1. $m_1 = 1$, $m_2 = 3$

$\Delta y = 0.45 \times 10^{-3}$ m

$D = 0.37$ m

$\lambda = 550 \times 10^{-9}$ m

$d \sin\theta = m\lambda$

a. $\tan\theta = \Delta y / D = 1.216 \times 10^{-3}$

$\theta = \tan^{-1}(1.216 \times 10^{-3}) = 1.215 \times 10^{-3}$

Small Angle Approx applies for $\theta \approx \sin\theta \approx \tan\theta$

$\sin\theta = m\lambda / d = \theta$; $m = 4$

$d = m\lambda / \theta = 1.809 \times 10^{-3}$ m

b. $d \sin\theta = m\lambda$, $m = 1$, d is constant

$\theta = \sin^{-1}(m\lambda / d) = 3.04 \times 10^{-4}$

2. $d \sin\theta = m\lambda$, $\theta = 52.3°$, $m = 1$

$(\sin\theta = \lambda / d)^{-1}$

$(\sin\theta)^{-1} = d / \lambda = 1.26$

Check calc Mode Rad ↔ Deg

3. $d = 1.5 \times 10^{-3}$ m, $r = 59 \times 10^{-6}$ m

4. $\lambda = 660 \times 10^{-9}$ m

Diffraction by circular aperture

1st min at θ: $\sin\theta = 1.22\lambda / d$

θ: Angle from central axis to 1st min

1.22 due to circular shape

Less image by diffraction important to resolve 2 pts or smaller: Diffraction by single slit

w/ small θ of separation 1st min at θ: $\sin\theta = \lambda / d$

θ of separation between 2 pts is such that central max of diffraction from pt 1 centers on 1st min of diffraction from pt 2.

This θ of separation $\theta_R = \sin^{-1}(1.22\lambda / d) \approx 1.22\lambda / d$

Because D/L is small, $\sin\theta \approx \cos\theta \approx \tan\theta \approx D/L \approx \theta$

$\theta = \theta_R \approx D/L$; $\theta_R = D/L = 1.22\lambda / d$

$\Delta = 1.22 L\lambda / d$; $L = \Delta d / (1.22\lambda)$

$\Delta = 2r = 118 \times 10^{-6}$ m

$L = (118 \times 10^{-6}\text{ m})(1.5 \times 10^{-3}\text{ m}) / (1.22 \times 660 \times 10^{-9}\text{ m}) = 0.22$ m

2. $q_1 = 15\ \mu C = 1.5 \times 10^{-5}\ C$
$q_2 = 11\ \mu C = 1.1 \times 10^{-5}\ C$
$q_3 = 13\ \mu C = 1.3 \times 10^{-5}\ C$
} all charges are positive

$r_{1,3} = 0.075\ m$

$r_{2,3} = 0.10\ m$

$\theta = 37°$

$(r_{1,2})^2 = (r_{1,3})^2 + (r_{2,3})^2$ Pythagorean Theorem

$\sin\ \theta = (r_{1,3})/(r_{1,2})$

$r_{1,2} = (r_{1,3})/(\sin\theta)$

$r_{1,2} = (0.075\ m)/(\sin 37°)$

$r_{1,2} = 0.1246\ m$

$F_{1,2} = k(q_1)(q_2)/(r_{1,2})^2$ Coulomb's Law

$= (8.99 \times 10^9\ N \cdot m^2/C^2)(1.5 \times 10^{-5}\ C)(1.1 \times 10^{-5}\ C)/(0.1246\ m)^2$

$= -95.54\ N$ q_1, q_2 positive : $F_{1,2}$ negative

$F_{1,3} = k(q_1)(q_3)/(r_{1,3})^2$ Coulomb's Law

$= (8.99 \times 10^9\ N \cdot m^2/C^2)(1.5 \times 10^{-5}\ C)(1.3 \times 10^{-5}\ C)/(0.075\ m)^2$

$= -311.65\ N$ q_1, q_3 positive : $F_{1,3}$ negative

$F_{net,x} = F_{(1,2),x} + F_{(3),1,x} = (-95.5N)\cos(37°) + (-311.65N)\cos(37°)$

$F_{net,y} = F_{(1,2),y} + F_{(1,3),y} = (-95.5N)\sin(37°) + (-311.65N)\sin(37°)$

$F_{net,x} = -276.30\ N \approx -276\ N$. $F_{net,y} = -245.1N \approx -250\ N$.

7. $C_1 = 13.2\,\mu F = 1.32 \times 10^{-5} F$

$C_2 = 5.22\,\mu F = 5.22 \times 10^{-6} F$

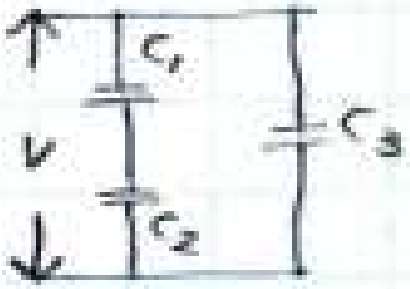
$C_3 = 4.13\,\mu F = 4.13 \times 10^{-6} F$

$1/C_S = 1/C_1 + 1/C_2$

$1/C_S = 267328.46\ F^{-1}$

$C_S = 3.7407 \times 10^{-6}\ F$

$= 3.7407\,\mu F$

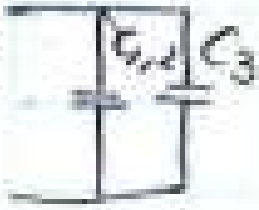


$C_P = C_{1,2} + C_3$

$= (3.7407 \times 10^{-6} + 4.13 \times 10^{-6})F$

$= 7.8707 \times 10^{-6} F$

$= 7.8707\,\mu F$



8. $C_1 = 8.76\,\mu F = 8.76 \times 10^{-6} F$

$C_2 = 5.53\,\mu F = 5.53 \times 10^{-6} F$

$C_3 = 5.38\,\mu F = 5.38 \times 10^{-6} F$

$C_P = C_1 + C_2$

$= (8.76 + 5.53) \times 10^{-6} F$

$= 1.429 \times 10^{-5} F$

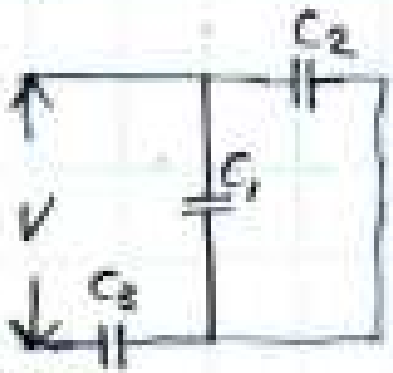
$1/C_S = 1/C_{1,2} + 1/C_3$

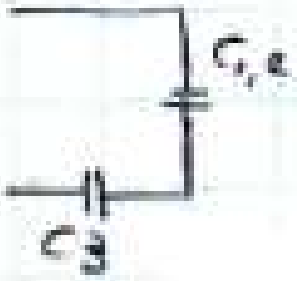
$= 1/(1.429 \times 10^{-5} F) + 1/(5.38 \times 10^{-6} F)$

$= 255852.6122\ F^{-1}$

$C_S = 3.9085 \times 10^{-6} F$

$= 3.9085\,\mu F$





8. $y = (2.4\ mm)\sin[(24\ m^{-1})x - (610\ s^{-1})t]$

$= y_{max} \sin[(2\pi/\lambda)x - (2\pi/T)t]$

d. $\lambda = 2\pi / 24\ m^{-1} = 0.2618\ m$

$T = 2\pi / 610\ s^{-1} = 0.0103\ s$

a. $y_m = 2.4\ mm = 0.0024\ m$

b. $f = 1/T = 97.08\ Hz$

c. $v = \lambda f = 25.416\ m/s$

e. $a = -\omega y_m \cos(kx - \omega t)$

$\omega = 2\pi f = 609.9\ rad/s$; $k = 2\pi/\lambda = 24.0\ rad/m$

$a = -(609.9\ rad/s)^2 (0.0024\ m) \cos[(24\ rad/m)x - (609.9\ rad/s)t]$

$a_{max} = -(609.9\ rad/s)^2 (0.0024\ m) = 1.46\ m/s^2$

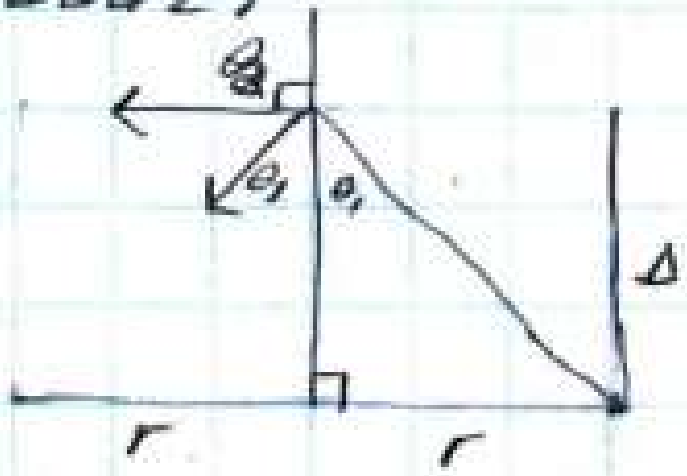
9. $\Delta = 65.9$ cm

$n_1 = 1.33$, $n_2 = 1.00029$

incident: θ_1

reflection: θ_1

refraction: θ_2



$\theta_2 = 90°$; $\theta_1 = \theta_c$

$n_1 \sin\theta_1 = n_2 \sin\theta_2$

$(1.33)\sin(\theta_c) = (1.00029)\sin(90°)$

$\theta_c = \sin^{-1}(1.00029/1.33) = 48.11°$

$\tan^{-1}(r/\Delta) = \theta_c$

$r = \Delta \tan(\theta_c) = 75.20$ cm

$d = 2r = 150.40$ cm

11. a. $d = 140\ km = 140000\ m$

$V = 2.998 \times 10^8\ m/s$

$t = d/V = 4.67 \times 10^{-4}\ s$

b. $d_1 = 3.8 \times 10^9\ m$

$d_2 = 1.5 \times 10^{11}\ m$

$V = 2.998 \times 10^8\ m/s$

$t = (d_1 + d_2)/V$

$t = (1.5 \times 10^{11})/V = 501.65$

c. $d = 2 \times 10^9\ km = 2 \times 10^{12}\ m$

$t = 2d/V = 13342.23\ s$

d. $d = vt$

$d = (2.998 \times 10^8\ m/s)(3153600\ s)$

$= 9.45459 \times 10^{15}\ m$

$(6/100\ d) = 5.76229 \times 10^{13}\ m$

$(6/100\ d)/V = t = 1.923 \times 10^5\ s = 6109\ y$

2. $f = 18.6\ cm = 0.186\ mm$

$r = 6.96 \times 10^{5}\ mm$

$\rho = 1.5 \times 10^{11}\ mm$

$h = 2r = 13.92 \times 10^{5}\ mm$

$\frac{1}{\rho} - \frac{1}{f} = -\frac{1}{z}$

$\frac{1}{(6.5 \times 10^{11}\ mm)} - \frac{1}{(-0.186\ mm)} = -\frac{1}{z} = -5.376$

$z = -0.186\ mm$

$m_M = -\frac{1}{\rho} = 1.24 \times 10^{-12}$

$|m_M| = \frac{h'}{h}$; $(1.24 \times 10^{-12})(13.92 \times 10^{5}\ mm) = h'$

$h' = 0.0017\ mm = 1.7\ \mu m$

8. $\theta = 0.21°$

$\lambda = 666\ nm = 666 \times 10^{-9}\ m$

$n = 1.33 = c/v$

$v = c/n = 225413533.8\ m/s$

$v = \lambda f = 225413533.8\ m/s$

$\lambda_n = \lambda v/c = 5.0075 \times 10^{-7}\ m$

$d = m\lambda / \sin\theta$

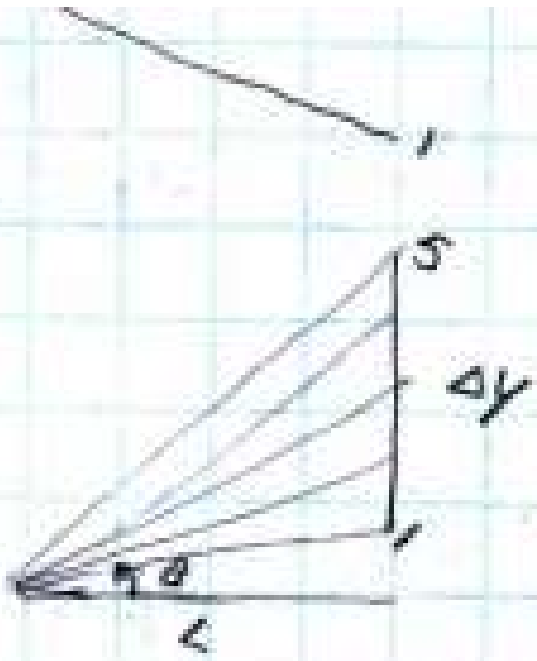
$= 1.8121 \times 10^{-4}\ m$

$\theta = \sin^{-1}(m\lambda/d)$

$= \sin^{-1}(\lambda_n/d)$

$= 0.1589$

1. continued



$\tan\theta \approx \sin\theta$

$\tan\theta = \Delta y / L$

$m\lambda = m\lambda / (\Delta y / L)$

$= (4 \times 550 \times 10^{-9}\ m) / (0.45\ mm / 37\ cm)$

$= 0.0018089\ m$

$\theta = \sin^{-1}(m\lambda / d)$

If $m = 1$: $\theta = 3.0405 \times 10^{-4}\ rad$

(1.) $\lambda = 550 \times 10^{-9}\ m$, $m = 4$

$a \sin\theta = m\lambda$, $\Delta y = 0.45\ mm$, $L = 3.1\ m$

Small Angle Approximation

let $\theta = 0.005$; $\sin\theta = 0.005$; $\tan\theta = 0.005$

? $m(1/a) = \sin\theta_5$, $m = 0.00000275\ m$

Thus $\theta_5 = 0.00000275\ m = \tan\theta_5$

11. $\lambda = 34.7 \times 10^{-12}$ mm

$p = hf/c = h/\lambda = 1.91 \times 10^{-23}$ J·s/mm

J·s/mm = N·mm·s/mm = N·s = kg·(m/s²)·s

= kg·m/s

$f = pc/h = (1.91 \times 10^{-23})(299792458)\,\lambda / h$

$= 8.6395521 \times 10^{18}$ Hz

$E = hf = 5.728 \times 10^{-15}$ J

$p = hf/c = E/c$; $1\ eV = 1.602 \times 10^{-19}$ J

$E = (5.728 \times 10^{-15}\ eV)/(1.602 \times 10^{-19})$

$= 35755.74969$ eV

$p = E/c = 35.755\,74969$ keV/c

1. Atom absorbs the emitted photon

$\lambda_{absorb} = 203 \times 10^{-9}\ m$

$\lambda_{emit} = 540 \times 10^{-9}\ m$

$hf = \Delta E = E_{high} - E_{low}$

$hc/\lambda = \left[-me^4/(8\varepsilon_0^2 h^3)\right]\left[\frac{1}{n_{high}^2} - \frac{1}{n_{low}^2}\right]$

$1/\lambda = R\left(\frac{1}{n_{lo}^2} - \frac{1}{n_{hi}^2}\right)$ $\quad R = 1.097373 \times 10^7\ m^{-1}$

$\Delta E = h(f_{high} - f_{low})$

$= h\left(\frac{c}{\lambda_{low}} - \frac{c}{\lambda_{high}}\right)$

$= hc\left(\frac{1}{\lambda_{low}} - \frac{1}{\lambda_{high}}\right)$

$= hc\left(\frac{1}{203} - \frac{1}{540}\right) \times 10^9\ eV = 3.815525126\ eV$

8. Where (n, l, m_l, m_s).

$e_1 = (1, 0, 0, 1/2)$.

$e_2 = (1, 0, 0, -1/2)$.

$e_3 : (2, 0, 0, \pm 1/2), (2, 1, \{-1, 0, 1\}, \pm 1/2)$

for $n = 1$: $l = 0$, $m_l = 0$, $m_s = \{1/2, -1/2\}$

for 3 electrons: $1s^2$, $2s^1$

For $2s^1$: $n = 2$, $l = \{0, 1\}$, $m_l = \{-1, 0, 1\}$

for lowest energy subshell: $l = 0$, $m_l = 0$

for higher energy subshell: $l = 1$, $m_l = \{-1, 0, 1\}$ and $m_s = \{1/2, -1/2\}$ in all cases

3. $T_{1/2} = \ln 2/\lambda = \tau \ln 2 = 5.27\ y$

$^{60}C_0 \rightarrow {}^{60}Ni + 2\,^0\gamma$

$E_\gamma = 1.2\ MeV$

$A = 5000\ Ci$

$\lambda = \ln 2/(5.27\ y)$

$1\ Ci = 3.7 \times 10^{10}\ Bq$ or $decay/s$

$A = 5000(3.7 \times 10^{10}\ decay/s)$

$= 1.85 \times 10^{14}\ decay/s$

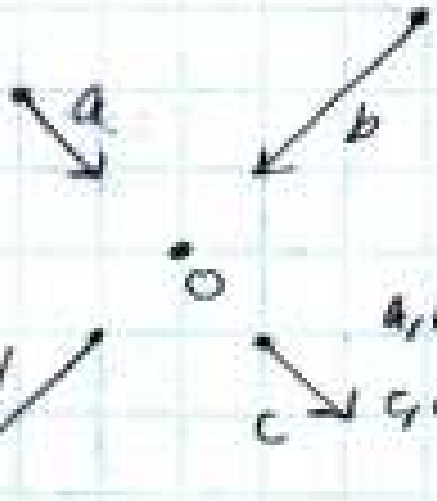
$\lambda = 4.1706\,9 \times 10^{-9}\ s$

$N = N_0 e^{-\lambda t}$

$A = \lambda N$

$N = A/\lambda = 4.435713\,32 \times 10^{22}$

1.



$v_a = v_b < v_c = v_d$

$f_a = f_b = f_c = f_d = f_0$

a, b: $f = f_0\sqrt{1+\beta^2}$

c, d: $f = f_0\sqrt{1-\beta^2}$

$b > a > c > d$

2. $\Delta t_s = 2.4)69\ \mu s$, $\beta_s = 0$

$\Delta t_m = 13.990\ \mu s$, $\Delta t_{0s} = \Delta t_{0m}$

$\Delta t = \Delta t_0/\sqrt{1-\beta^2}$

$\Delta t_0 = \Delta t\sqrt{1-\beta^2}$

$\Delta t_s\sqrt{1-\beta_s^2} = \Delta t_m\sqrt{1-\beta_m^2}$

$\beta_m = \sqrt{-(\Delta t_s/\Delta t_m)^2+1}$

$= \sqrt{-(2.4)69/13.990)^2+1} = 0.9842$

3. $\gamma = 1/\sqrt{1-\beta^2}$; $\beta = \sqrt{-(1/\gamma^2)+1}$

a. $\gamma = 1.031941\,9$; $\beta = 0.2468)\,08$

b. $\gamma = 7.548\,1863$; $\beta = 0.9911)\,043$

c. $\gamma = 109.)340$; $\beta = 0.999\,9584\,8$

d. $\gamma = 1405.0946$; $\beta = 0.999999\,9)46)$

1. $L_0 = 121\ m$, $v = 0.600c$, $\beta = 0.600$

a. $L = L_0\sqrt{1-\beta^2}$

$= (121\ m)\sqrt{1-(0.600)^2} = 96.8\ m$

b. $L = v\,\Delta t_0$, $v = \beta c = 1)98)54)4.8\ m/s$

$\Delta t_0 = L/v = 5.381\,500\,)36 \times 10^{-7}\ s$

7. $T_{1/2} = 30.2\,y$

$m_{Cs} = 136.9071u$, $m_{Ba} = 136.9058u$

$Q = -\Delta m c^2$; $c^2 = 931.4943\ MeV/u$

$= 1.21\ MeV$

8. $m = 5.90\,g = 0.0059\,kg$

$R = 63.1\ decay/min$

$R_0 = 15.3\ decay/(min \cdot g)$

$R/m = 10.6949\ decay/(min \cdot g)$

$T_{1/2} = 5730\,y = 3.0168 \times 10^9\,min$

$\lambda = 2.30152586 \times 10^{-10}\,min^{-1}$

$t = -\ln(R/R_0)/\lambda = 1555985986\,min$

4. $q = 2e = 3.204 \times 10^{-19} C$

$m = 4u = 4 \times 1.6605 \times 10^{-27} kg$

$r = 4.67 cm = 0.0467 m$

$B = 1.52 T$

$F_c = m\frac{v^2}{r} = qvB$

$v = qBr/m$

$= (3.204 \times 10^{-19} C)(1.52 T)(0.0467 m)/(6.642 \times 10^{-27} kg)$

$= 34241.60439 \, m/s$ (a)

$T = 2\pi r/v = 8.569 \times 10^{-8} s$ (b)

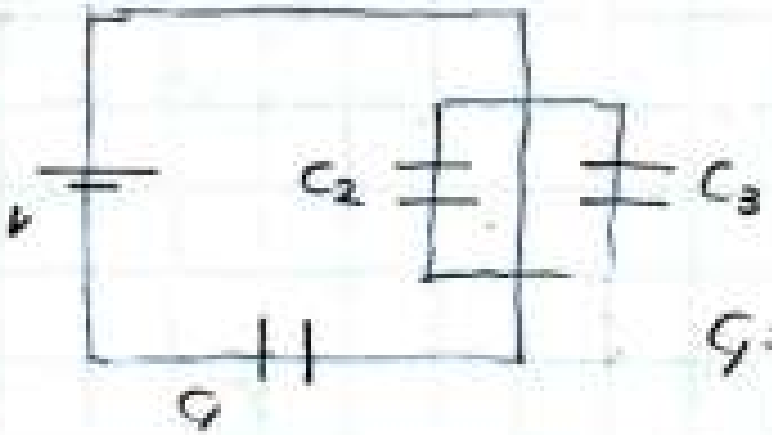
$K = \frac{1}{2}mv^2 = 3.894 \times 10^{-14} J = 243060.6 eV$ (c)

$m = (qr^2/2V)B^2 \; ; \; V = (qr^2/2m)B^2$

$V = [(1.602 \times 10^{-19} C)(0.046 m)^2/2(6.642 \times 10^{-27} kg)](1.52 T)^2$

$= 60165.15 V$ (d)

8.



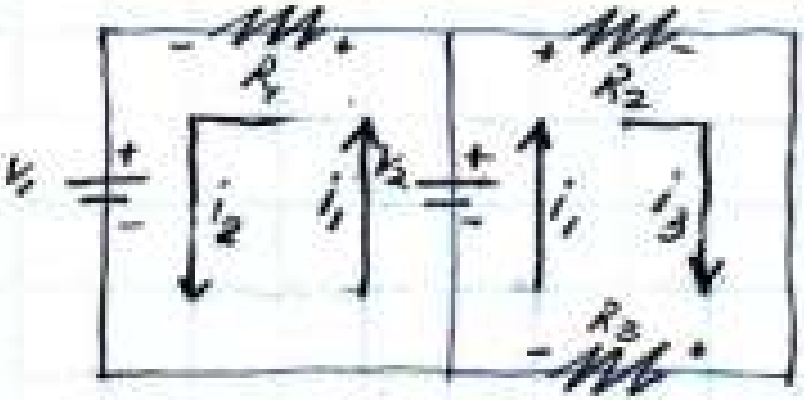
$V = 100\,F$

$C_1 = C_2 = C_3 = 1\,\mu F$

$C_{23} = C_2 + C_3 = 2\,\mu F$

$C_{123} = \left(\frac{1}{C_1} + \frac{1}{C_{23}}\right)^{-1} \approx 0.67\,\mu F$

9.



$V_1 = 3V, \quad V_2 = 5V$

$R_1 = 10\Omega, R_2 = 15\Omega, R_3 = 20\Omega$

$i_1' = i_2' + i_3'$

① $5V - 10\Omega\, i_2 - 3V = 0$

② $5V - 15\Omega\, i_3 - 20\Omega\, i_3 = 0$

① $2V / 10\Omega = i_2 = 0.2A$

② $5V / 35\Omega = i_3 = 0.1429A$

$i_1 = 0.2A + 0.1429A = 0.3429A$

8. $P = 1130\ W$

$V = 115\ V$

$I = P/V$

$= 1130\ W / 115\ V = 9.826\ A$ (a)

$R = V^2/P$

$= (115\ V)^2 / (1130\ W) = 11.7\ \Omega$ (b)

$P = dE/dt$

$dt = 3.55\ h = 12780\ s$

$dE = P\ dt$

$= (1130\ W)(12780\ s)$

$= 14441400\ J$ (c)

9. $P = 160\ W = 0.160\ kW$

$V = 120\ V$

$t = 31\ d = 2678400\ s = 744\ h$

$C = \$0.08/(kW \cdot h)$

$C(P(t)) = \$0.08/(kW \cdot h) \cdot P \cdot t$

$C(P(t)) = (\$0.08/(kW \cdot h))(0.160\ kW)(744\ h)$

$= \$4.52$ (a)

$R = V^2/P = (120\ V)^2/(160\ W) = 90\ \Omega$ (b)

$I = P/V = (160\ W)/(120\ V) = 1.33\ A$ (c)

12. $\mathcal{E} = 12\,V$

$R = 1.13\,M\Omega = 1.13 \times 10^6\,\Omega$

$C = 2.03\,\mu F = (2.03 \times 10^{-6})\,F$

$\mathcal{E} - IR - q/C = 0$

$\tau = RC$

$= (1.13 \times 10^6\,\Omega)(2.03 \times 10^{-6}\,F) = 2.294\,s$

$q_{max} = CV_0 = (2.03 \times 10^{-6}\,F)(12V) = 2.436 \times 10^{-5}\,C$

$V = [1 - e^{(-t/RC)}]V_0$; $t =$

$V = [1 - e^{(-t/2.634)}]12\ V$

$q = CV$; $q = 13.7\,\mu C$

$13.7\,\mu C = (2.03 \times 10^{-6}\,F)(1 - e^{(-t/2.294s)})12\,V$

$.56239 = 1 - e^{(-t/2.294s)}$

$e^{(-t/2.294s)} = 0.4376$

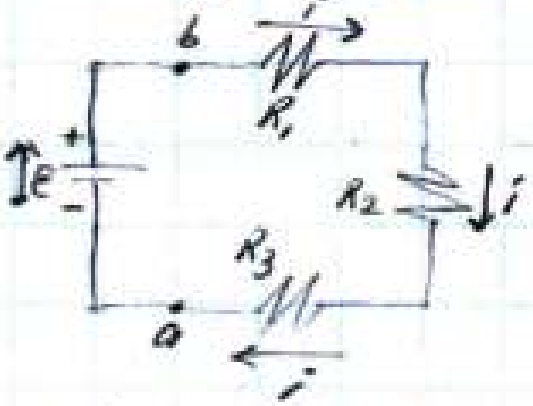
$-t/2.294\,s = \ln(0.4376)$

$t = -(2.294\,s)\ln(0.4376)$

$= 1.8959\,s$

13. $\mathcal{E} = 15.1\,V$

$R_1 = 3.84\,\Omega \quad R_2 = 5.42\,\Omega \quad R_3 = 4.22\,\Omega$



$R_{eq} = R_1 + R_2 + R_3 = 13.48\,\Omega$

$\mathcal{E} = IR$; $I = \mathcal{E}/R = 1.12\,A$

$V_2 = IR_2 = (1.12A)(5.42\,\Omega) = 6.07\,V$