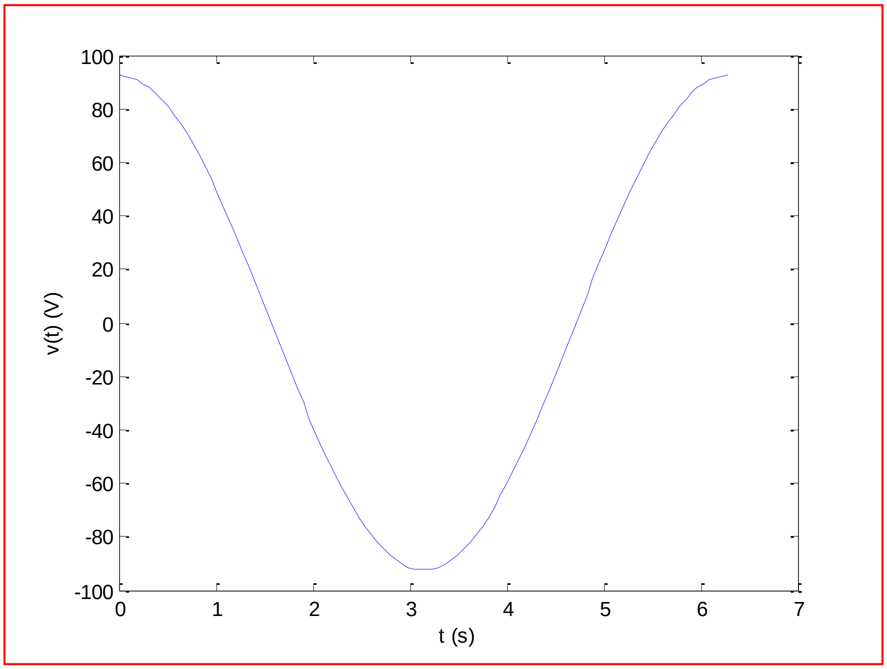
$I_{max} = V_{max}/R = +10/2000 = 5$ mA

(a)



(b) slope = $dI/dV = 5\times10^{-3}/10$ = 500 μs

41. We expect the voltage to be 33 times larger than the current, or 92.4 cos t V.



42. (a) $R = 5/0.05\times10^{-3}$ = $\boxed{100\ \text{k}\Omega}$

(b) $R = \boxed{\infty}$

(c) $R = \boxed{0}$

43. (a) ∞

(b) 10 ns

(c) 5 s

44. $G = 10$ mS; $R = 1/G = 100\ \Omega$

(a) $i = 2\times10^{-3}/100 = \boxed{20\ \mu\text{A}}$

(b) $i = 1/100 = \boxed{10\ \text{mA}}$

(c) $i = 100e^{-2t}/100 = \boxed{e^{-2t}\ \text{A}}$

(d) $i = 0.01(5) \sin 5t = \boxed{50 \sin 5t\ \text{mA}}$

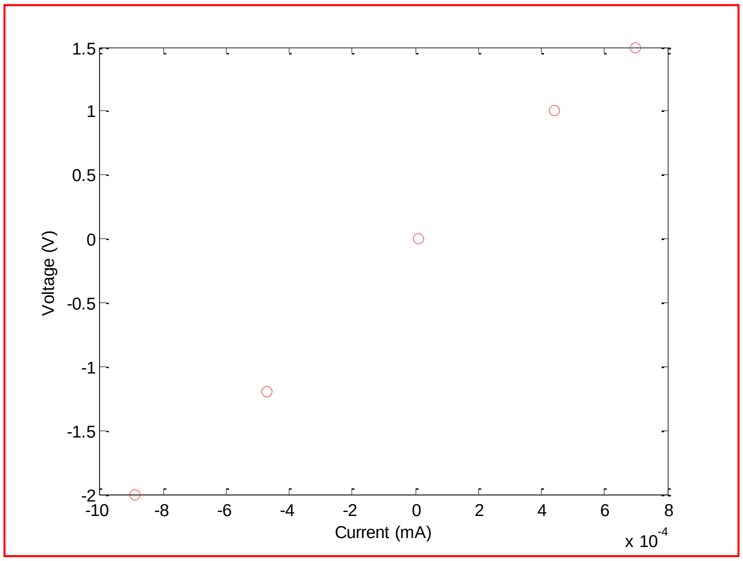
(e) $i = \boxed{0}$

45. (a) $i_{lo} = 9/1010 = 8.91$ mA;
$i_{hi} = 9/990 = 9.09$ mA

(b) $P_{lo} = 9^2/1010 = 80.20$ mW;
$P_{hi} = 9^2/990 = 81.82$ mW

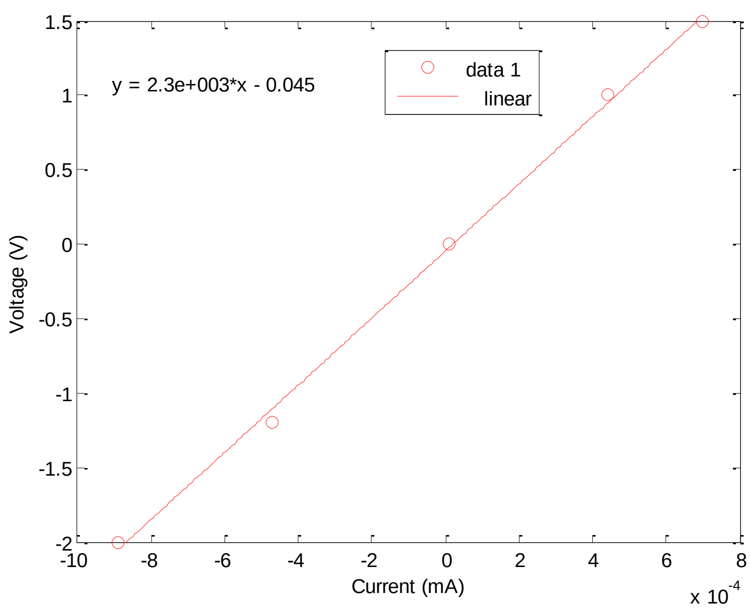
(c) $9/1100 = 8.18$ mA;
$9/900 = 10$ mA;
$9^2/1100 = 73.6$ mW;
$9^2/900 = 90.0$ mW

46. (a) Plotting the data in the table provided,



(b) A best fit (using MATLAB fitting tool in plot window) yields a slope of 2.3 kΩ.

However, this is only approximate as the best fit does not intersect zero current at zero voltage.



47. Define I flowing clockwise. Then

P_{Vs}(supplied) = $V_s I$

P_{R1}(absorbed) = $I^2 R_1$

P_{R2}(absorbed) = $(V_{R2})^2/R_2$

Equating, $V_s I = I^2 R_1 + (V_{R2})^2/R_2$ [1]

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

or $I = V_s/(R_1 + R_2)$ [2]

We substitute Eq. [2] into Eq. [1] and solve for $(V_{R2})^2$:

$$(V_{R2})^2 = V_s^2\left[\frac{R_2^2}{(R_1+R_2)^2}\right] \text{ hence } V_{R2} = V_s\left[\frac{R_2}{R_1+R_2}\right].$$ QED.

48. TOP LEFT: $I = 5/10\times10^3 = 500\ \mu A$

$P_{abs} = 5^2/10\times10^3 = 2.5\ mW$

TOP RIGHT: $I = -5/10\times10^3 = -500\ \mu A$

$P_{abs} = (-5)^2/10\times10^3 = 2.5\ mW$

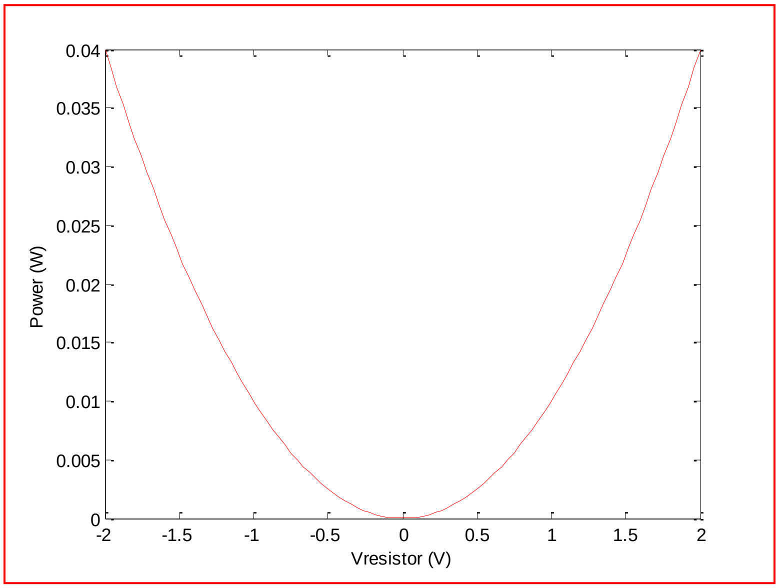
BOTTOM LEFT: $I = -5/10\times10^3 = -500\ \mu A$

$P_{abs} = (-5)^2/10\times10^3 = 2.5\ mW$

BOTTOM RIGHT: $I = -(-5)/10\times10^3 = 500\ \mu A$

$P_{abs} = (-5)^2/10\times10^3 = 2.5\ mW$

49. Power = V^2/R so



50. <DESIGN>

One possible solution:

$$R = \rho \frac{L}{A} = \frac{L}{A(qN_D\mu_n)} = 10 .$$

Select $N_D = 10^{14}$ atoms/cm^2, from the graph, $\mu_n = 2000$ cm^2/Vs.

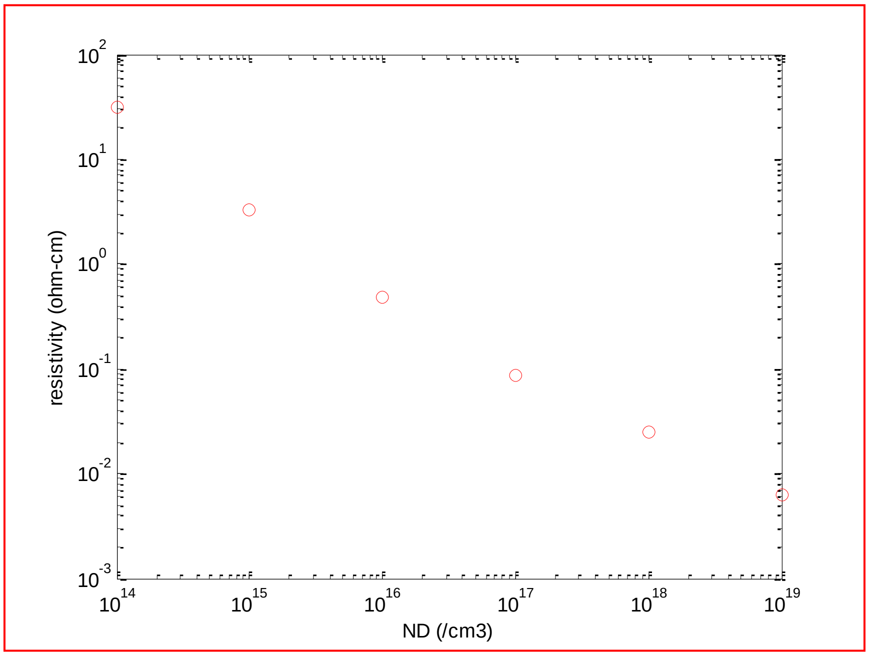
Hence, $qN_D\mu_n = 0.032$, so that L/A = 0.32 μm^{-1}.

Using the wafer thickness as one dimension of our cross sectional area A, A = 300x μm^2 and y is the other direction on the surface of the wafer, so L = y.

Thus, L/A = y/300x = 0.32. Choosing y = 6000 μm, x = 62.5 μm.

Summary: Select wafer with phosphorus concentration of 10^{14} atoms/cm^3, cut surface into a rectangle measuring 62.5 μm wide by 6000 μm long. Contact along narrow sides of the 6000 μm long strip.

51. $\rho = (qN_D\mu_n)^{-1}$. Estimating μ_n from the graph, keeping in mind "half-way" on a log scale corresponds to 3, not 5,



52. <DESIGN> One possible solution:

We note 28 AWG wire has a resistance of 65.3 ohms per 1000 ft length (at 20°C).

There, 1531 ft is approximately 100 ohms and 7657 ft is approximately 500 ohms.

These are huge lengths, which reincorces the fact that copper wire is a very good conductor.

*Wrap the 7657 ft of 28 AWG wire around a (long) nonconducting rod.

*Connect to the left end.

*The next connection slides along the (uninsulated) coil. When connection is approximately 20% of the length as measured from the left, R = 100 ohms. When it is at the far (right) end, R = 500 ohms.

53. 14 AWG = 2.52 ohms per 1000 ft.

R = (500 ft)(2.52 ohms/1000 ft) = 1.26 ohms

$$P = I^2R = (25)^2(1.26) = \boxed{787.5\ \text{W}}$$

54. (a) 28 AWG = 65.3 ohms per 1000 ft therefore length = 1000(50)/65.3 = **766 ft**

(b) $110.5^{o}F = 43.61^{o}C$

Thus, $R_2 = (234.5 + 43.61)(50)/(234.5 + 20) = 54.64$ ohms

We therefore need to reduce the length to 50(766)/54.64 = **701 ft**

55. <Design> One possible solution:

Choose 28 AWG wire. Require (10)(100)/(65.3) = 153 feet (rounding error within 1% of target value). Wrap around 1 cm diameter 47 cm long wooden rod.

56. B415 used instead of B33; gauge unchanged.
The resistivity is therefore 8.4805/1.7654 = 4.804 times larger

(a) With constant voltage, the current will be (100/4.804) = 20.8% of expected value

(b) No additional power wil be wasted since the error leads to lower current: P = V/R where V = unchanged and R is larger (0%)

57. $R = \rho L/A = (8.4805\times10^{-6})(100)(2.3/7.854\times10^{-7}) = 2483\ \Omega$

$P = i^2R$ so

B415: 2.48 mW; B75: 504 μW

58. $\beta = 100$, $I_B = 100\ \mu A$

(a) $I_C = \beta\ I_B = \boxed{10\ mA}$

(b) $P_{BE} = (0.7)(100\times10^{-6}) = \boxed{70\ \mu W}$

59. Take the maximum efficiency of a tungsten lightbulb as 10%. Then only ~10 W (or 10 J/s) of optical (visible) power is expected. The remainder is emitted as heat and invisible light.

60. Assuming the batteries are built the same way, each has the same energy density in terms of energy storage.

The AA, being larger, therefore stores more energy.

Consequently, for the same voltage, we would anticipate the larger battery can supply the same current for longer, or a larger maximum current, before discharging completely.

1. (a) 5 nodes

   (b) 7 elements

   (c) 7 branches