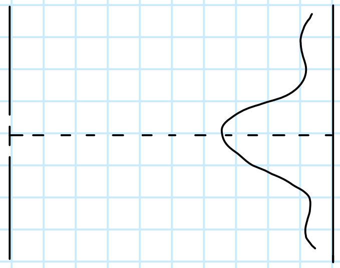
Problem 1

a.



Double Slit, constructive interference
$\longrightarrow m\lambda = d\sin\theta$

$$\lambda = \frac{d\sin\theta}{m} = \frac{(0.01\cdot10^{-3}m)\sin 10.95°}{3}$$

$$= 6.33\cdot10^{-7}m$$

$$\boxed{\lambda = 633\ nm}$$

b. The number of bright fringes is $2m_{max}+1$. We can find m_{max} by looking at what order m we get at $\theta = 90°$

$$m_{max}\lambda = d\,\cancel{\sin 90}^{\,1} \Rightarrow m_{max} = \frac{d}{\lambda} = \frac{0.01\cdot10^{-3}m}{6.33\cdot10^{-7}m} = 15.8$$

We can see the $m=15$ bright spot, but not the $m=16$ ones. We must round down here so that

$$m_{max} = 15$$

Then

$$\#\text{bright spots} = 2(15)+1 = \boxed{31\ \text{bright spots}}$$

c. Single Slit, destructive interference
$\longrightarrow p\lambda = a\sin\theta$

We know $p=3$ is at $10.95°$. The laser wavelength was found above. Then

$$a = \frac{p\lambda}{\sin\theta} = \frac{3(6.33\cdot10^{-7})m}{\sin(10.95)} \approx 1.00\cdot10^{-5} = \boxed{0.01\ mm = a}$$

d. Let's start by finding p_{max}.

$$p_{max} = \frac{a\sin 90}{\lambda} = \frac{0.01\cdot10^{-3}m}{6.33\cdot10^{-7}m} = 15.8 \xRightarrow{\text{round down}} p_{max} = 15$$

We have $2p_{max} = 2(15) = 30$ total dark fringes. There is one bright spot between two dim spots. This means

$$\#\text{bright spots} = 2p_{max} - \underset{\text{central spot}}{1} = 2(15)-1 = \boxed{29\ \text{bright spots}}$$

e. Diffraction grating, constructive interference
$\longrightarrow m\lambda = D\sin\theta$

At $m=0$, we get white light. For every other value of m, our light spreads out. We can find y_{violet} and y_{red} using the relationship $\quad 0 \quad$. We need to find at what angle the violet/red maxima are at.

$m\lambda = D\sin\theta$
$\sin\theta = \frac{m\lambda}{D}$
$\tan - - = y_m/L$
$\theta = \sin^{-1}\left(\frac{m\lambda}{D}\right)$

$D = 10{,}000$ slits/cm

$$\frac{0.01m}{10{,}000\ \text{slits}} = \frac{1\cdot10^{-2}}{1\cdot10^{4}} = 1\cdot10^{-6}\ m/\text{slit}$$

$\Rightarrow$ Slits are $1\mu m$ apart

For violet then at $m=1$,

$$\theta_v = \sin^{-1}\left(\frac{\lambda_v}{D}\right) = \sin^{-1}\left(\frac{380\cdot10^{-9}m}{1\cdot10^{-6}m}\right) = 22.33°$$

For red at $m=1$,

$$\theta_r = \sin^{-1}\left(\frac{\lambda_r}{D}\right) = \sin^{-1}\left(\frac{760\cdot10^{-9}m}{1\cdot10^{-6}m}\right) = 49.46°$$

* As expected, the red light is farther from the central maximum

Problem 1

e. Now we can use $\tan\theta = Y/L$.

$$Y_{1,v} = L \tan\theta_v$$

$$Y_{1,r} = L \tan\theta_r$$

$$\Rightarrow \quad Y_{1,r} - Y_{1,v} = L(\tan\theta_r - \tan\theta_v)$$

$$= (1.5\,m)(\tan 49.46 - \tan 22.33)$$

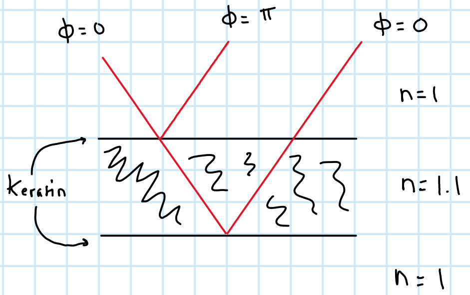
$$= 1.5m\,(0.758)$$

$$= \boxed{1.14m}$$

ight
Central

Problem 2

This problem's interpretation may be difficult. The keratin merely separates the substance in the wings from the air. The keratin acts only as a boundary between the substance with n=1.1 and air. This isn't super clear in the problem statement.



The light has a relative phase shift, so for constructive interference,

$$(m+1/2)\lambda_{film} = 2t$$

We choose m=1 to get λ film. Now

$$\lambda_{film} = \frac{2t}{(3/2)} = \frac{2(275 \cdot 10^{-9}\,m)}{3/2} = 3.66 \cdot 10^{-7}\ m$$

$$= 366\ nm = \lambda_{film}$$

Now we need the wavelength in air

$$\lambda_{film} = \frac{\lambda_{air}}{n_{film}}$$

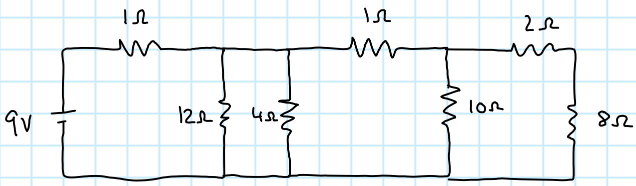
$$366\ nm = \frac{\lambda_{air}}{1.1} \Rightarrow \lambda_{air} = 1.1(366nm) = \boxed{403\ nm = \lambda}$$

b. This is a violet color!

ight
Central

Problem 3

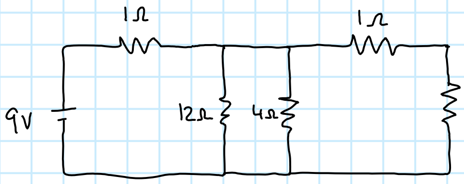
a. Original Circuit



Let's combine things right to left. The 2Ω and 8Ω resistors are in series.

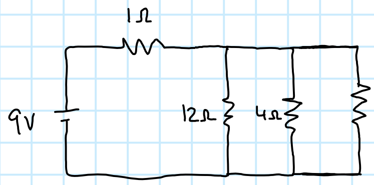
$R = 2\Omega + 8\Omega = 10\Omega$

The new equivalent resistor is 10Ω. This is in parallel with the other 10Ω resistor.



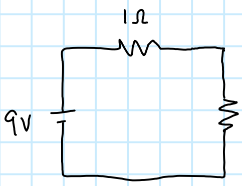
$R = \left(\frac{1}{10\Omega} + \frac{1}{10\Omega}\right)^{-1} = 5\Omega$

The 1Ω and new 5Ω resistors are in series



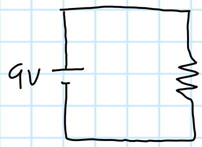
$R = 1\Omega + 5\Omega = 6\Omega$

We now have the 12Ω, 4Ω, and 3Ω resistors in parallel



$R = \left(\frac{1}{12\Omega} + \frac{1}{4\Omega} + \frac{1}{6\Omega}\right)^{-1} = 2\Omega$

The final two resistors are in series



$R = 1\Omega + 2\Omega = 3\Omega$

$\boxed{\text{The equivalent resistance is } 3\Omega}$

b. First, let's find the total current drawn by the circuit.

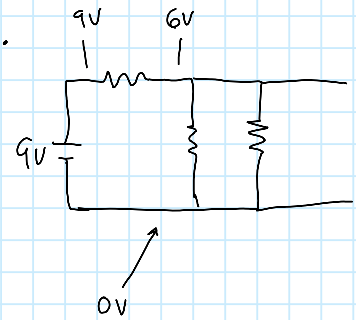
$$V = IR \Rightarrow \quad I = \frac{V}{R} = \frac{9V}{3\Omega} = 3A$$

The 4Ω resistor and 12Ω resistor will have the same ΔV. There is a resistor between the battery and the 12Ω/4Ω resistors. We need to know the voltage after the 1Ω resistor. The current going into the resistor is 3A.

$$V = IR \Rightarrow \quad V = (3A)(1\Omega) = 3V$$

Problem 3

b.

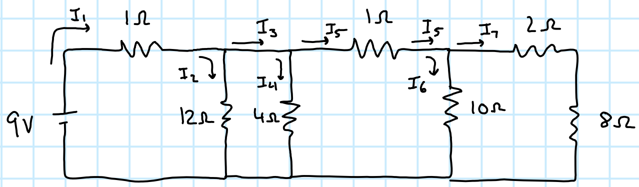


The voltage drops by 3V after the 1Ω resistor

There is a 6V drop over the 4Ω resistor (6V to 0V)

$$P = V^2/R = (6V)^2/4\Omega = \boxed{9W = P}$$

c. We will need to do this the boring way !!



We want to find I_7

$I_1 = 3A$

$6V = I_2(12\Omega) \Rightarrow I_2 = \frac{6V}{12\Omega} = 0.5\text{ A}$

$I_1 = I_2 + I_3 \Rightarrow 3A = 0.5A + I_3 \Rightarrow I_3 = 2.5A$

$I_4 = \frac{6V}{4\Omega} = 1.5A$ 6V bc parallel w/ 12Ω resistor

$I_3 = I_4 + I_5 \Rightarrow 2.5A = 1.5A + I_5 \Rightarrow I_5 = 1A$

We need to find I_6. If we know the voltage drop across the 10Ω resistor, we can use Ohm's law.

Let's start by finding the voltage drop across the 1Ω resistor.

$$V = IR \Rightarrow (1A)(1\Omega) = 1V$$

The voltage after the 1Ω resistor is then 5V. Now the current going through the 10Ω resistor is

$$I = \frac{5V}{10\Omega} = 0.5A$$

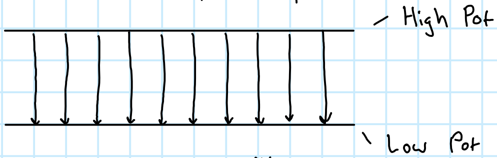
Now then $I_5 = I_6 + I_7$.

$$I_7 = I_5 - I_6 = 1A - 0.5A = 0.5A$$

The current going through the 2Ω resistor is $\boxed{0.5A}$

Problem 4

a. This is like a parallel plate capacitor



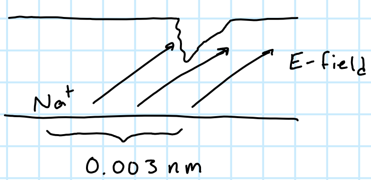
A positive charge goes from the high potential to the low potential. Electric field lines point in the direction a positive charge would travel.

b. We know that $|E| = \Delta V / d$, so

$$|E| = \frac{50 \cdot 10^{-3}\,V}{53.4 \cdot 10^{-6}\,m} = 936.32\ V/m$$

$$\vec{E} = 936.32\ V/m \langle 0, 1 \rangle \quad \text{(only in y-direction)}$$

c. I forgot to include a diagram. Whoops!



$V_i = 0\ m/s$

charge of Na^+ is e

$$F = qE \Rightarrow F_x = qE_x = (1.602 \cdot 10^{-19}\,C)\underbrace{(940\ V/m)(1/\sqrt{2})}_{E_x} = 1.06 \cdot 10^{-16}\,N$$

$$F = ma \Rightarrow a = F/m = (1.06 \cdot 10^{-16}\,N)/(3.817 \cdot 10^{-26}\,kg) = 2.7 \cdot 10^{9}\ m/s^2$$

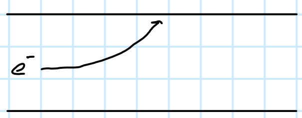
$$\Delta x = \cancel{v_0 t}^{\,0} + \frac{1}{2} a t^2$$

$$t = \sqrt{\frac{2\Delta x}{a}} = \sqrt{\frac{2(0.003 \cdot 10^{-9})\,m}{2.7 \cdot 10^{9}\,m/s^2}} = \boxed{2.18 \cdot 10^{-21}\ s}$$

That's really fast...

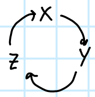
Problem 5

a.



* You need an initial velocity here which I forgot to give. Let's say $V_i = 1200$ m/s in the x- direction

The electron must feel a force going up, so if $\vec{F} = q\vec{v} \times \vec{B}$ and $\vec{F}$ is in the $\hat{y}$ direction and v is in the $\hat{x}$ direction we have $\hat{y} = -\hat{x} \times ?$. The direction of the $\vec{B}$ field must be in the $\hat{z}$ direction



$\hat{x} \times \hat{y} = \hat{z}$ $\qquad$ $\hat{y} \times \hat{x} = -\hat{z}$ $\qquad$ $-\hat{y} = \hat{x} \times \hat{z}$

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$\hat{z} \times \hat{x} = \hat{y}$ $\qquad$ $\hat{z} \times \hat{y} = -\hat{x}$ $\qquad$ $\hat{y} = -\hat{x} \times \hat{z}$

b. $F = q\vec{v} \times \vec{B} = ma \Rightarrow a = \dfrac{q\vec{v} \times \vec{B}}{m} = q|\vec{v}||\vec{B}| \sin\theta$ $\quad$ here $\theta = 90°$ (angle between V and B)

$$a = \frac{(1.602 \cdot 10^{-16}\,C)(1200\,m/s)(1 \cdot 10^{-6}\,T)}{(9.11 \cdot 10^{-31}\,kg)} = 2.11 \cdot 10^{11}\ m/s^2$$ BIG!

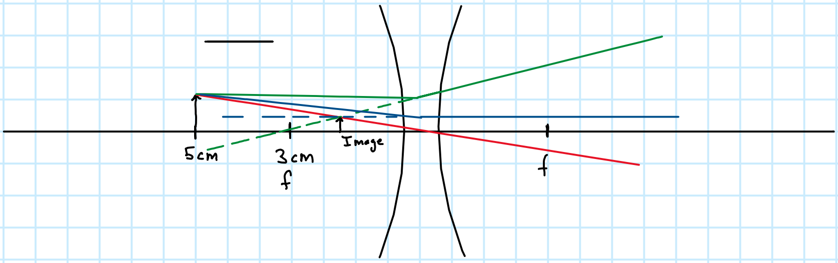
c. $V_0 = 1200$ m/s
$a = 2.11 \cdot 10^{11}\ m/s^2$
$t = 2.6$ s

$\Rightarrow \Delta x = (1200\,m/s)(2.6s) + \frac{1}{2}(2.11 \cdot 10^{11}\,m/s^2)(2.6s)^2$

$= 7.13 \cdot 10^{11}$ m $\quad$ Wow! Big! I picked bad numbers

Problem 6

a.



b. The rays had to be traced back to form an image, so this is virtual

c. We need to find the image distance

$$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o} \Rightarrow \frac{1}{f} - \frac{1}{d_o} = \frac{1}{d_i} \Rightarrow d_i = \left(\frac{1}{f} - \frac{1}{d_o}\right)^{-1} = \left(\frac{1}{-3cm} - \frac{1}{5cm}\right)^{-1} = -1.875\,cm$$

↳ f is negative for diverging lens

$$m = -\frac{d_i}{d_o} = -\frac{(-1.875)\,cm}{5\,cm} = \boxed{0.375 = m}$$

d. The magnification is 0.375, so

$$h_i = m h_o \Rightarrow h_i = (0.375)(1cm)$$

$$\boxed{h_i = 0.375}$$

Problem 7

a. No - The area isn't changing, the magnetic field isn't changing, so $\Phi_i = \Phi_f$ and $\Delta\Phi = 0$ so $\mathcal{E} = \frac{\Delta\Phi}{\Delta t} = 0$ so $V = IR \Rightarrow 0 = IR \Rightarrow I = 0$ since $R = 3.0\Omega$.

b. We need to find the flux here.

$$\begin{aligned}\Delta\Phi = \Phi_f - \Phi_i &= \vec{B}_f \cdot \vec{A} - \vec{B}_i \cdot \vec{A} \\ &= |B_f||A|\cos\theta - |B_i||A|\cos\theta \\ &= 0 - (1.6T)\pi(0.025m)^2 \\ &= -0.0031\,T\,m^2\end{aligned}$$

The flux is decreasing, so the induced magnetic field must be going into the board to minimize this change in flux.

c. $\mathcal{E} = \frac{\Delta\Phi}{\Delta t} = \frac{(-0.0031Tm^2)}{0.10s} = \boxed{-0.031\,V = \mathcal{E}}$

d. $\mathcal{E} = IR \Rightarrow -0.031\,V = I(3\Omega)$

$$I = \frac{-0.031\,V}{3\Omega} = \boxed{0.01\,A = I}$$