Pre-final online office hours?

Final Exam Review – PHY 132

Per request: lenses and mirrors and what they create

Some comprehensive examples

Some mean and horrible questions

Some oldies but goodies basics

Light of wavelength 0.65 µm passed through two slits separated by distance d=4.0 µm and creates an interference pattern that can be observed on a screen placed distance 1.3 m away. The bright fringes in the pattern are **not** equidistant.

What is the distance between **second** and **third** bright band observed on the screen?
Provide your answer in centimeters, with a precision one place after decimal.

$\sin\theta < 0.175$ $\quad\quad$ $m\lambda = d\sin\theta \rightarrow \frac{m\lambda}{d} < 0.175$

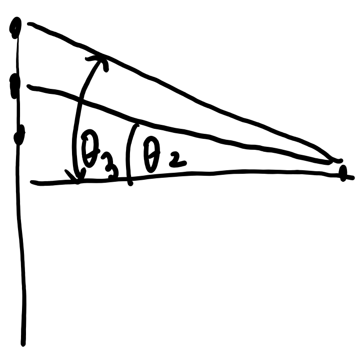
$\rightarrow$ not small angle

$d\sin\theta_2 = 2\lambda$ $\quad\quad$ $d\sin\theta_3 = 3\lambda$

$\sin\theta_2 = \frac{2\lambda}{d}$ $\quad\quad$ $\sin\theta_3 = \frac{3\lambda}{d}$

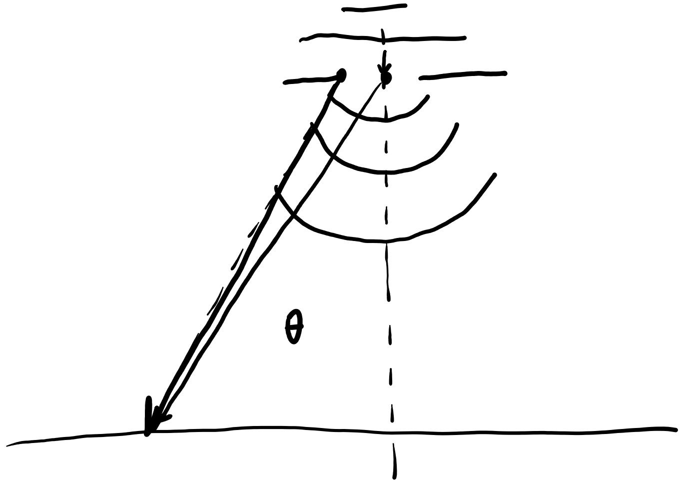
$\downarrow$ $\quad\quad$ $\downarrow$

θ_2 $\quad\quad$ θ_3



$\tan\theta_2 = \frac{y_2}{L}$ $\quad\quad$ $\tan\theta_3 = \frac{y_3}{L}$

How do you differentiate between the equations for single slit and double slit?

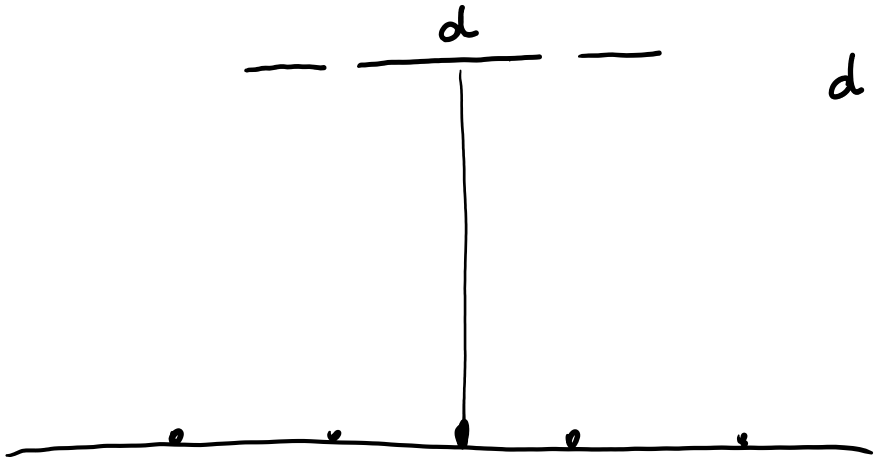


$a > \lambda$ $\quad a \rightarrow$ size of the slit

$\frac{1}{2}\lambda = \frac{a}{2}\sin\theta$

$a \sin\theta = m\lambda$

MINIMUM

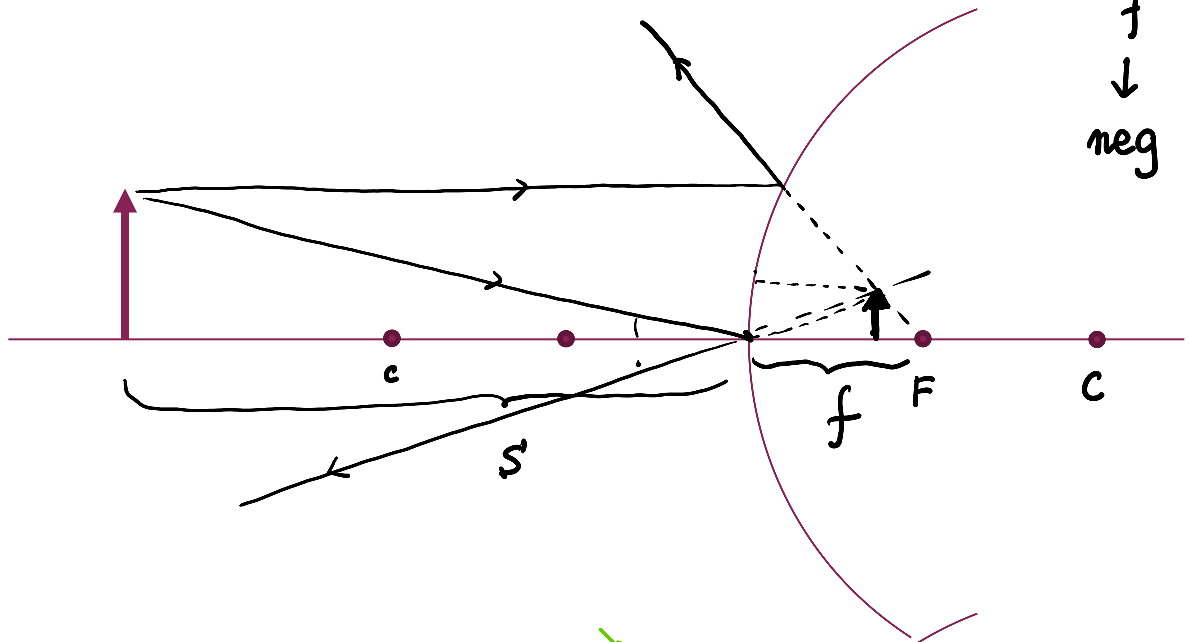


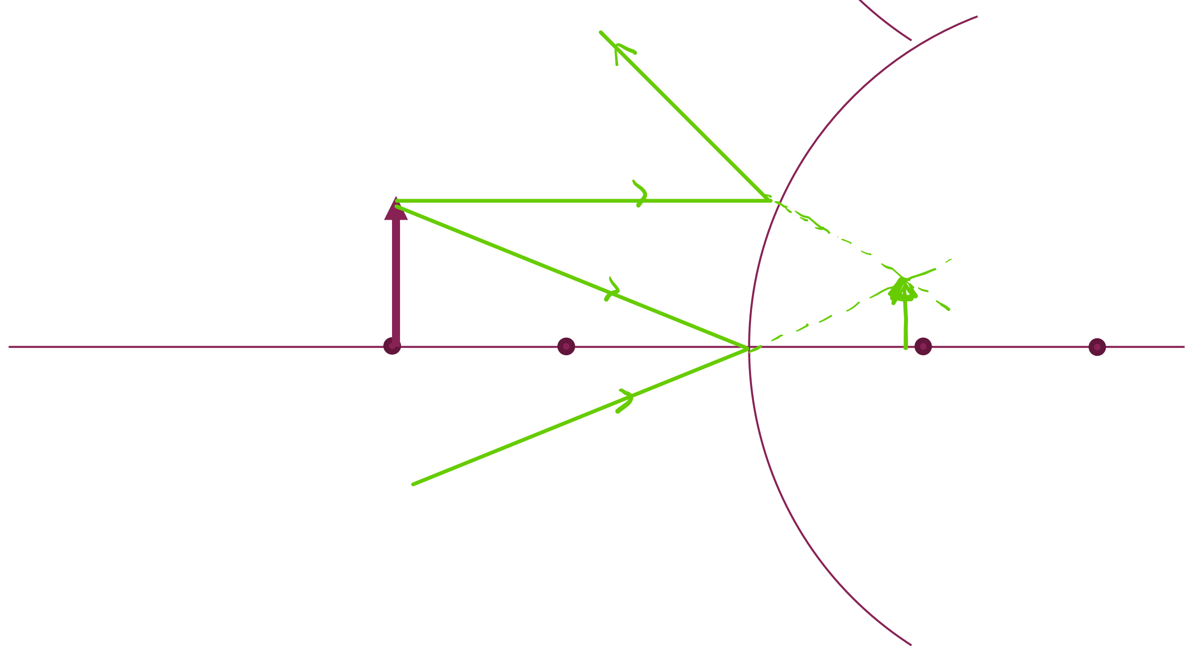
$d \sin\theta = m\lambda$

Mirrors and Lenses

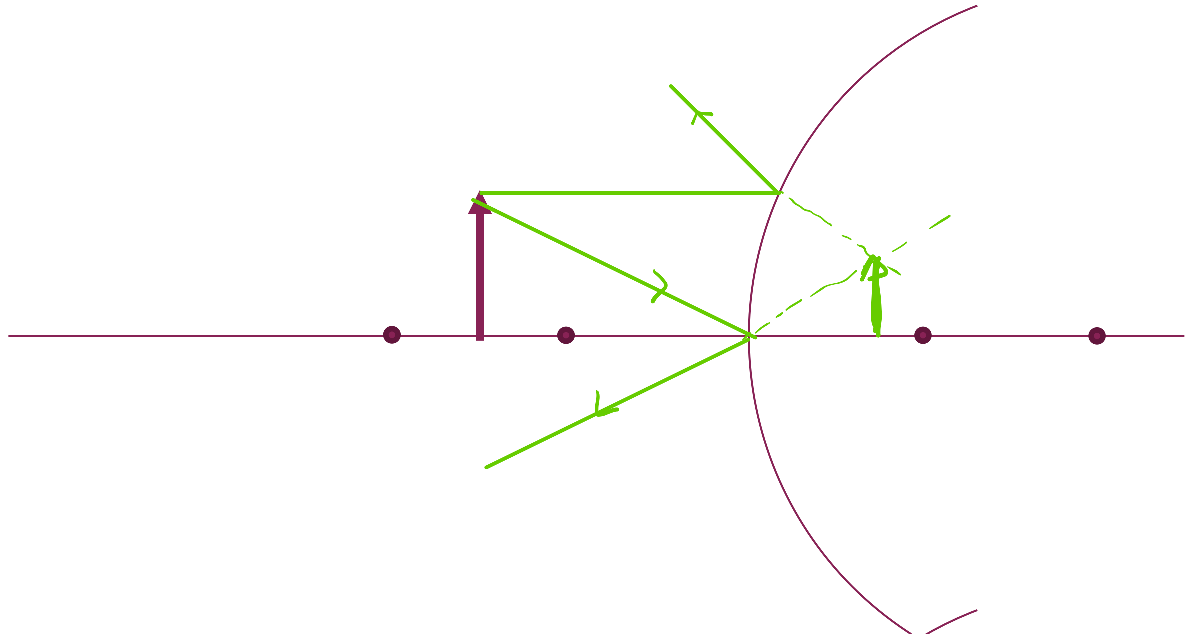
$$\frac{1}{f} = \frac{1}{s} + \frac{1}{s'}$$

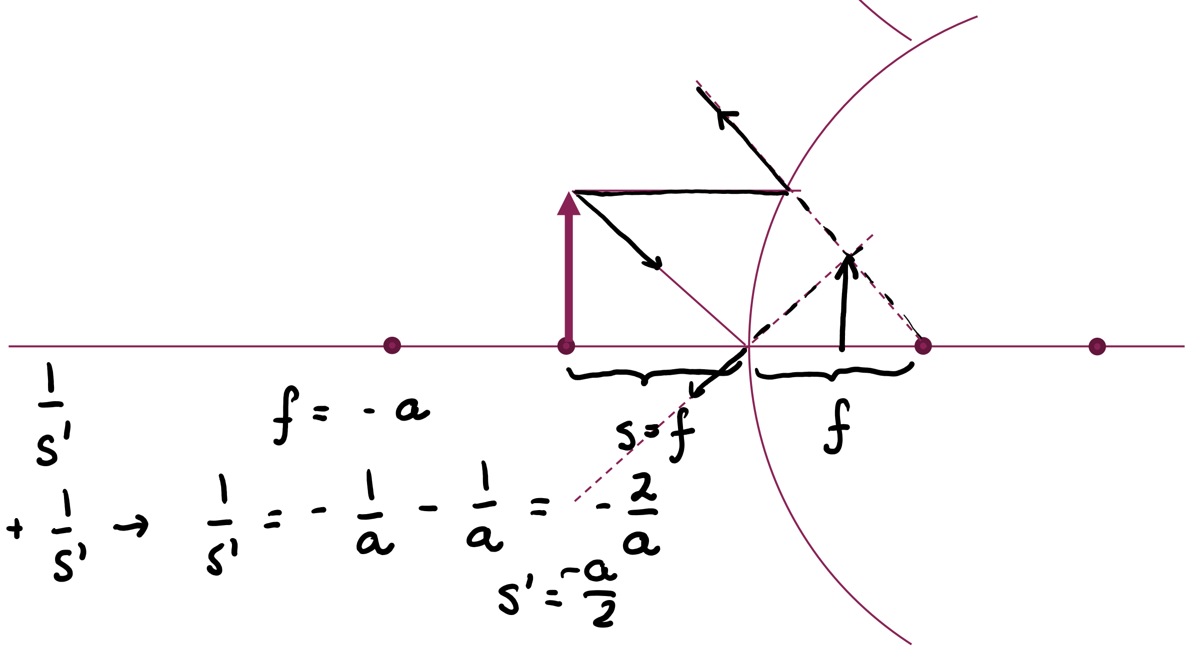
neg — positive





Mirrors and Lenses





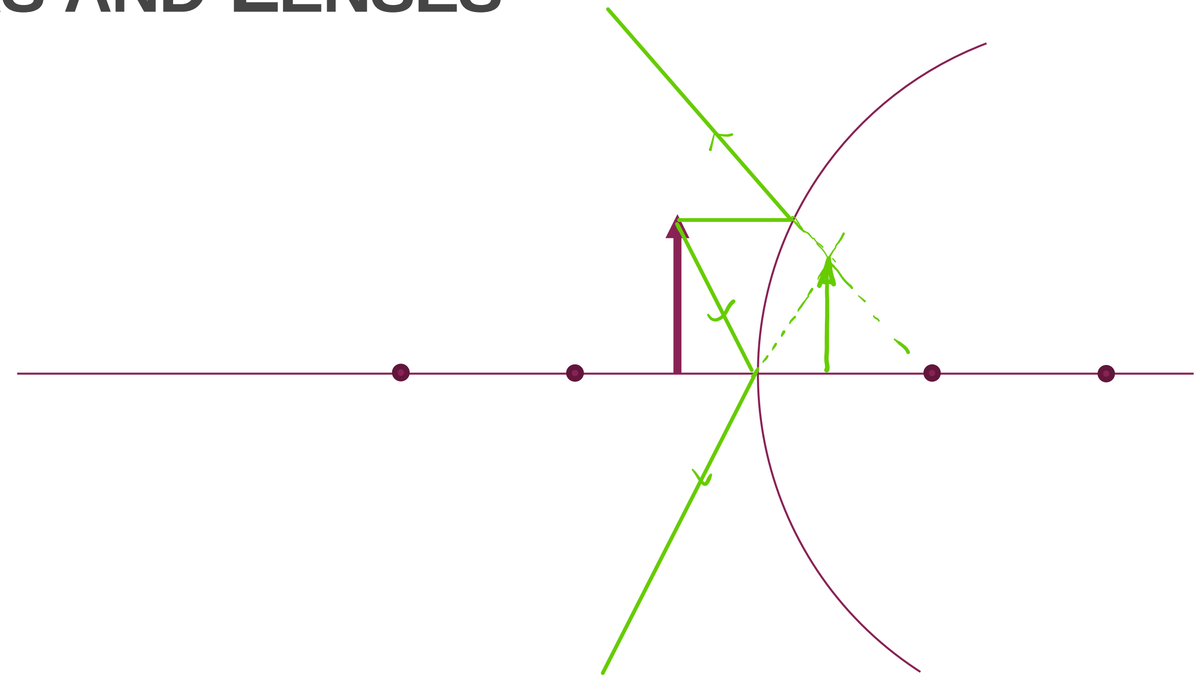
$$\frac{1}{f} = \frac{1}{s} + \frac{1}{s'}$$

$$f = -a$$

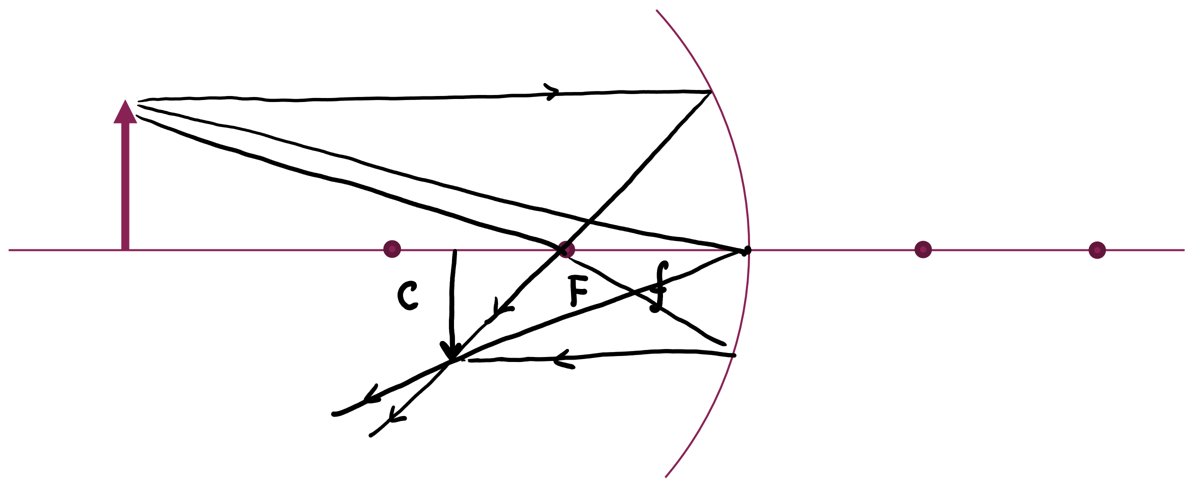
$$-\frac{1}{a} = \frac{1}{a} + \frac{1}{s'} \rightarrow \frac{1}{s'} = -\frac{1}{a} - \frac{1}{a} = -\frac{2}{a}$$

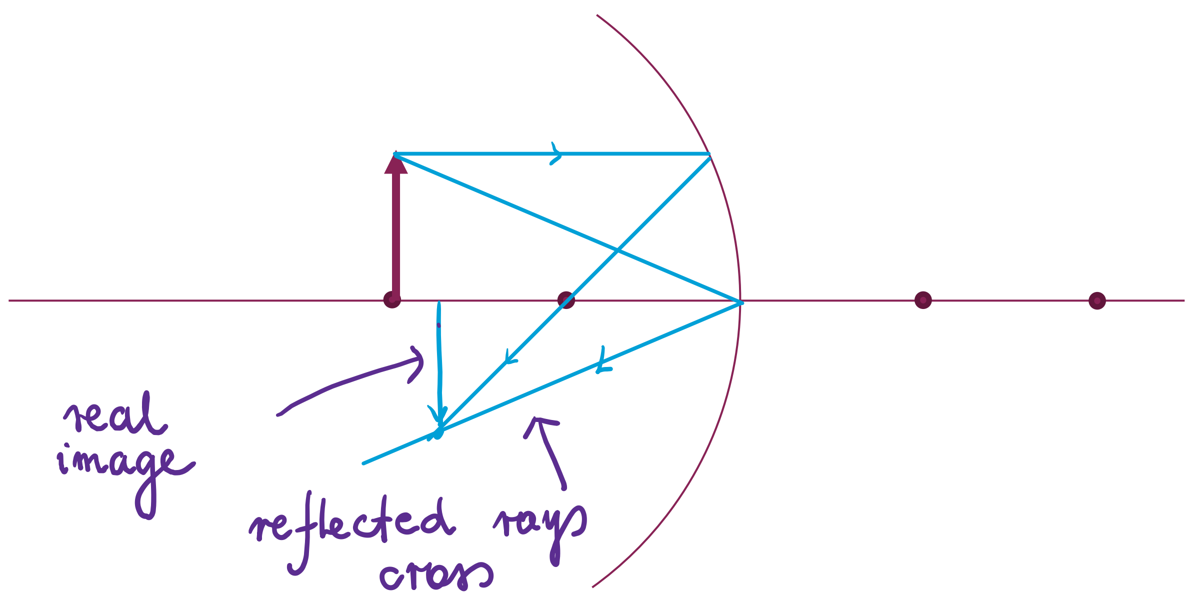
$$s' = \frac{-a}{2}$$

Mirrors and Lenses



Mirrors and Lenses





MIRRORS AND LENSES

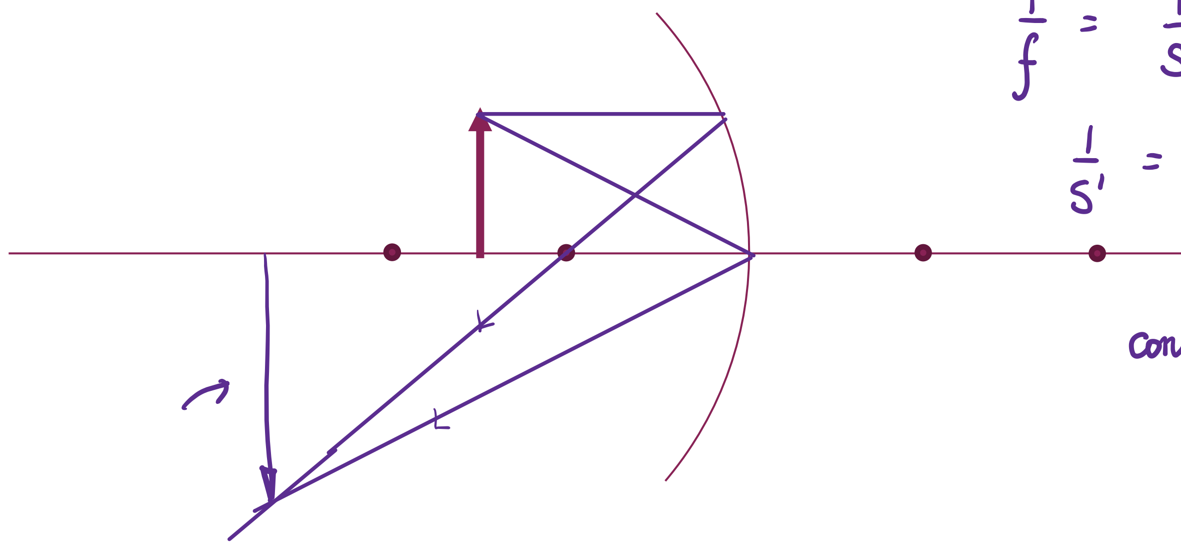
$f > 0$

$$\frac{1}{f} = \frac{1}{s} + \frac{1}{s'}$$

$$\frac{1}{s'} = \frac{1}{f} - \frac{1}{s}$$

constant

the closer it gets to f the smaller $\frac{1}{s'}$ → larger s'



real image

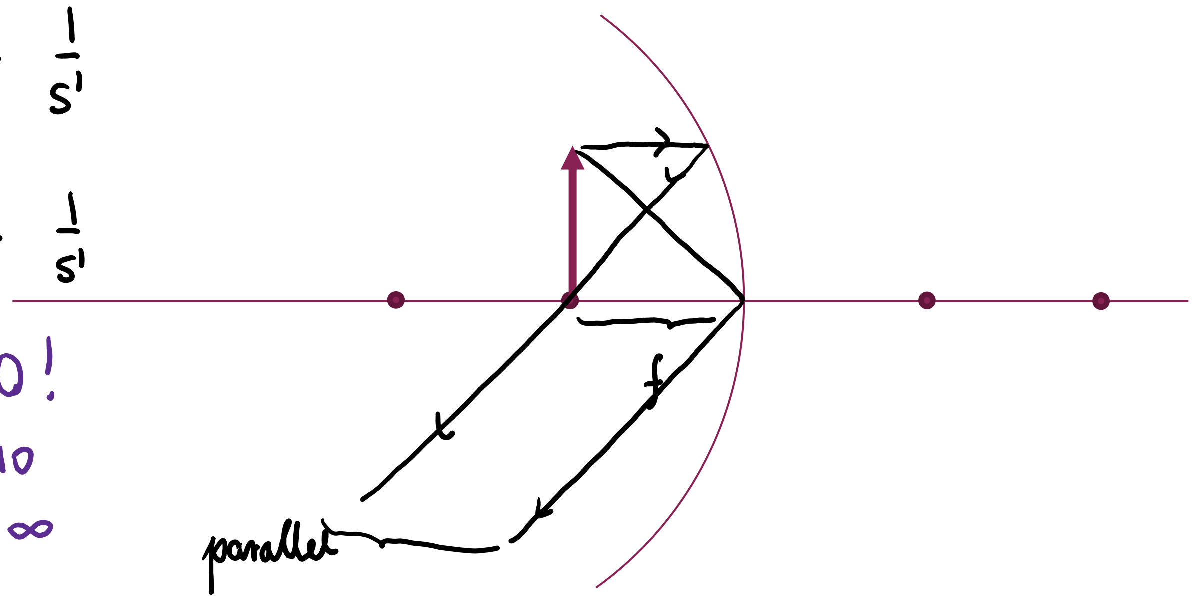
$$\frac{1}{f} = \frac{1}{s} + \frac{1}{s'}$$

$$\frac{1}{f} = \frac{1}{f} + \frac{1}{s'}$$

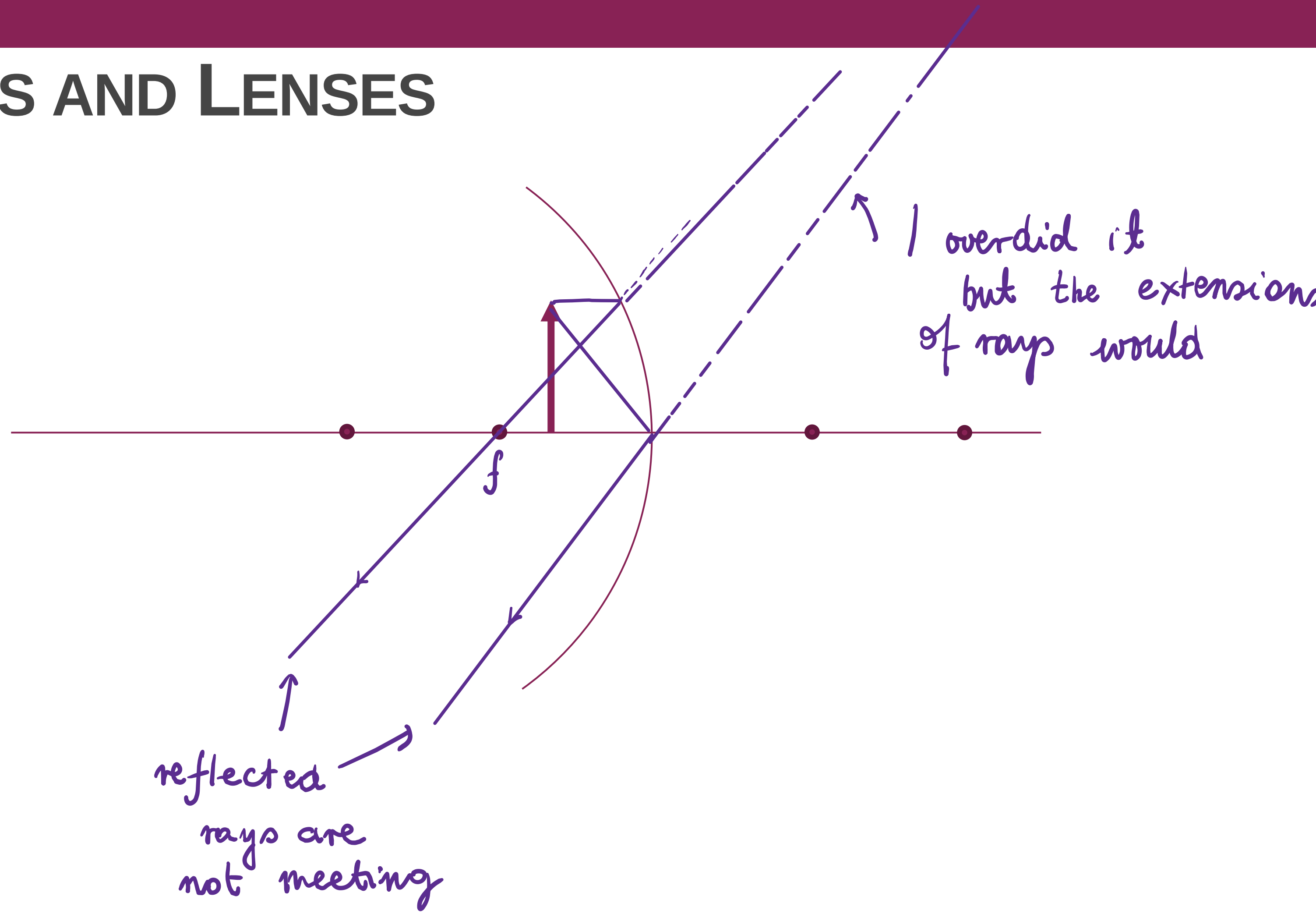
$\frac{1}{s'} = 0$!

OH NO

$s' \to \infty$

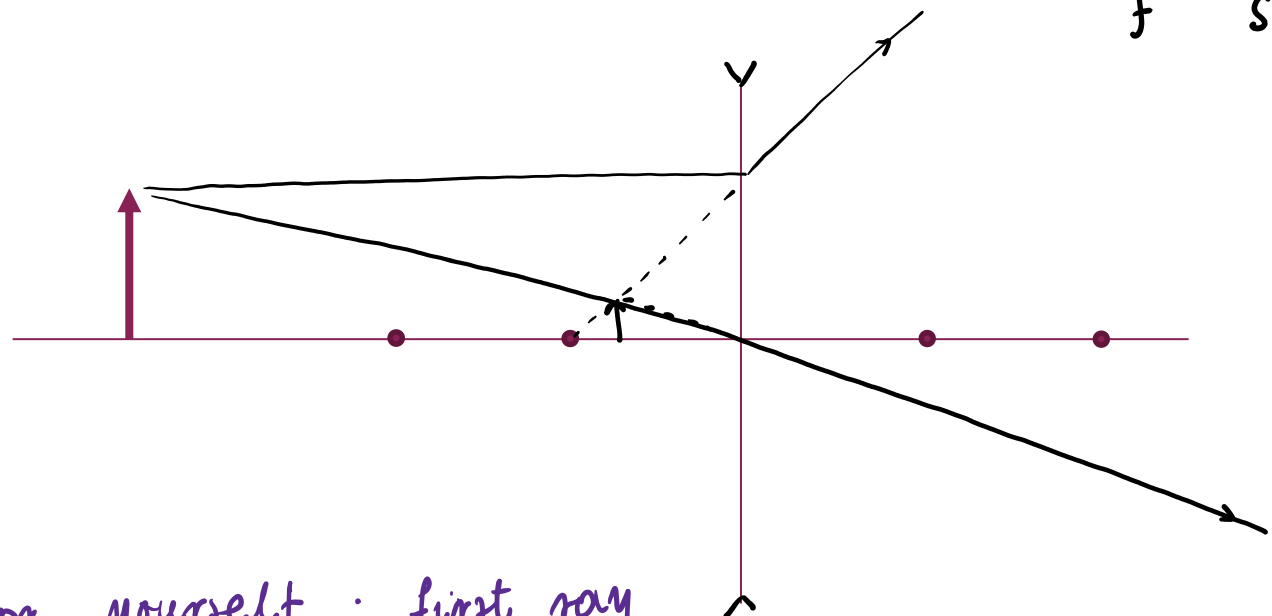


MIRRORS AND LENSES

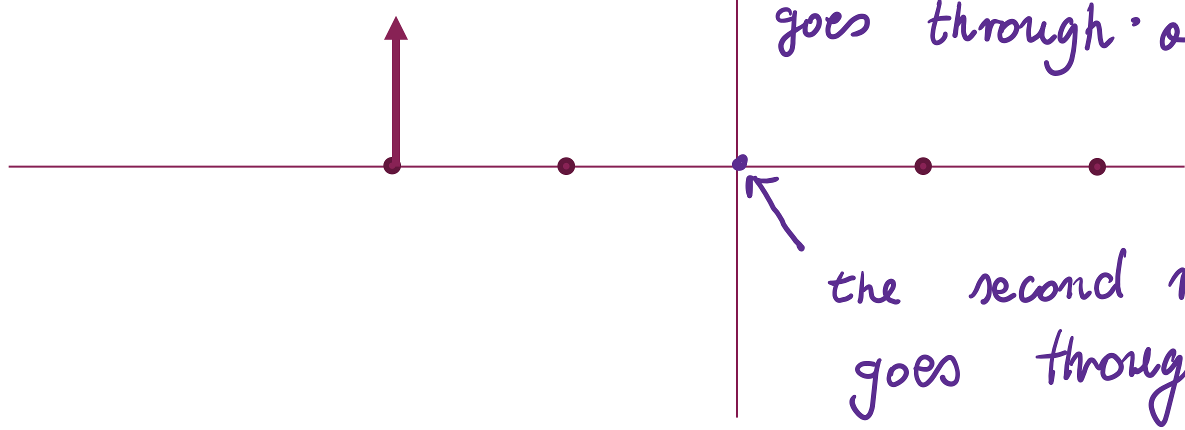


Mirrors and Lenses

$$\frac{1}{f} = \frac{1}{s} + \frac{1}{s'}$$

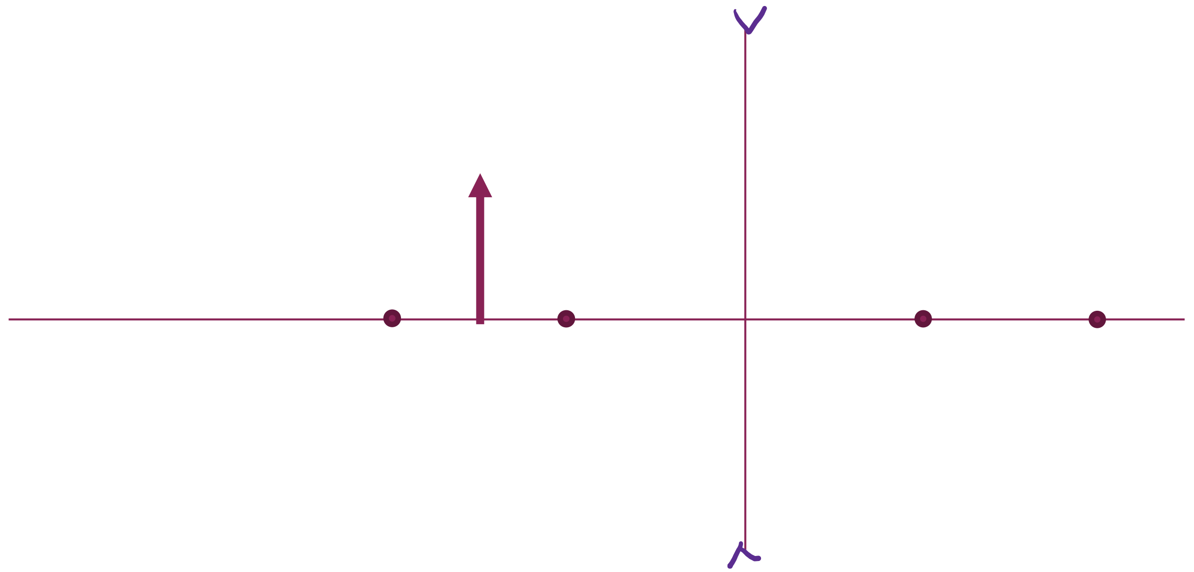


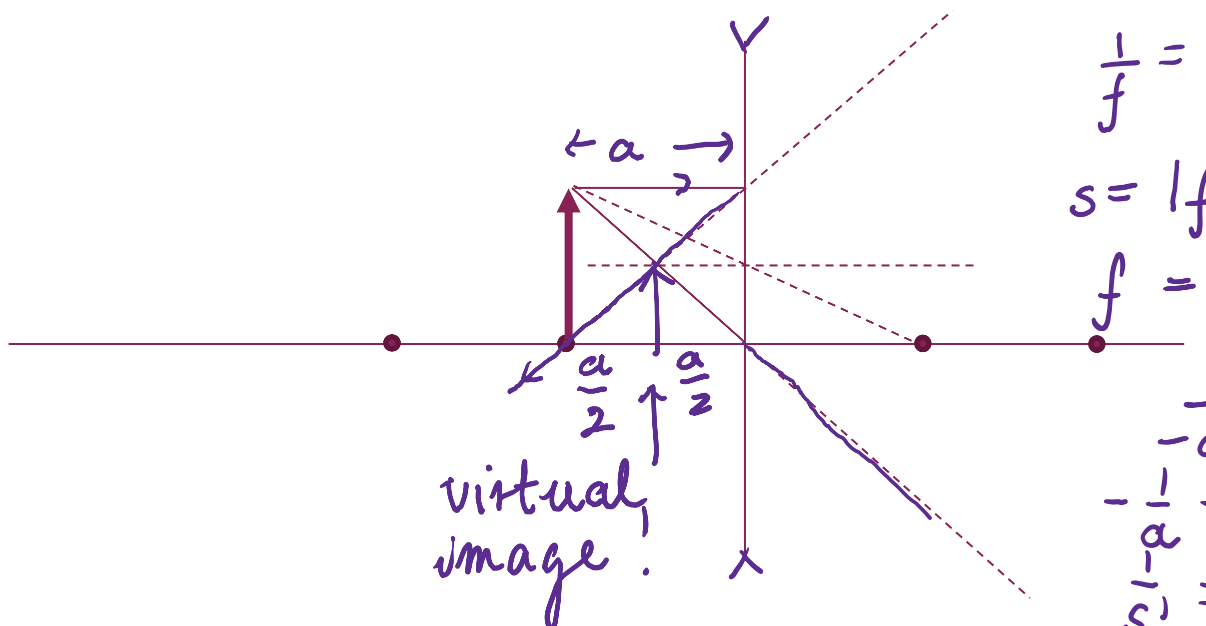
Try for yourself: first ray goes parallel to the principal axis and refracts so its extension goes through a focal point!



the second ray just goes through the central spot

Mirrors and Lenses





$$\frac{1}{f} = \frac{1}{s} + \frac{1}{s'}$$

$$s = |f| = a$$

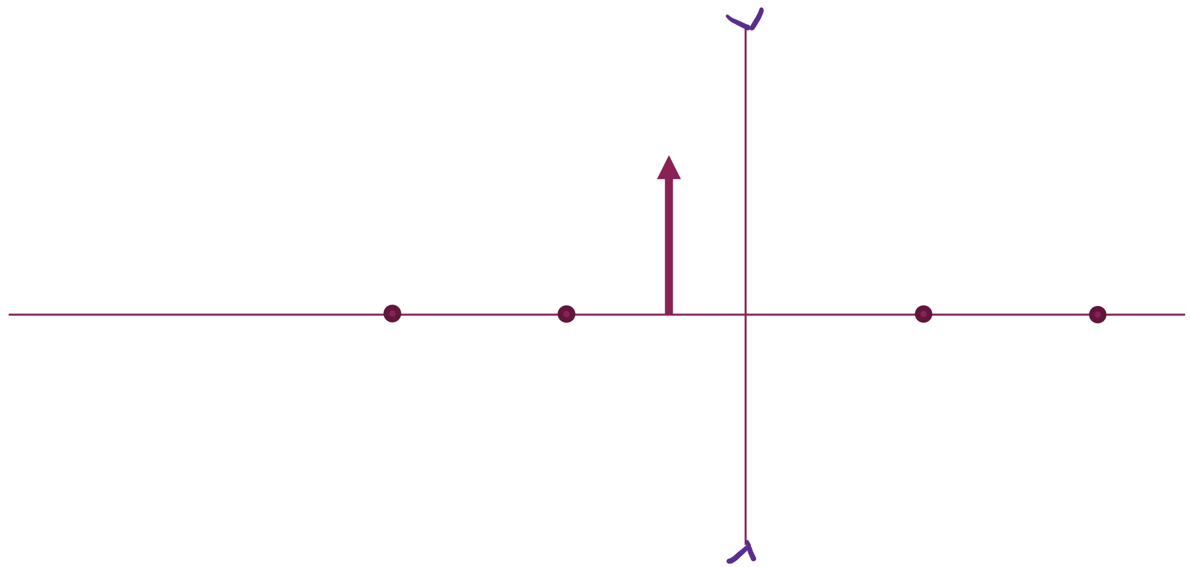
$$f = -a$$

$$\frac{1}{-a} = \frac{1}{a} + \frac{1}{s'}$$

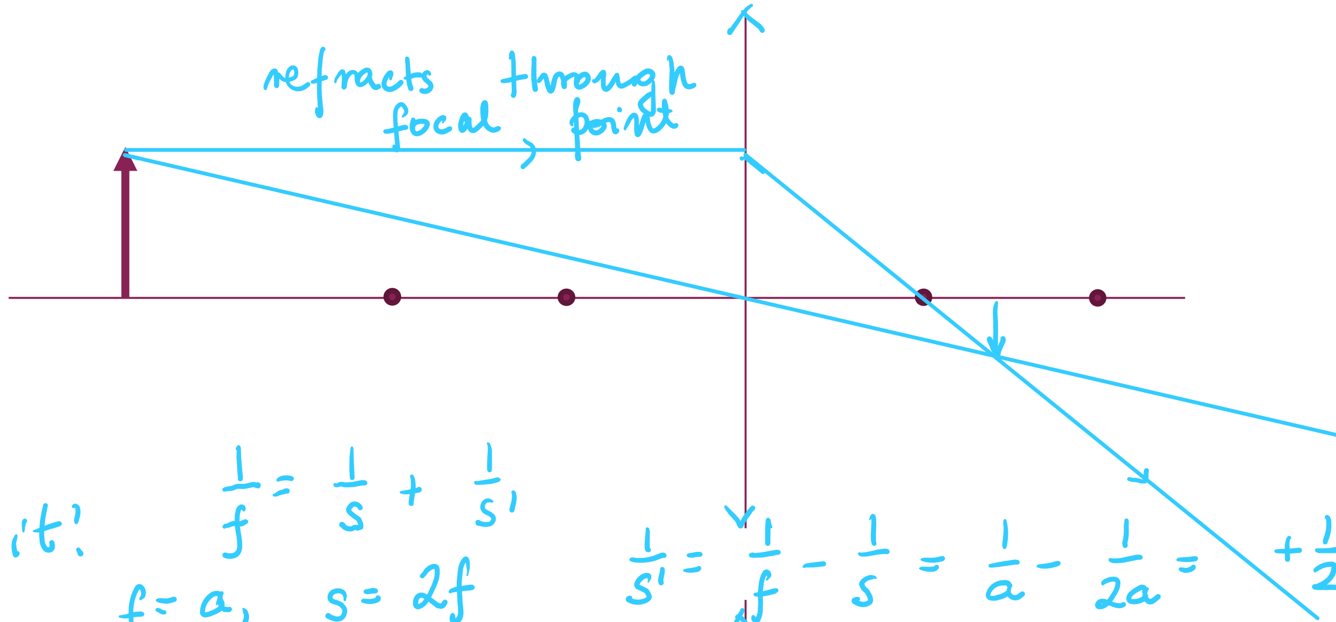
$$-\frac{1}{a} - \frac{1}{a} = \frac{1}{s'}$$

$$\frac{1}{s'} = \frac{-2}{a} \rightarrow s' = -\frac{a}{2}$$

Mirrors and Lenses



MIRRORS AND LENSES - convex lens



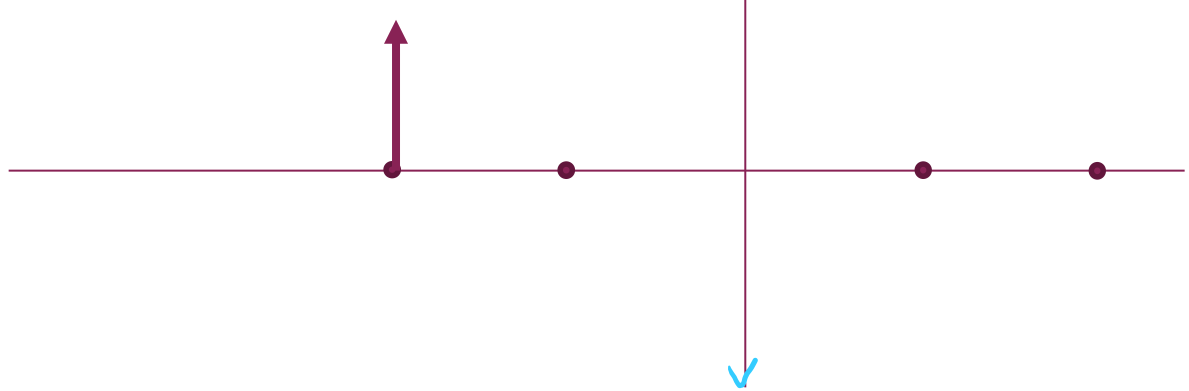
Try it! $\frac{1}{f} = \frac{1}{s} + \frac{1}{s'}$

$f = a, \quad s = 2f$

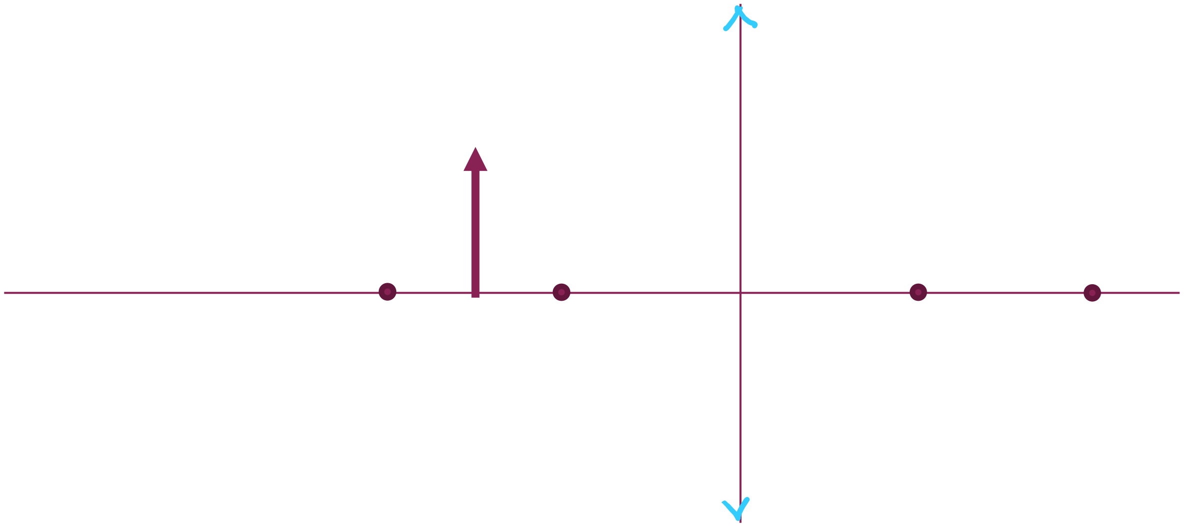
$\frac{1}{s'} = \frac{1}{f} - \frac{1}{s} = \frac{1}{a} - \frac{1}{2a} = +\frac{1}{2a}$

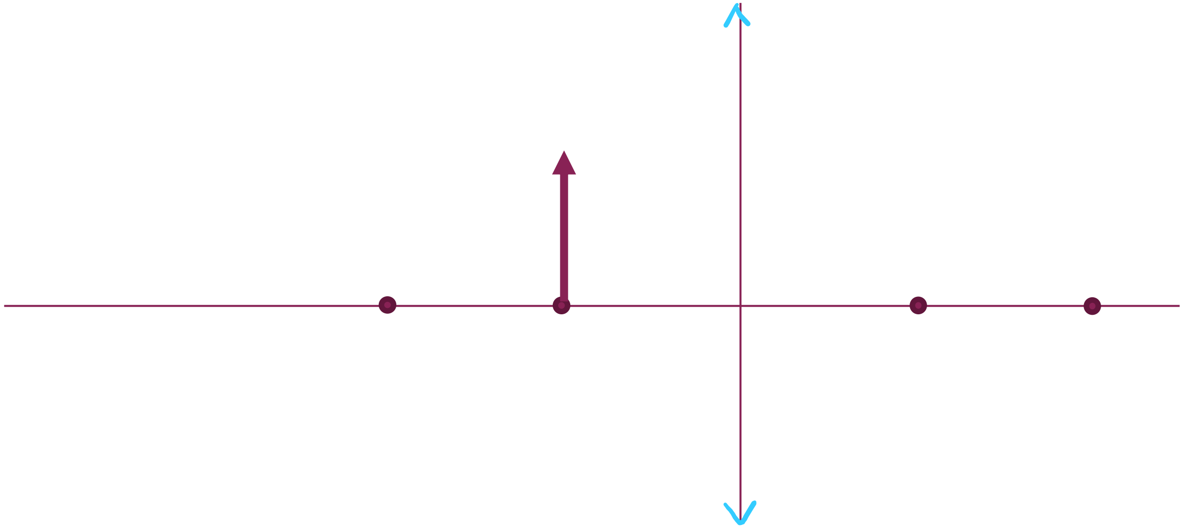
$s' = 2a$

see if it works!

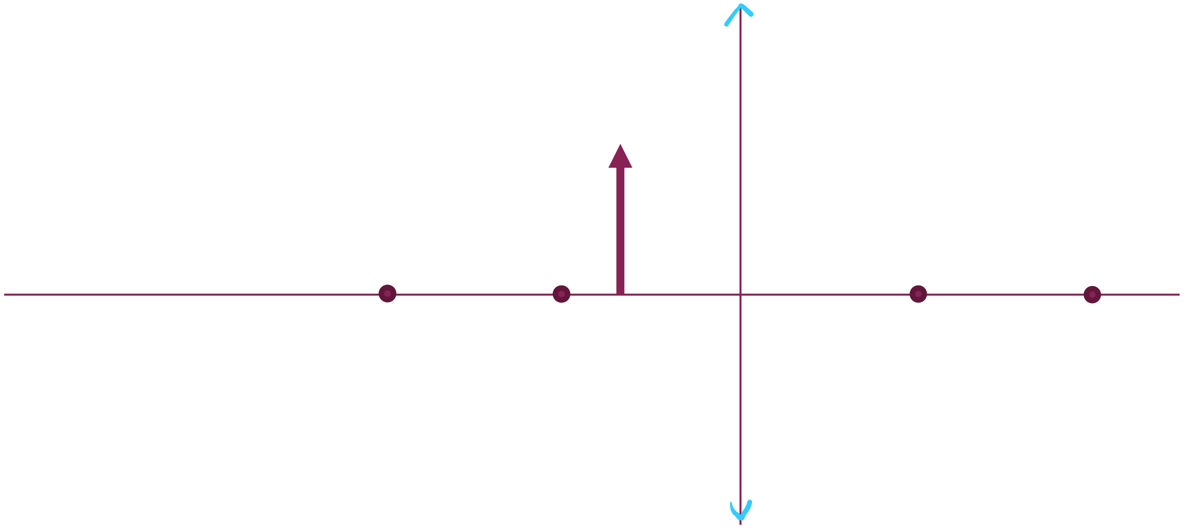


Mirrors and Lenses





Mirrors and Lenses



A convex lens creates a virtual image that is 2.0 times as large as the original object.
Where, relative to the focal point is the object placed?

$f > 0$ $\quad |m| = 2$ $\quad m = -\frac{s'}{s} = 2$ (s' is neg. cause the image is virtual)

$s' = -2s$

$$\frac{1}{f} = \frac{1}{s} + \frac{1}{s'}$$

$$\frac{1}{f} = \frac{1}{s} + \frac{1}{-2s} = \frac{1}{s} - \frac{1}{2s} = \frac{2}{2s} - \frac{1}{2s} = \frac{1}{2s}$$

$$2s = f \rightarrow s = \frac{1}{2}f$$

When an object is placed $s = 1.5|f|$ away from the convex mirror an image is formed.

What is the height of the image relative to the height of the object?

Convex mirror : $f < 0$

$$\frac{h'}{h} = m = -\frac{s'}{s}$$

convex mirror ALWAYS creates a virtual image

figure out s'

$$f = -a \quad , \quad s = 1.5a$$

$$\frac{1}{f} = \frac{1}{s} + \frac{1}{s'} \rightarrow \frac{1}{s'} = \frac{1}{f} - \frac{1}{s} = \frac{1}{-a} - \frac{1}{1.5a} = -\frac{1}{a} - \frac{2}{3a}$$

$$\frac{1}{s'} = -\frac{3}{3a} - \frac{2}{3a} = \frac{-5}{3a}$$

$$s' = -\frac{3}{5}a \rightarrow m = -\frac{-\frac{3}{5}\cancel{a}}{\frac{3}{2}\cancel{a}} = \frac{2}{5} \rightarrow h' = \frac{2}{5}h$$

FINAL EXAM REVIEW – PHY 132

PER REQUEST: LENSES AND MIRRORS AND WHAT THEY CREATE

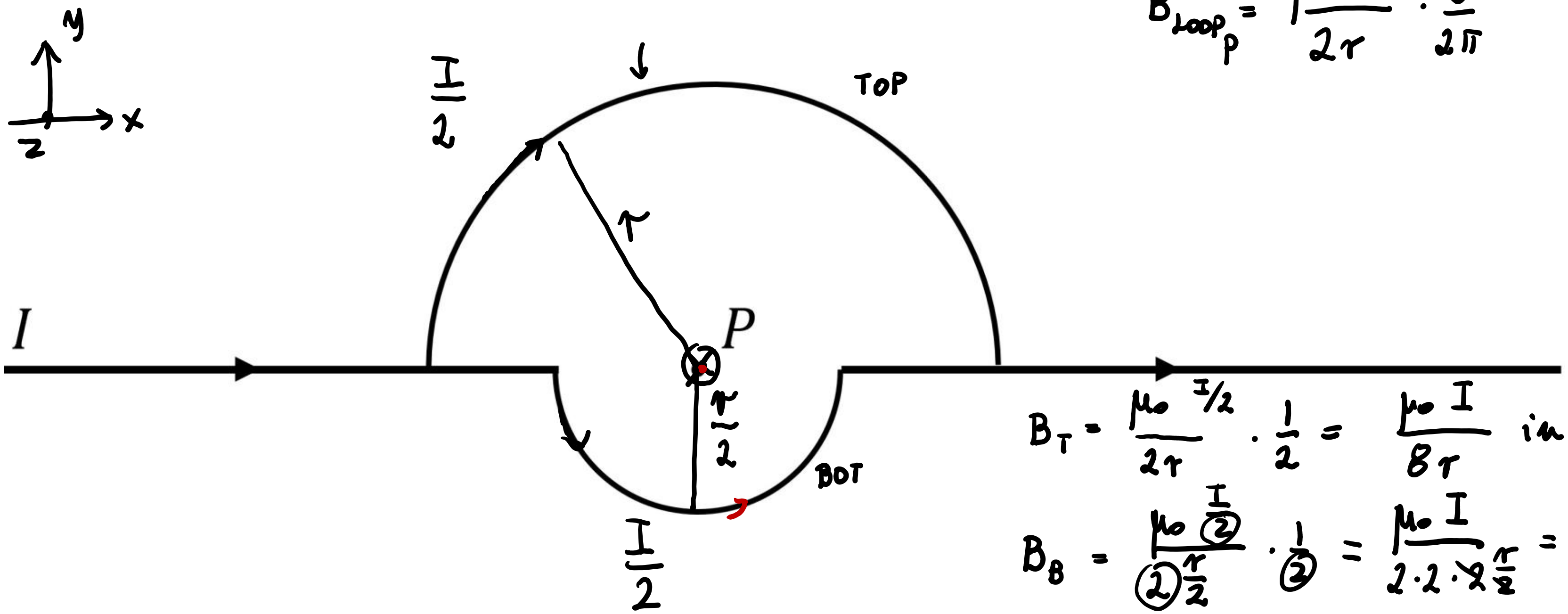
SOME COMPREHENSIVE EXAMPLES

SOME MEAN AND HORRIBLE QUESTIONS

SOME OLDIES BUT GOODIES BASICS

This one, which would be a nightmare for me as a student:

$$B_{loop_p} = \frac{\mu_0 I}{2r} \cdot \frac{\theta}{2\pi}$$



$$B_T = \frac{\mu_0 \, I/2}{2r} \cdot \frac{1}{2} = \frac{\mu_0 I}{8r} \text{ in}$$

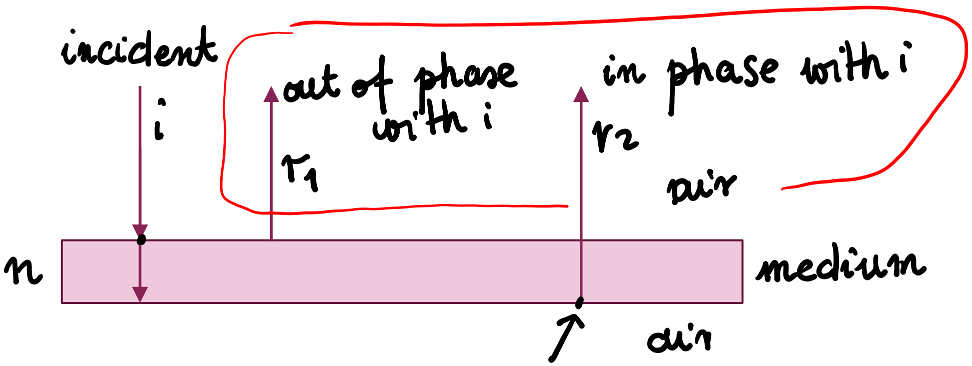
$$B_B = \frac{\mu_0 \frac{I}{2}}{2 \frac{r}{2}} \cdot \frac{1}{2} = \frac{\mu_0 I}{2 \cdot 2 \cdot \cancel{2} \frac{r}{\cancel{2}}} = \frac{\mu_0 I}{4r}$$

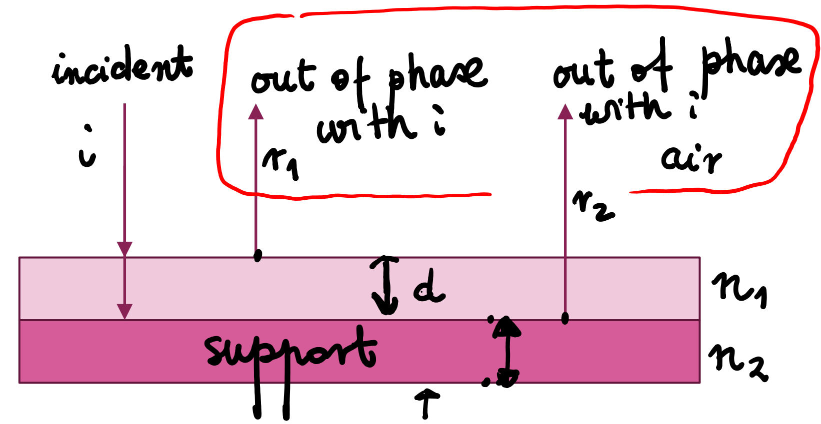
out

$$B_{net} = -\frac{\mu_0 I}{8r} + \frac{\mu_0 I}{4r} = +\frac{\mu_0 I}{8r}$$

or out of the page

$$n_{air} < n_1 < n_2$$





CONSTRUCTIVE

$$2d = \left(m+\tfrac{1}{2}\right)\lambda_{medium}$$

$$2n_1 d = \left(m+\tfrac{1}{2}\right)\lambda_{air}$$

DESTRUCTIVE

$$2n_1 d = m\lambda_{air}$$

CONSTRUCTIVE

$$2d = m\cdot\lambda_{medium} = m\frac{\lambda}{n_1}$$

$$2n_1 d = m\lambda_{air} \leftarrow$$

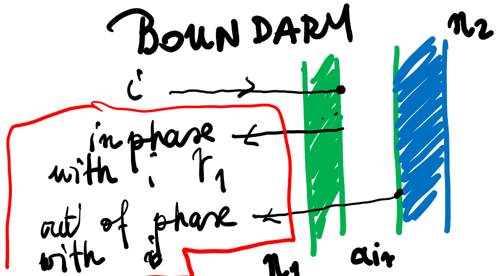
DESTRUCTIVE

$$2d = \left(m+\tfrac{1}{2}\right)\lambda_{med} = \left(m+\tfrac{1}{2}\right)\frac{\lambda}{n_1}$$

$$2n_1 d = \left(m+\tfrac{1}{2}\right)\lambda_{air}$$

$$m = 0, 1, 2, \ldots$$

BOUNDARY

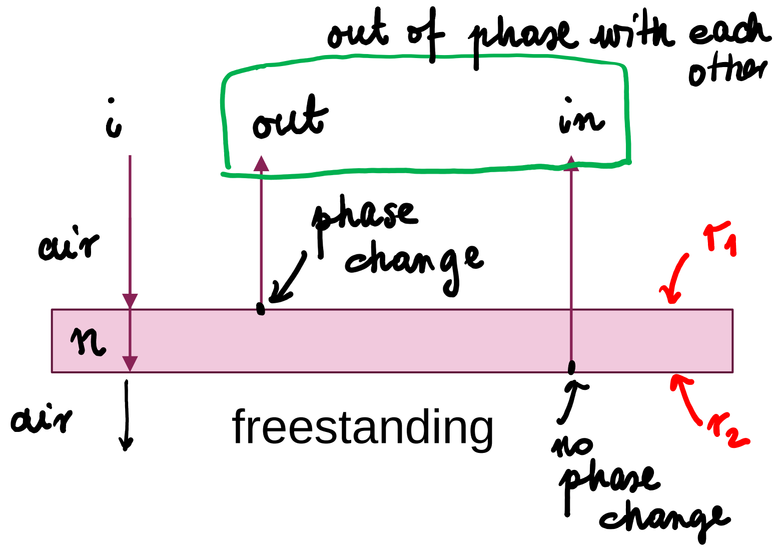


Δ

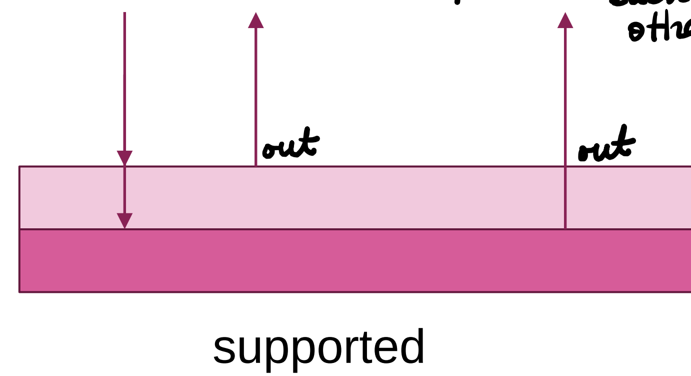
Consider a 1.0 μm film, with $n = 1.5$

$n_{before} > n_{after}$: no flip

$n_{before} < n_{after}$: flip



in phase with each other



Which wavelength would reflect the brightest and which would disappear in each film?

free standing

$m = 0$ $\quad 2dn = \left(0 + \frac{1}{2}\right)\lambda$

$2 \cdot 1 \times 10^{-6} \cdot 1.5 = 0.5\lambda$

$3 \times 10^{-6} = 0.5\lambda$

$\lambda = 6 \times 10^{-6}\ m$

$m = 1$ $\quad 2dn = 1.5\lambda$

$3 \times 10^{-6} = 1.5\lambda$

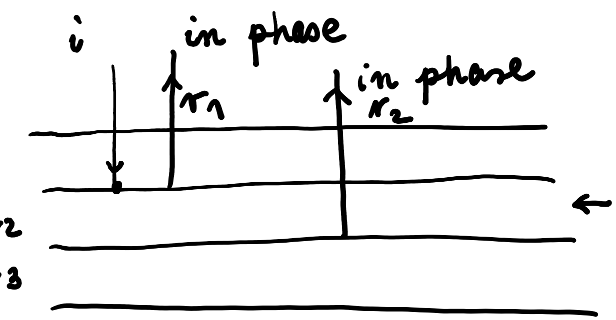
$m = 1$ $\quad 2nd = \lambda$

$2nd = 2\lambda$

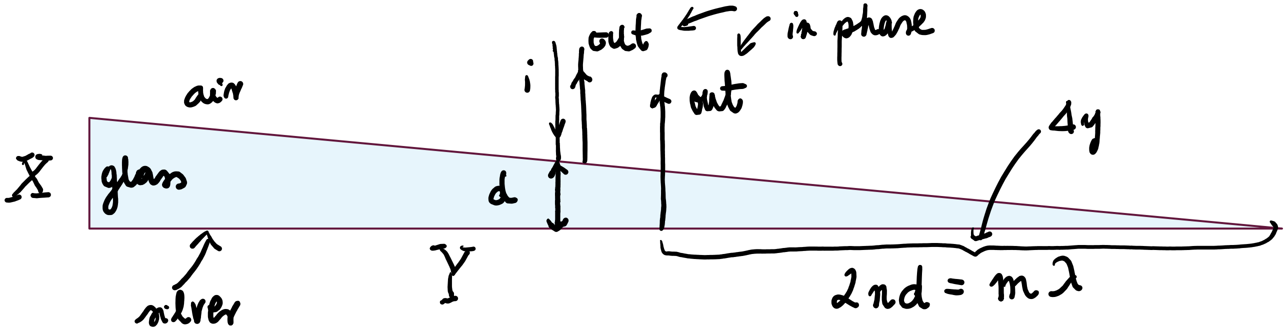
$\vdots$

Emily q.

$n_1 > n_2 > n_3$



That wedge question on MC?



$$\frac{x}{y} = \frac{d}{\Delta y}$$

Final Exam

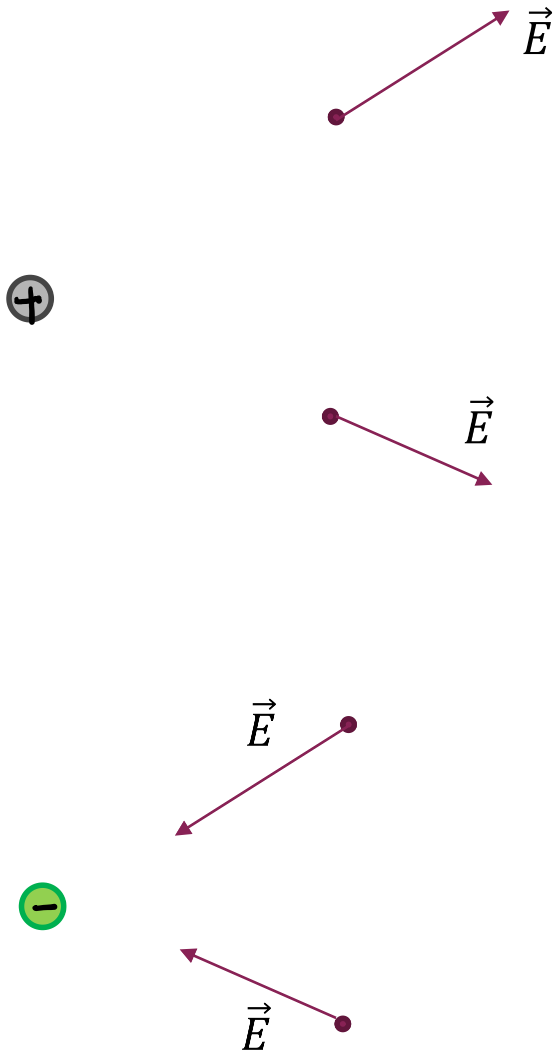
Question Type	Question Numbers/ Labels	Number of Questions	Points per question	Total points
True/False Style Questions (A/B)	**1 – 10**	10	1	**10**
MC Questions (A/B/C/D)	**11 – ~~21~~** 30	20	2	**40**
Long-Answer Questions	**Long – Answer A/B**	2	10	**20**

TOTAL: 70 points

- Could be on any topic, regardless what was covered in MC
- **Could** include concepts from more than one topic, e.g. potential and energy, charge creating both electric and magnetic field, energy and field, wave and geometric optics…

- Topics in order of appearing in the course in each; first question **is** very much meant to be simple.
- As proportional to the amount of time spent on the topic as humanly possible (e.g. one question max on relativity and induction as we spent only one class on each topic)

Electric Forces and Electric Fields



Magnitude of the electric field from a point charge Q at distance r away:

$$E = \frac{k_e Q}{r^2}$$

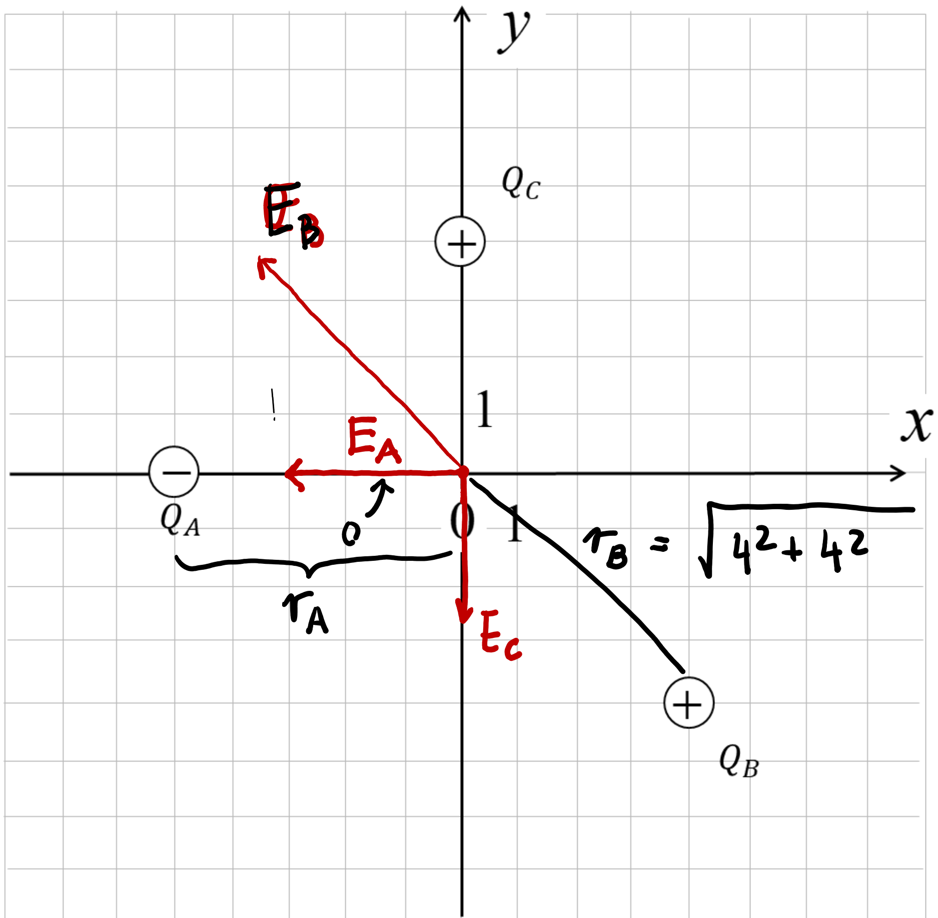
Direction of the electric field: points away from the positive charge and towards the negative charge. (Direction is the same as the direction of the electric force acting on a positive charge placed at the point where electric field is calculated.)

The magnitude of the electric force on a charge q placed in the electric field created by charge Q:

$$F = qE = \frac{k_e |Q||q|}{r^2}$$

Direction of the force: along the direction of the electric field for positive charge q and against the direction of the electric field for a negative charge q.

Electric Field



$$E_A = \frac{k_e Q_A}{r_A^2}$$

$$E_{Ax} = -\frac{k_e Q_A}{r_A^2} \cdot \underset{0}{\underset{\uparrow}{\cos\theta}}$$

$$E_{Ay} = \frac{k_e Q_A}{r_A^2} \sin\theta$$

$$E_B = \frac{k_e Q_B}{r_B^2}$$

$$E_{Bx} = -\frac{k_e Q_B}{r_B^2} \cdot \boxed{\frac{4}{r_B}}$$

$$E_{By} = +\frac{k_e Q_B}{r_B^2} \boxed{\frac{4}{r_B}}$$

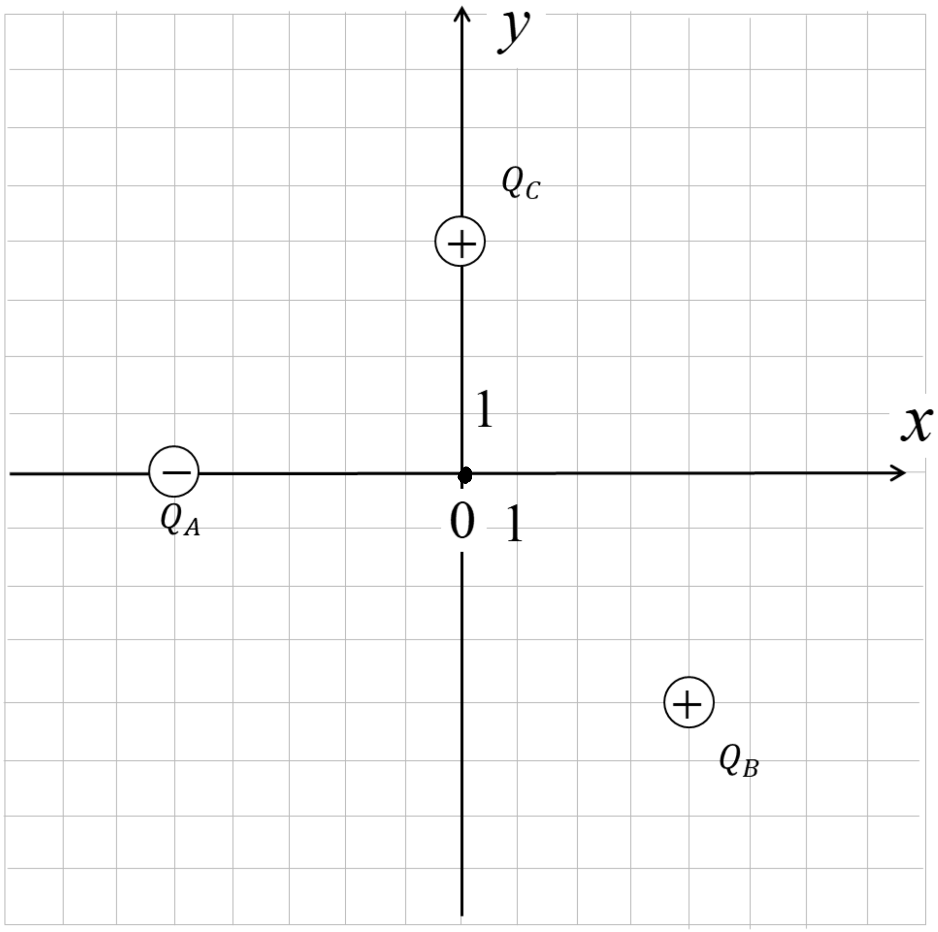
$$E_c = \frac{k_e Q_c}{r_c^2}$$

$$E_{x\,TOT} = E_{Ax} + E_{Bx} + E_{cx}$$

$$E_{y\,TOT} = E_{Ay} + E_{By} + E_{cy}$$

$$E_T = \sqrt{E_{x\,TOT}^2 + E_{y\,TOT}^2}$$

ELECTRIC POTENTIAL



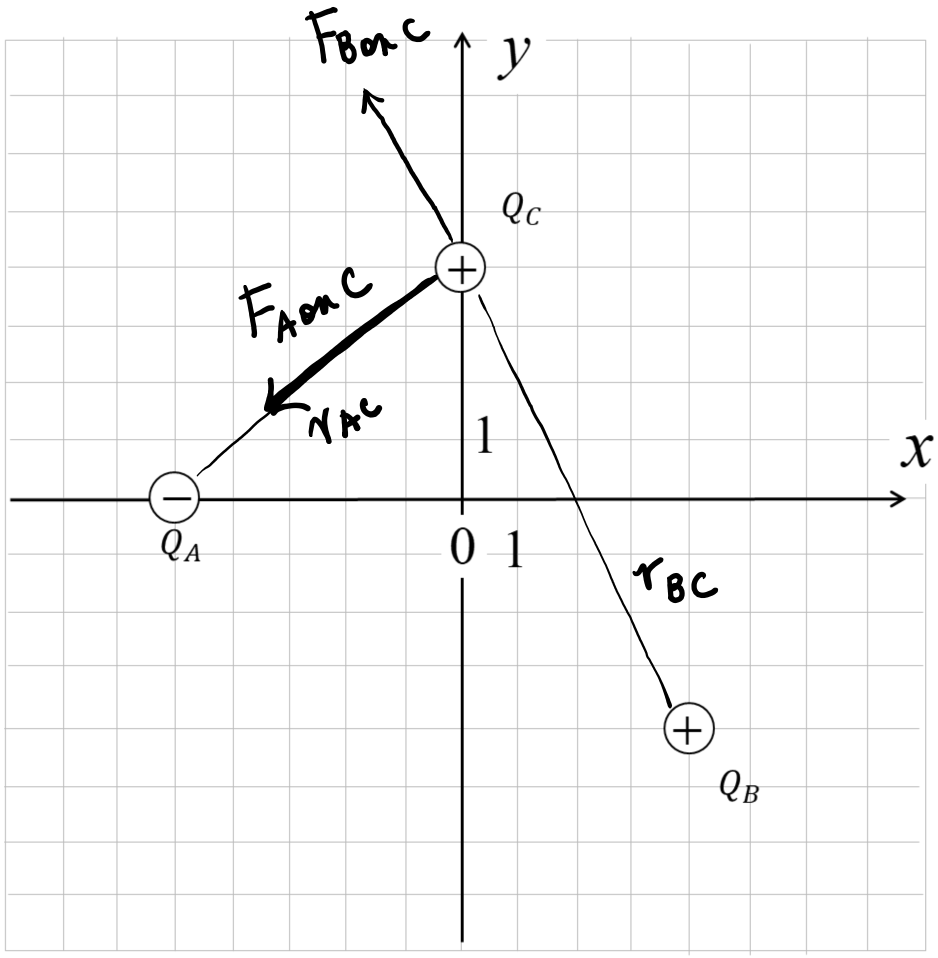
no Components

$$V_T = V_A + V_B + V_C$$

$$= \frac{k_e Q_A}{r_A} + \frac{k Q_B}{r_B} + \frac{k_e Q_C}{r_C}$$

$-$ $\quad$ $+$ $\quad$ $+$

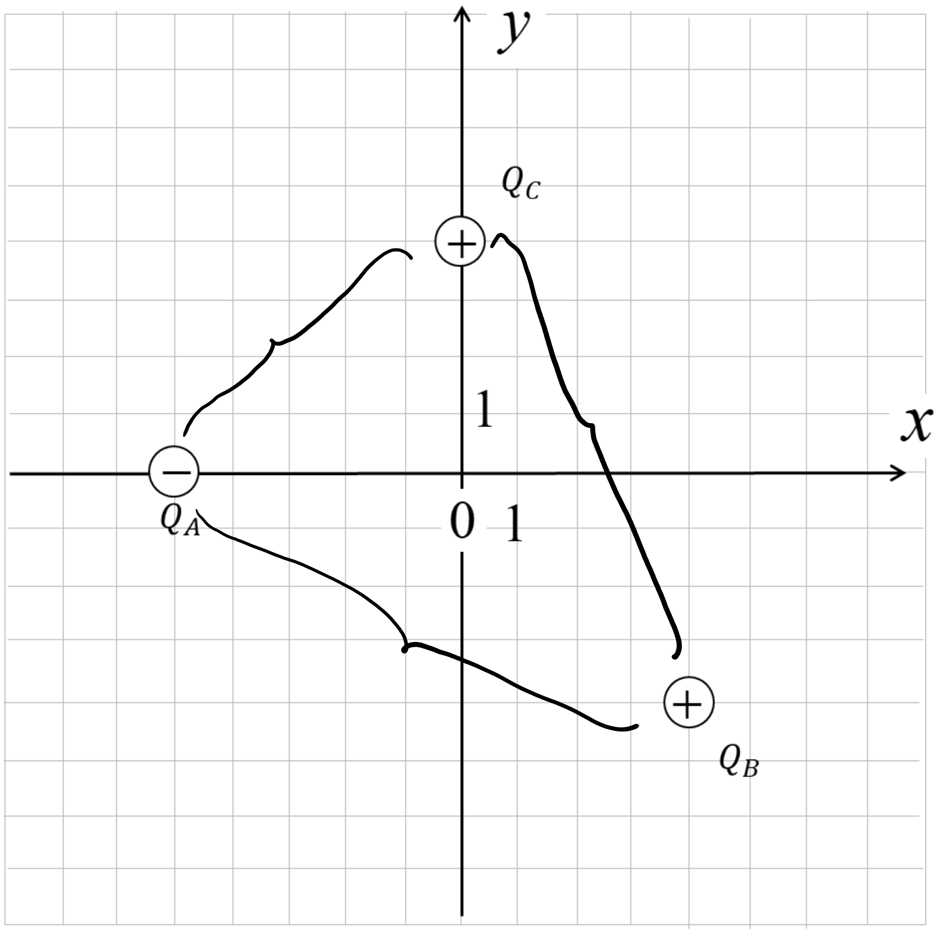
FORCE ON THE THIRD CHARGE



Q_A & Q_B on Q_C

vectors!

ELECTRIC POTENTIAL ENERGY

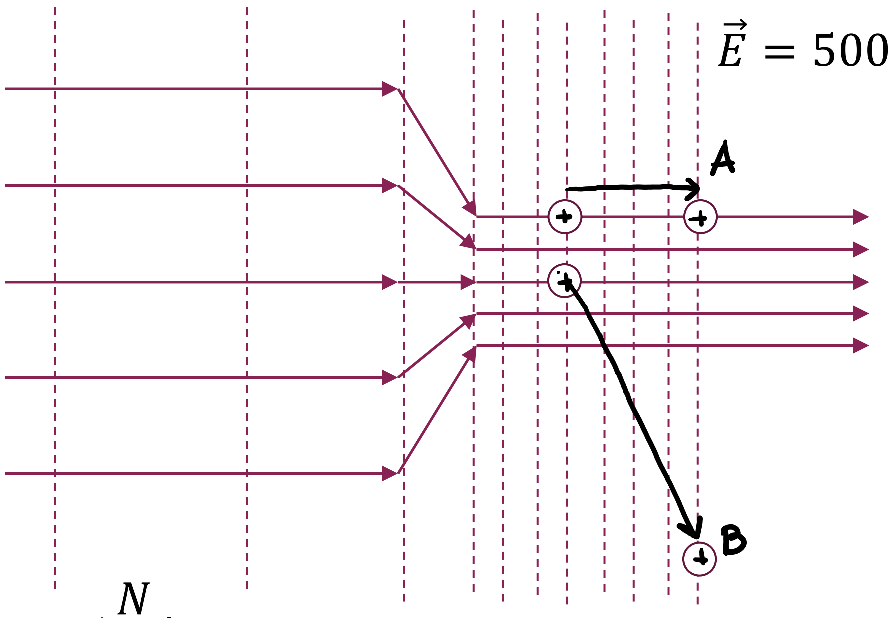


~~no components~~

$U_T = U_{AC} + U_{BC} + U_{AB}$

Electric Potential and Electric Field Lines

$$\vec{E} = 500\,\frac{N}{C}\,\hat{\imath}$$



$$\vec{E} = 125\,\frac{N}{C}\,\hat{\imath}$$

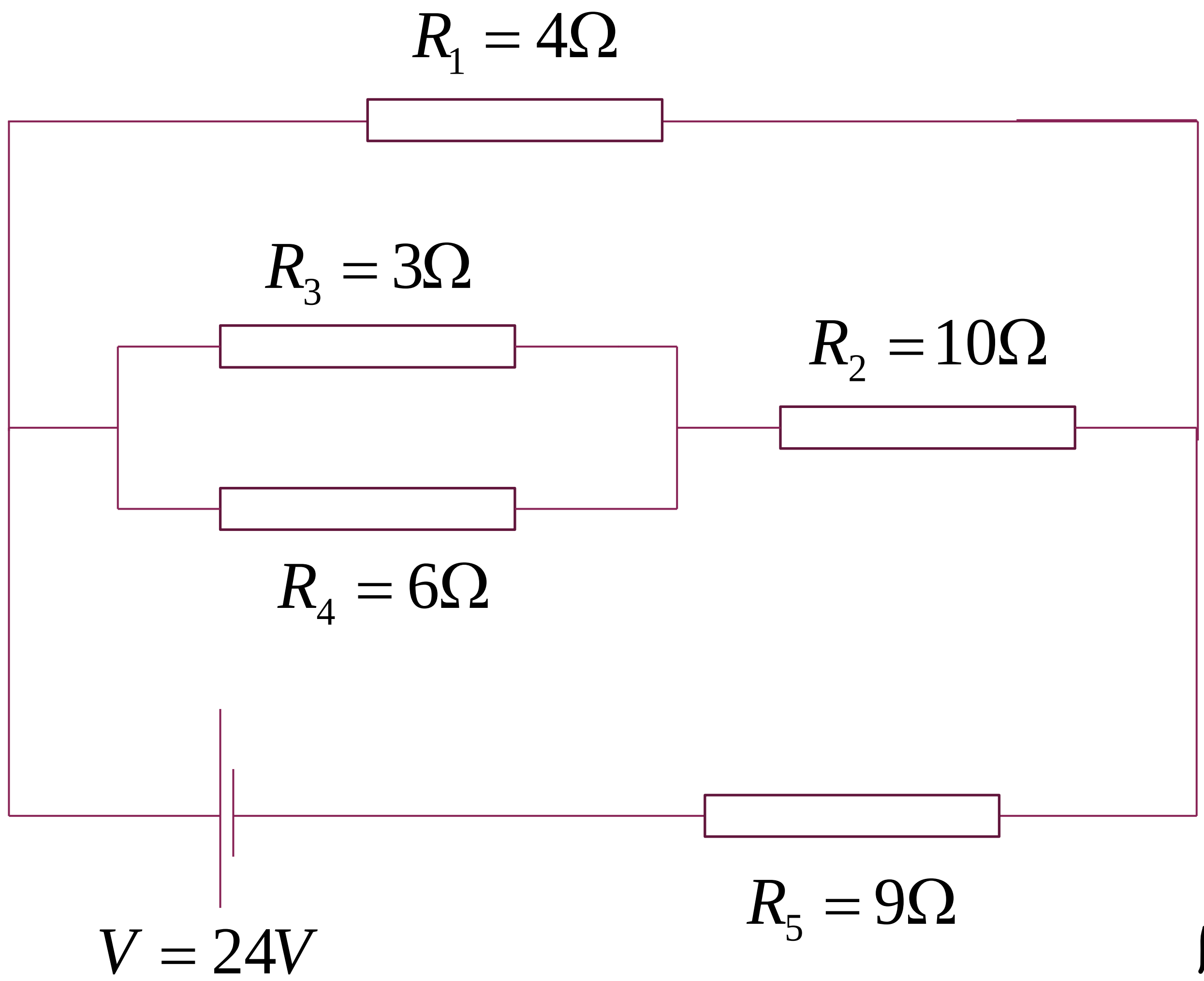
electric potential decreases $|E|$ amount per meter in $+x$ dir

$W_A = W_B$

$\Delta U_A = \Delta U_B$

QUESTION 4A

Determine the equivalent resistance of circuit below.



R_3 & R_4 are in parallel

$$\frac{1}{R_A} = \frac{1}{R_3} + \frac{1}{R_4} = \frac{1}{3} + \frac{1}{6}$$

$$R_A = 2.0\Omega$$

R_A & R_2 are in series

$$R_B = R_A + R_2 = 12.0\Omega$$

R_B & R_1 are in parallel

$$\frac{1}{R_c} = \frac{1}{R_1} + \frac{1}{R_B}$$

$$\frac{1}{R_c} = \frac{1}{4} + \frac{1}{12} = \frac{4}{12}$$

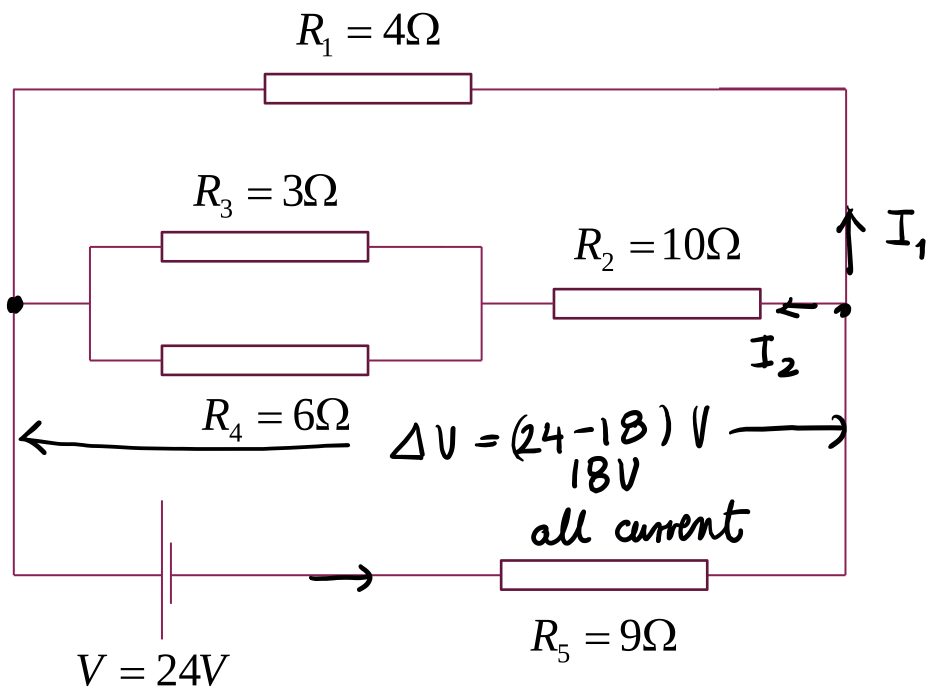
$$R_c = 3\Omega$$

R_c & R_5 are in series

$$R_{eq} = 12\Omega$$

QUESTION 4B

Knowing that the equivalent resistance of this circuit is $R_{eq} = 12\Omega$, determine the current through resistor R_3 and total power dissipated by the circuit.



	R [Ω]	V [V]	I [A]	P [W]	
1	4	6V	1.5	9	
2	10	5V	0.5	2.5	
3	3	1V	1/3	1/3	
4	6	1V	1/6	1/6	
5	9	18	2	36	
Tot	12	24	2	sum all powers 48	

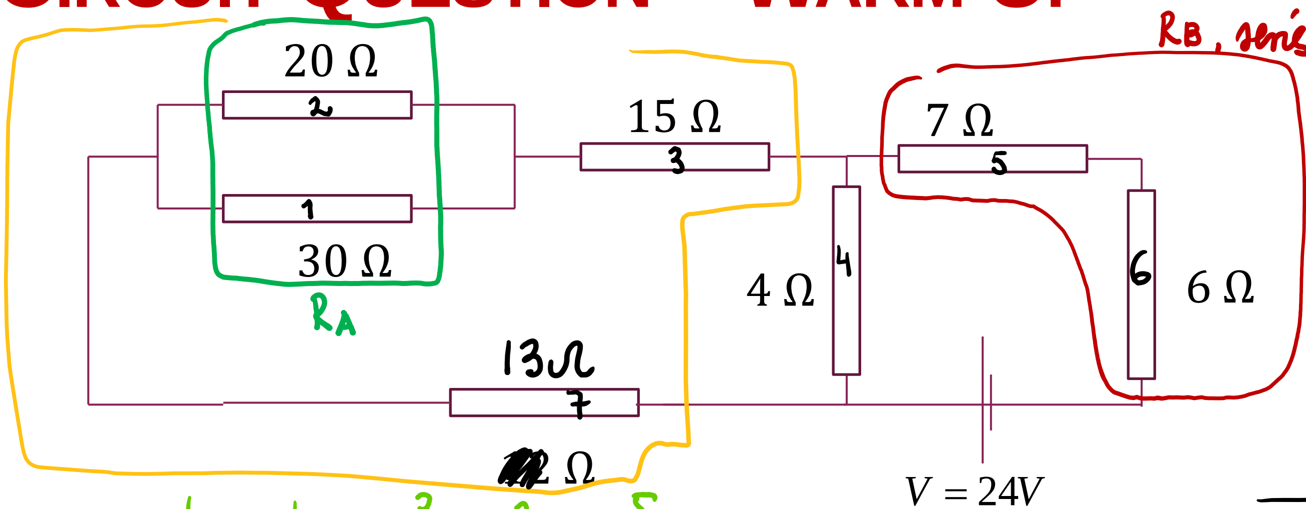
$$I = \frac{\Delta V}{R}$$

$$P = I\Delta V$$

$$\Delta V = IR$$

$$I_2 = I_T - I_1$$

Circuit Question – Warm Up



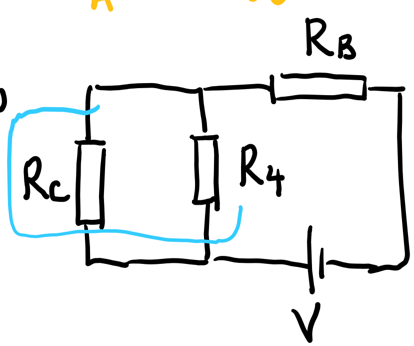
$$\frac{1}{R_A} = \frac{1}{20} + \frac{1}{30} = \frac{3}{60} + \frac{2}{60} = \frac{5}{60}$$

$$R_A = 12\,\Omega$$

$$R_B = 7\,\Omega + 6\,\Omega = 13\,\Omega$$

$$R_C = R_A + 15\,\Omega + 13\,\Omega = 12\,\Omega + 15\,\Omega + 13\,\Omega = 40\,\Omega$$

Redraw



$$\frac{1}{R_C} + \frac{1}{R_4} = \frac{1}{R_D} = \frac{1}{40} + \frac{1}{4}$$

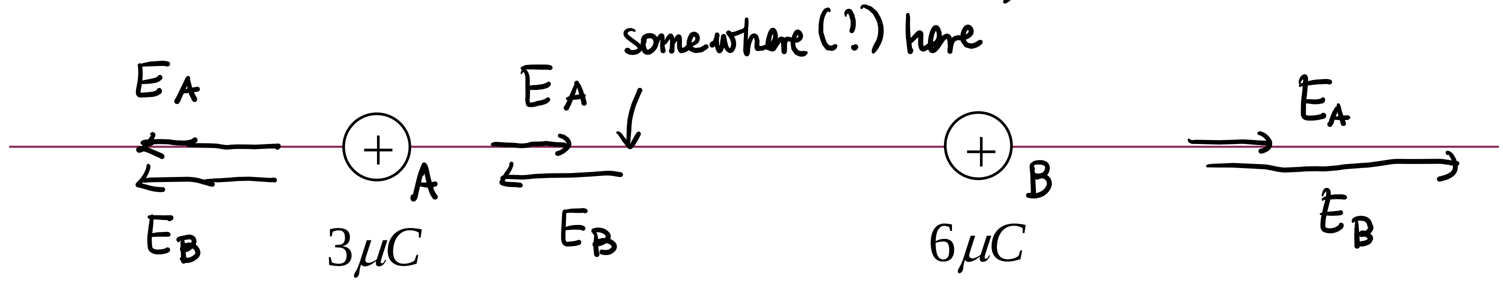
$$R_D = \frac{40}{11}\,\Omega =$$

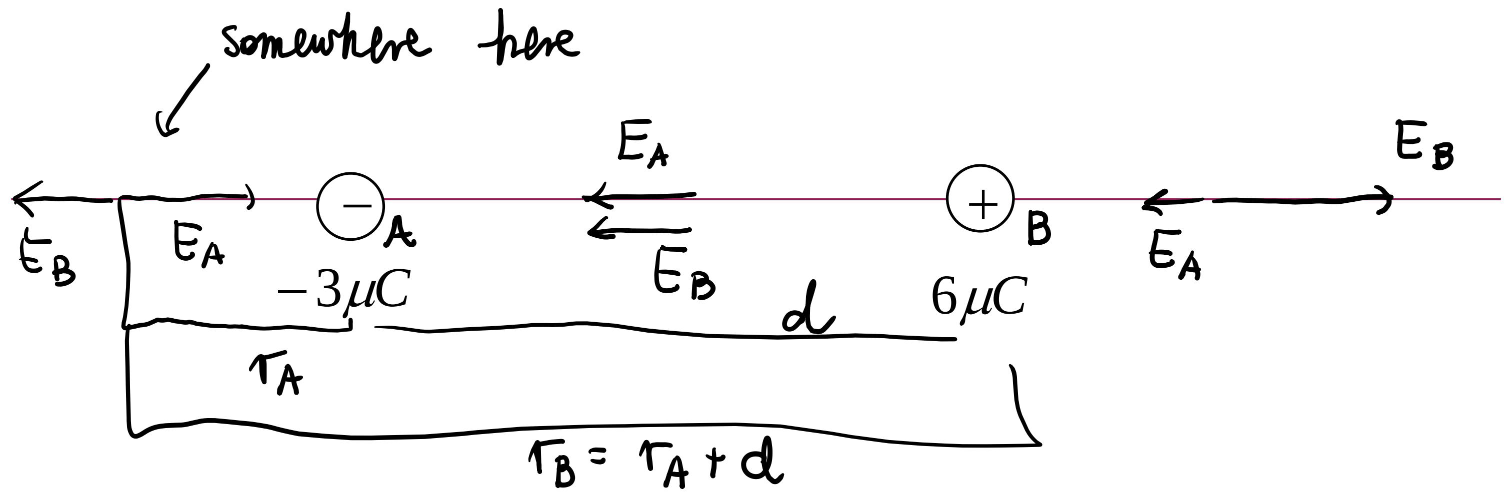
$$R_{eq} = 13 + \frac{40}{11} = \ldots$$

	(Ω) R	(V) V	(A) I	(W) P
1	30			
2	20			
3	15			
4	4			
5	7			
6	6			
7	13			
T		24 V.		

EXAMPLE – ZERO FIELD

$$\frac{kQ_A}{r_A^2} = \frac{kQ_B}{r_B^2} \rightarrow \sqrt{\frac{|Q_A|}{|Q_B|}} = \frac{r_A}{r_B}$$





EXAMPLE – ZERO NET POTENTIAL

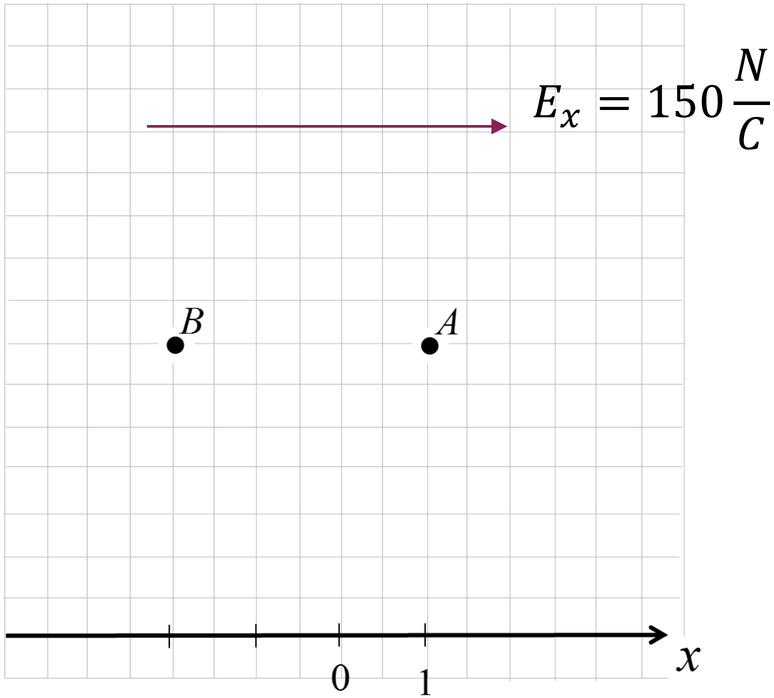
nowhere (± infinity

$$|V_A| = |V_B| \rightarrow \frac{kQ_A}{r_A} = \frac{kQ_B}{r_B}$$

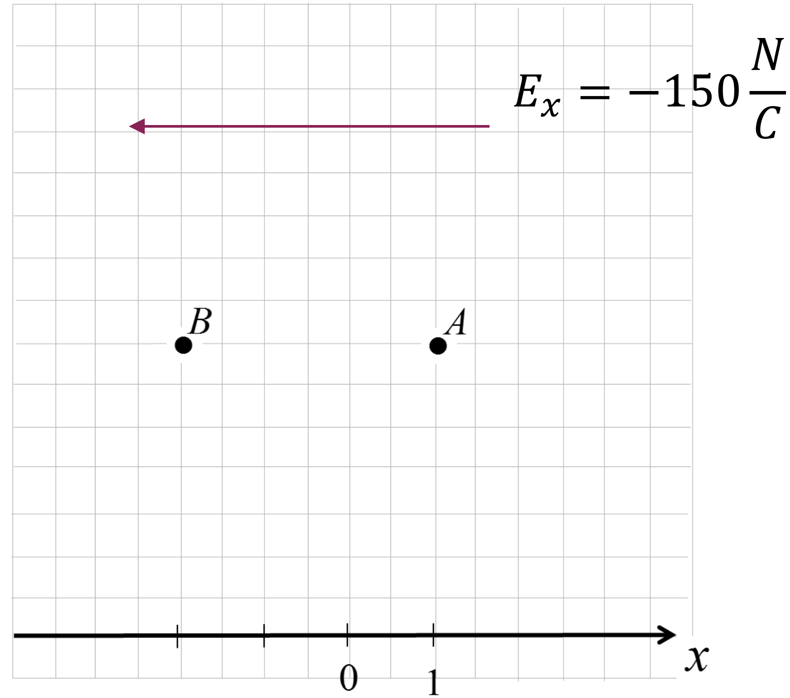
here

but also here where $\frac{r_A}{r_A+d} = \frac{Q_A}{Q_B}$

ELECTRIC POTENTIAL AND ELECTRIC FIELD



$V_A < V_B$



$V_A > V_B$

$$V_A - V_B = -E \cdot (x_B - x_A)$$

EXAMPLE

The electric potential in a region of uniform electric field is $-1900\ V\ at\ x\ =\ -1.60\ m$ and $+\ 1000\ V$ at $x\ = +1.30\ m$. What is E_x?
Express your answer with the appropriate units.

x_A

V_A

V_B x_B

$$\Delta V = -E_x \cdot \Delta x$$

$$-\frac{V_B - V_A}{x_B - x_A} = E_x$$

$$E_x = -\frac{1000-(-1900)}{1.3-(-1.6)} = -\frac{2900}{2.9} = -1000\,\frac{V}{m}$$

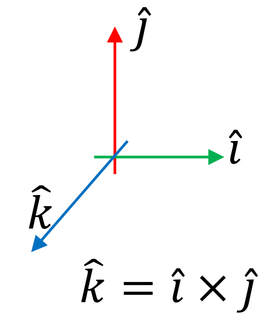
or: $$|E_x| = \frac{|\Delta V|}{|\Delta x|} = \frac{|V_B - V_A|}{|x_B - x_A|} = \frac{|1000-(-1900)|}{|1.3-(-1.6)|} = 1000\,\frac{V}{m}$$

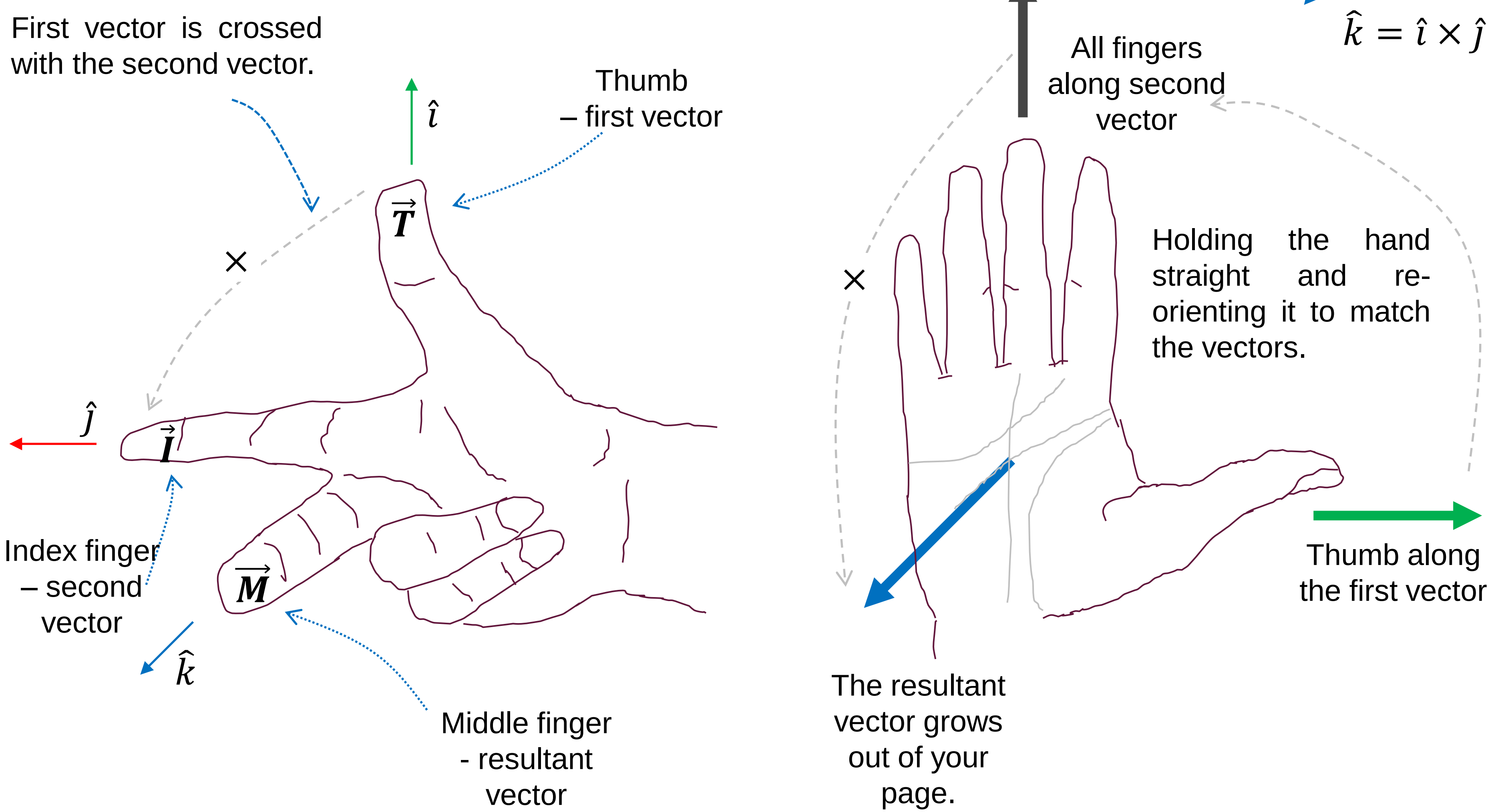
ΔV increases in $+x$, E_x must be neg

Regular Cross Product

$(t_{\text{thumb}} - i_{\text{index}} - m_{\text{middle}})$

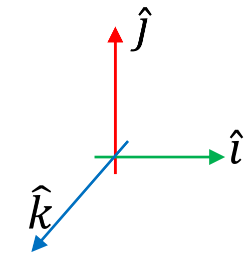
$$\vec{T} \times \vec{I} = \vec{M}$$





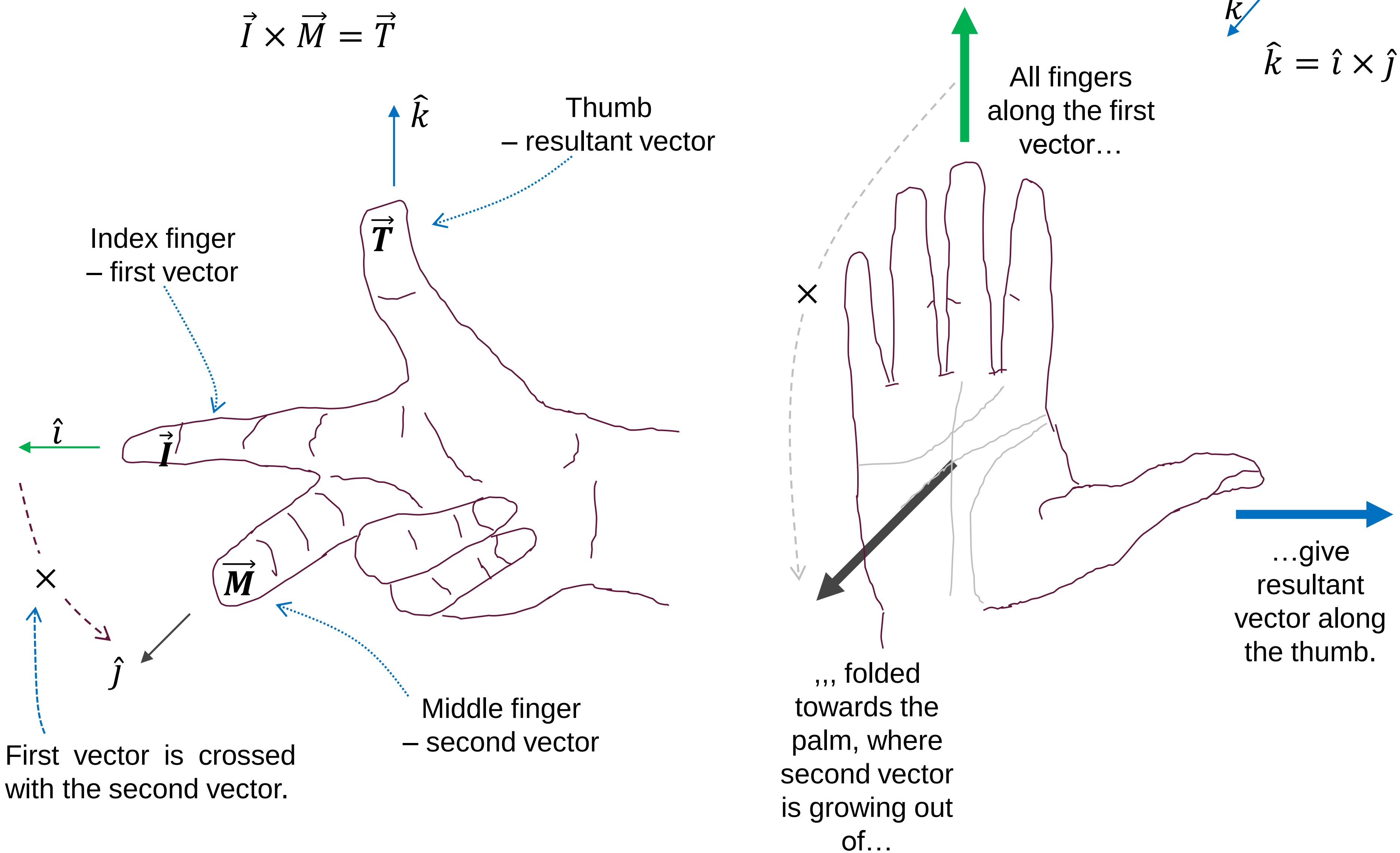
REGULAR CROSS PRODUCT

($\mathbf{i_{index}} - \mathbf{m_{middle}} - \mathbf{t_{thumb}}$)



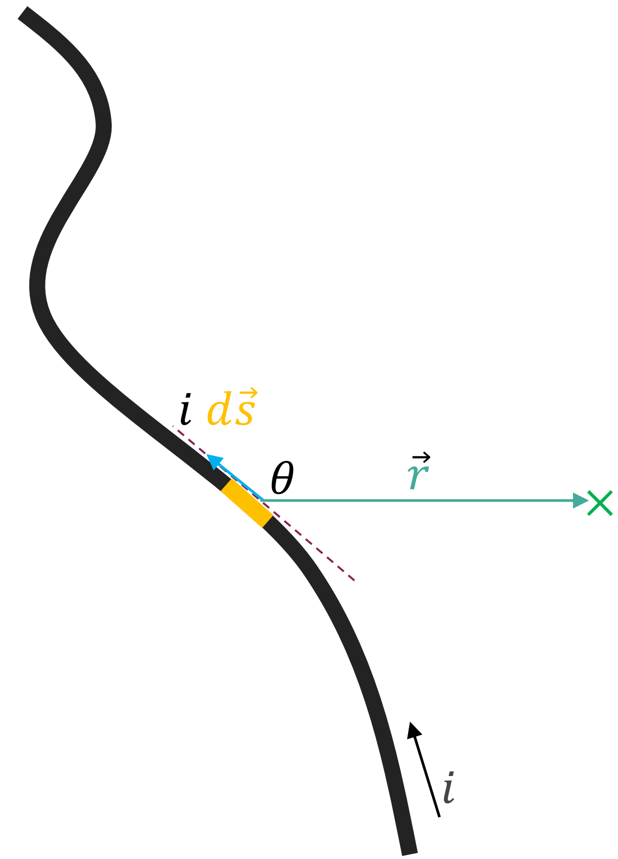
$$\hat{k} = \hat{\imath} \times \hat{j}$$

$$\vec{I} \times \vec{M} = \vec{T}$$



MAGNETIC FIELD DUE TO A CURRENT

Consider a wire of arbitrary shape carrying a current i.

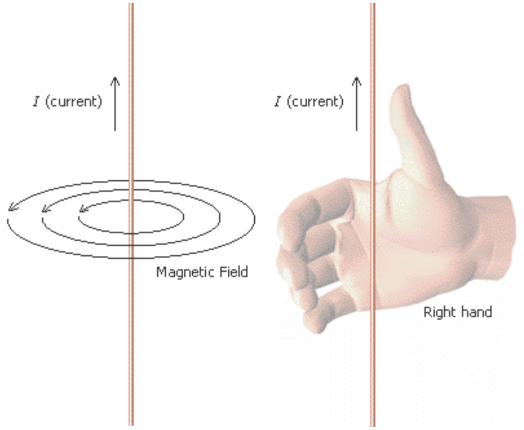


Magnetic field due to a length element $d\vec{s}$ carrying current i at point P located distance r from the element is defined by Biot-Savart Law:

$$d\vec{B} = \frac{\mu_0}{4\pi}\frac{i d\vec{s} \times \hat{r}}{r^2} \rightarrow \mathrm{B}_{\mathrm{longwire}} = \frac{\mu_0 I}{2\pi d}$$

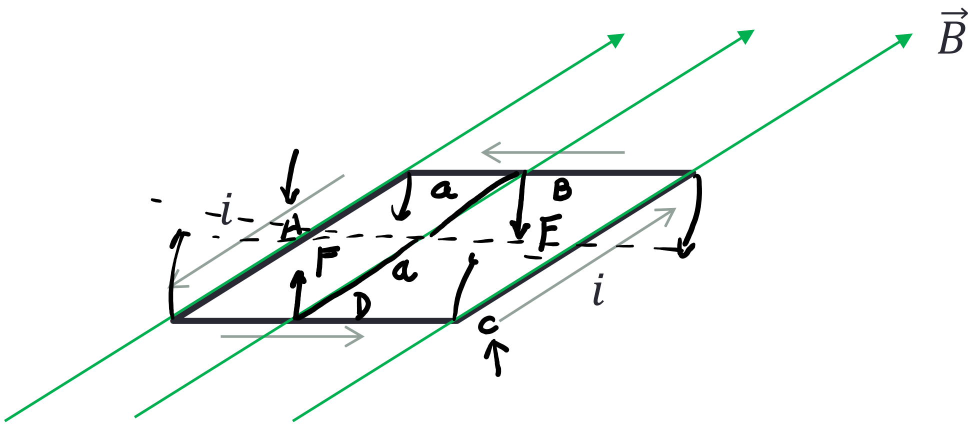
NOTE: magnitude of the field element $dB = \frac{\mu_0}{4\pi}\frac{ids\sin\theta}{r^2}$
The direction can be determined using a hand rule.

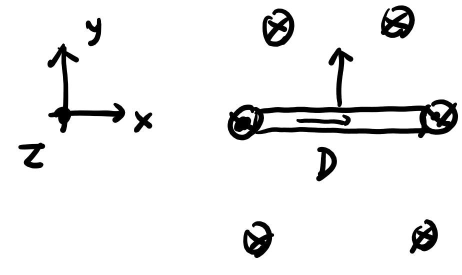
oooor this handy cheat:



$$\mu_0 = 4\pi \times 10^{-7}\, T \cdot \frac{m^2}{A}$$

Torque

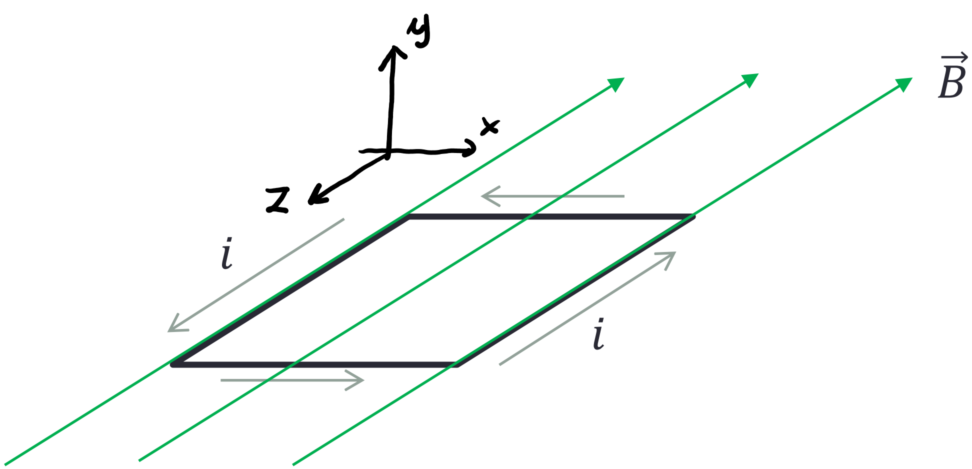




$$\tau_D = aF$$

$$\tau_B = aF$$

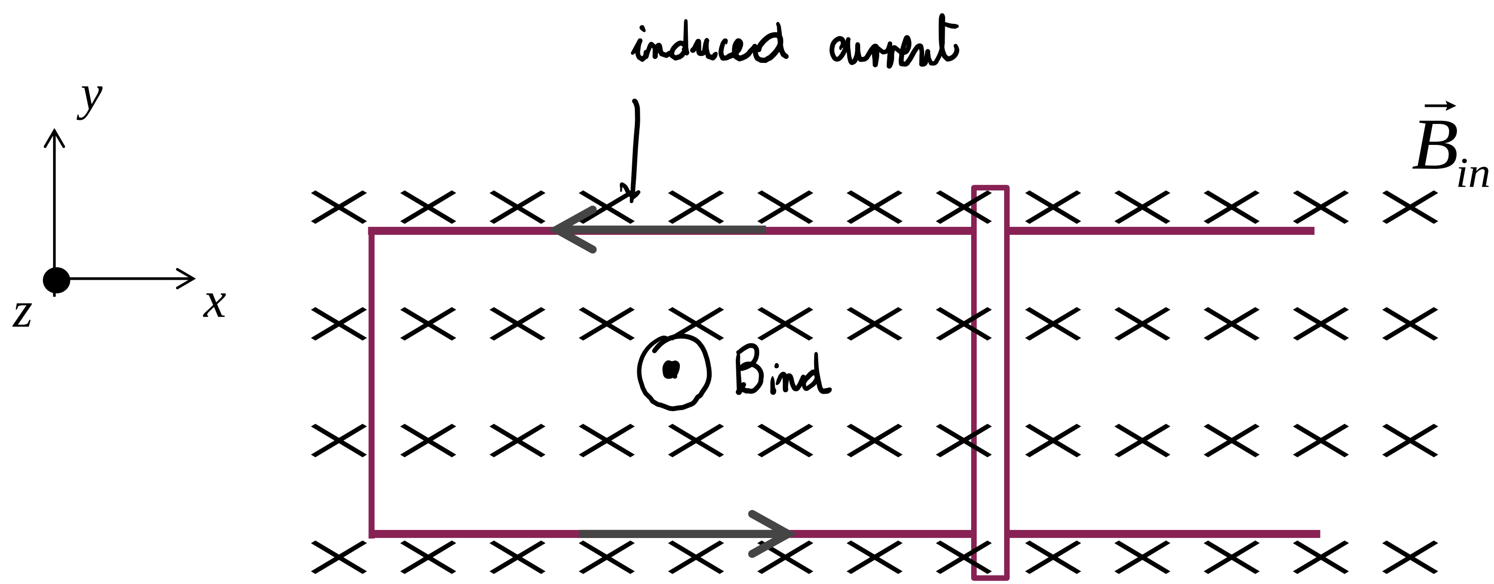
$$F = I \cdot L \cdot B$$



Challenge

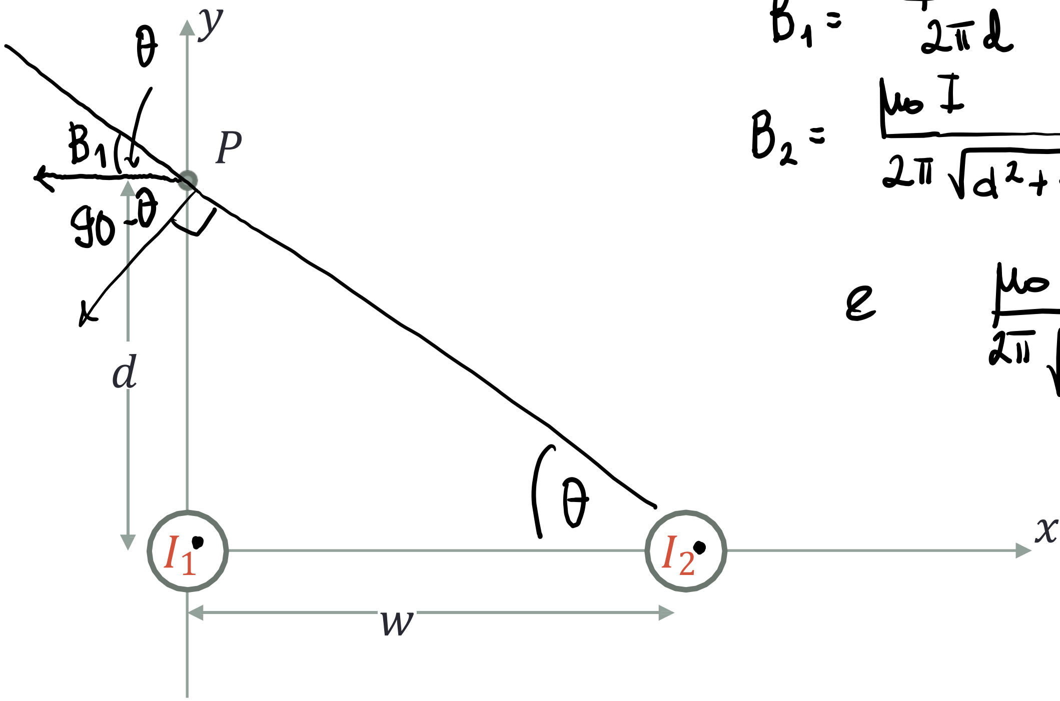
Which way is the bar moving if the current is induced as shown in the picture?

$$A)\ left \quad B)\ right$$



opposes what is there so... what's there must be increasing

DETERMINE MAGNETIC FIELD AT POINT P



$$B_1 = \frac{\mu_0 I_1}{2\pi d} \quad \text{all in } -x$$

$$B_2 = \frac{\mu_0 I}{2\pi \sqrt{d^2 + w^2}} \cdot \cos(90 - \theta) \text{ in } -x$$

$$\& \quad \frac{\mu_0 I}{2\pi \sqrt{d^2 + w^2}} \cdot \sin(90 - \theta) \text{ in } -y$$

WORK DONE IN ELECTRIC FIELD

$$W = \Delta K$$
$$W = W_{nc} + W_c = \Delta K$$

W_{nc} == work done by external forces

W_c == work done by conservative forces $(here: \vec{E})$

$$if\ W_{nc} = 0\ \ W_c = \Delta K$$

BUT $W_c = -\Delta U$

$$\Delta U = q\Delta V = q(V_f - V_i)$$

Work Done in Electric field – Example (1)

DIY

Charge $q = -3.0\ \mu C$ has been moved from point A=(-1.0, 0) cm to point B=(2.0, 2.0) cm in an electric field $\vec{E} = (-100\ \mathrm{V/m}, 0\ \mathrm{V/m})$. All potential energy is converted to kinetic energy.

What is
a) change in the kinetic energy of the charge
b) Change in potential energy of the charge?
c) Work done by electric field?
d) Work done by other non-conservative forces?

WORK DONE IN ELECTRIC FIELD – EXAMPLE (2)

DIY

Charge $q = -3.0\ \mu C$ has been moved from point A=(-1.0, 0)cm to point B=(2.0, 2.0) cm in an electric field $\vec{E} = (-100\ \mathrm{V/m}, 0\ \mathrm{V/m})$ **at a constant speed**

E just in - x dir

What is

a) change in the kinetic energy of the charge

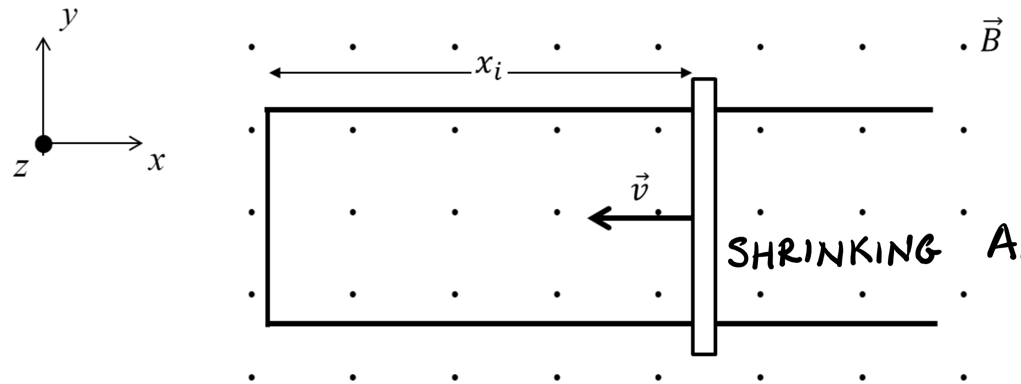
b) Change in potential energy of the charge?

c) Work done by electric field?

d) Work done by a non-conservative force?

A sliding metal bar of length $l = 0.150\ m$ is moving along two parallel, conducting rails with constant velocity $\vec{v} = -0.75\frac{m}{s}\hat{\imath}$ as shown in the figure below for $t = 0.0\ s$. The rails are located in magnetic field $\vec{B} = (3.0 - t^2)\hat{k}$, where B is in teslas. At time $t = 0.0\ s$ the length of the rails $x_i = 0.25\ m$.

decreases



SHRINKING AREA

1. Which of the following is true regarding induced magnetic field and the force $\vec{F}_B$ on the metal bar?
   a. $\vec{B}_{ind} = -B_{ind}\hat{k}, \vec{F}_B = -F_B\hat{\imath}$
   b. $\vec{B}_{ind} = -B_{ind}\hat{k}, \vec{F}_B = +F_B\hat{\imath}$
   c. $\vec{B}_{ind} = +B_{ind}\hat{k}, \vec{F}_B = -F_B\hat{\imath}$
   d. $\vec{B}_{ind} = +B_{ind}\hat{k}, \vec{F}_B = +F_B\hat{\imath}$

wants to enhance what's there

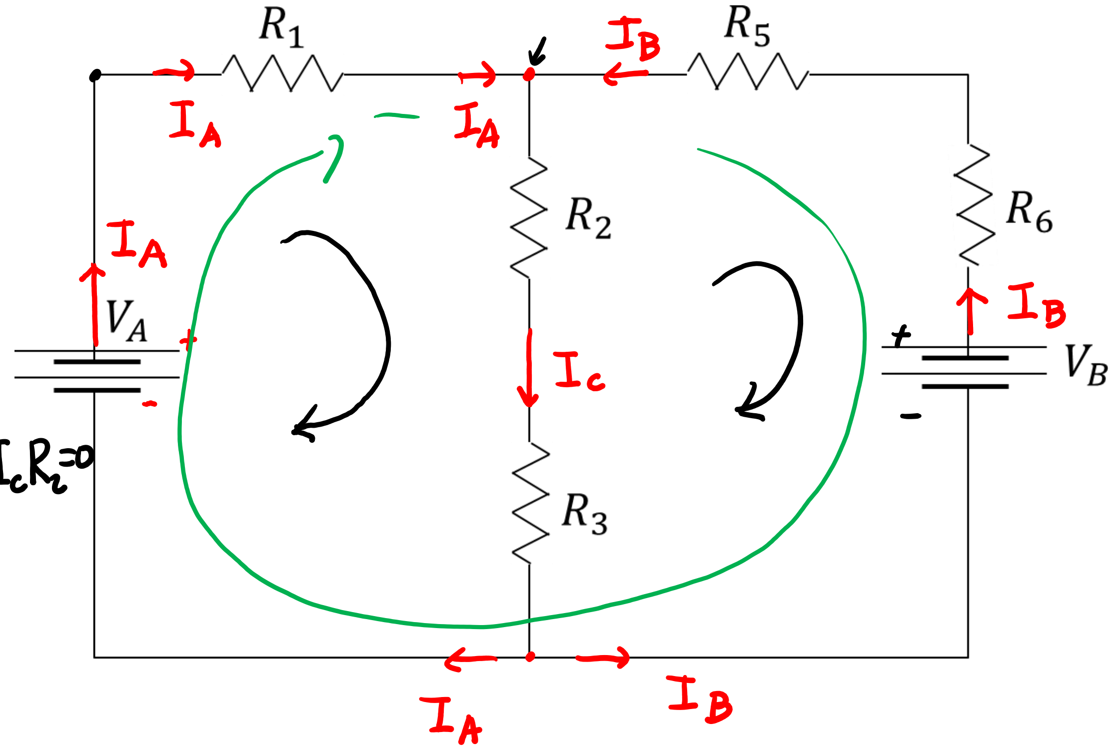
[d]

KIRCHHOFF'S LOOPS

$I_c = I_A + I_B$

$- I_A R_1 - I_c R_2 - I_c R_3 + V_A = 0$

$+ I_B R_5 + I_B R_c - V_B + I_c R_3 + I_c R_2 = 0$



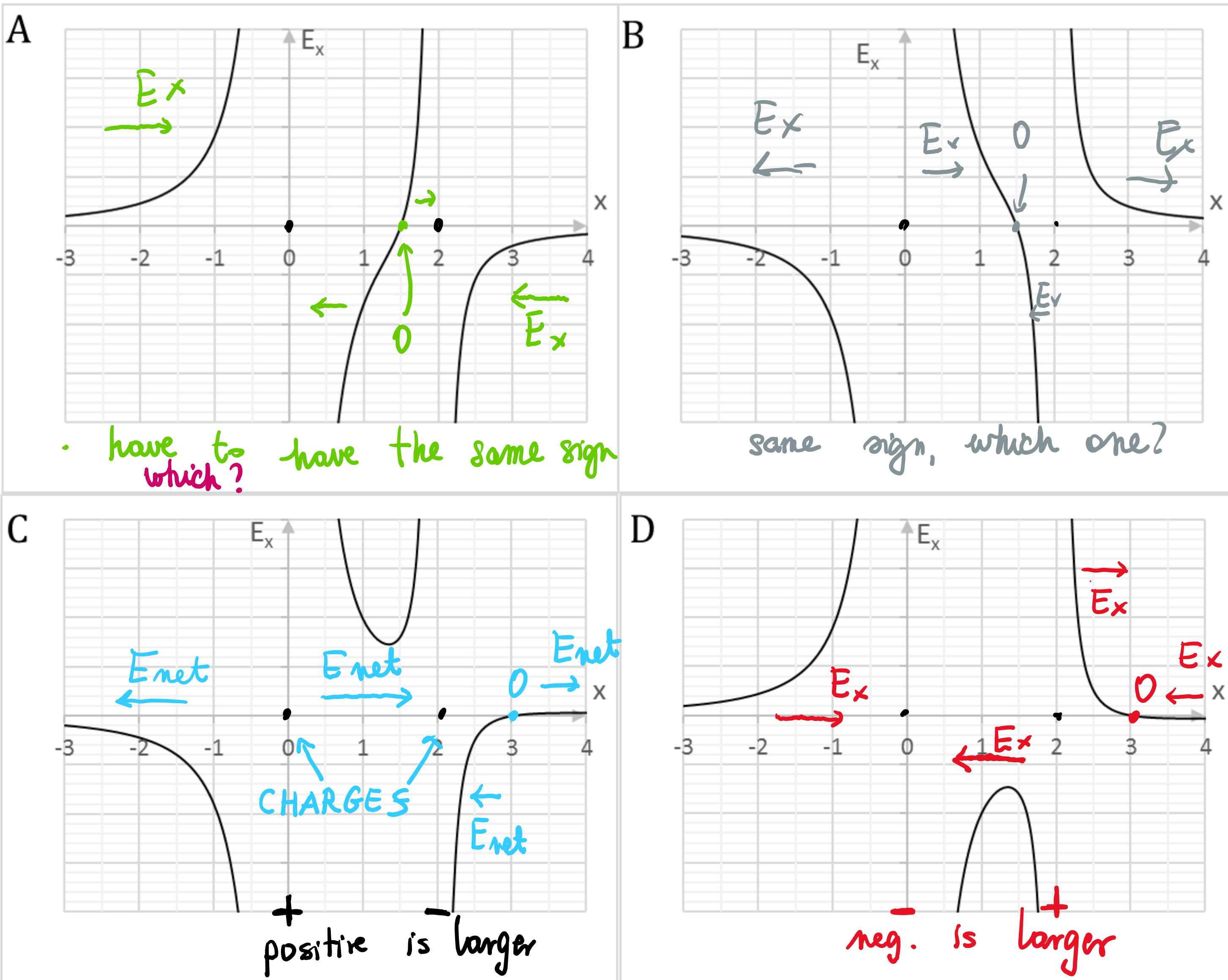
WHAT ARE THE SIGNS OF THE CHARGES?

E_x above x axis

E points in +x dir

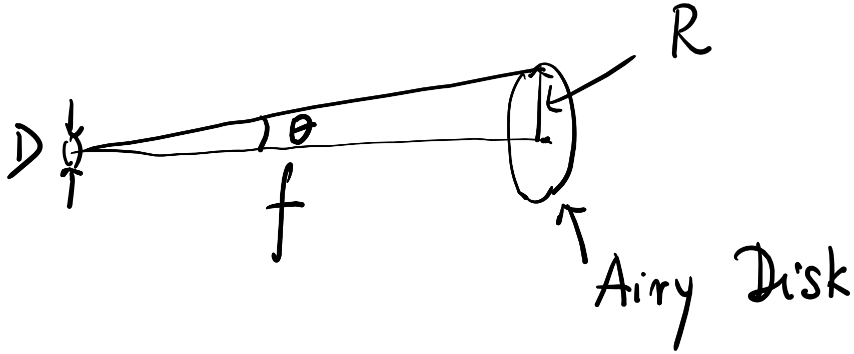
E_x below x axis

E points in −x dir



$$\sin\theta = \frac{1.22\lambda}{D}$$

circular opening



$$\frac{R}{f} = \tan\theta$$