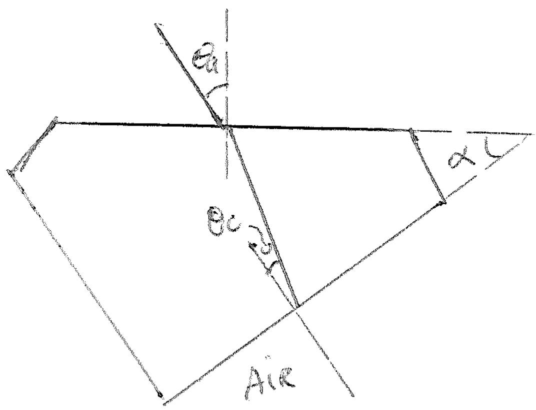
Physics 152, HW #10

Mastering: 10 Questions from Chapters 18 AND 30

ONE WRITTEN QUESTION

5 BONUS QUESTIONS

A sparkling Diamond



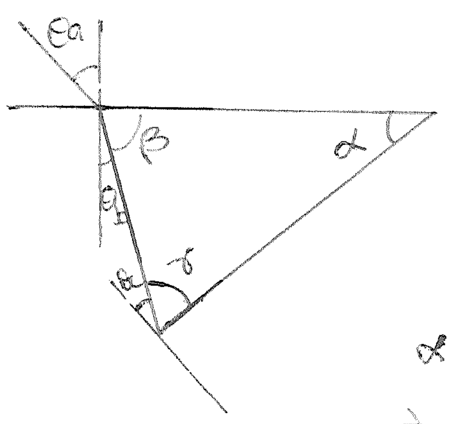
Blue light in Diamond: $n_b = 2.45$

Find Critical Angle. Outside is Air $\Rightarrow n_b \sin\theta_c = (1)\sin 90°$

$\Rightarrow n_b \sin\theta_c = 1 \Rightarrow \sin\theta_c = \frac{1}{n_b} = \frac{1}{2.45} = 0.408$

$\Rightarrow \theta_c = \sin^{-1}(0.408) = 24.0895° = 24.09°$

b) Find largest θ_a so $\theta_c = 24.09°$, $\alpha = 45°$



$\theta_c + \gamma = 90°$ since together they make the Normal line

$\Rightarrow \gamma = 90° - \theta_c = 90° - 24.09° = 65.91°$

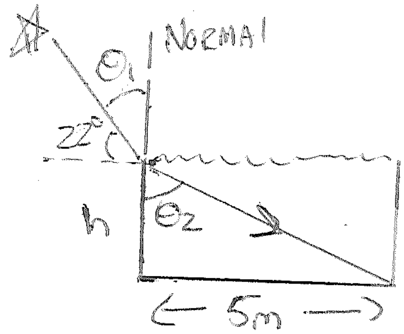
$\alpha + \beta + \gamma = 180°$ since A triangle

$\Rightarrow \beta = 180° - \alpha - \gamma = 180° - 45° - 65.91° = 69.09°$

$\beta + \theta_b = 90° \Rightarrow \theta_b = 90° - 69.09°$
$= 20.91°$

Finally: Snell's Law $\Rightarrow \underset{\text{Air}}{(1)}\sin\theta_a = (2.45)\sin 20.91° \Rightarrow \theta_a = \sin^{-1}(0.8744) = 60.98°$

18.12



LIGHT MUST be REFRACTING ENOUGH to miss bottom of ~~pole~~ pool $\Rightarrow$ at least to FARSIDE AS SHOWN

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

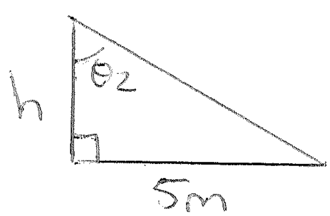
$n_1 = 1$ SINCE AIR

$n_2 = 1.33$ SINCE water

$$\theta_1 = 90° - 22° = 68°$$

$$\therefore (1)\sin 68° = 1.33 \sin\theta_2 \Rightarrow \sin\theta_2 = \frac{\sin 68°}{1.33} = 0.69713$$

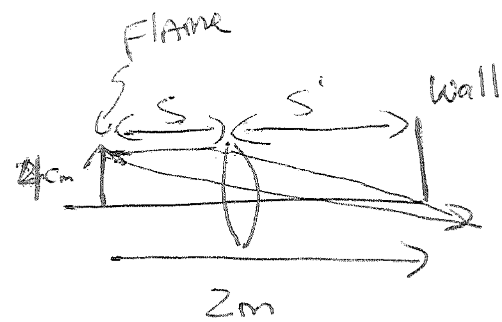
$$\therefore \theta_2 = \sin^{-1}(0.69713) = 44.2°$$



$$\tan\theta_2 = \frac{5m}{h} \Rightarrow h = \frac{5m}{\tan\theta_2} = \frac{5m}{\tan 44.2°}$$

$$\Rightarrow h = 5.1m$$

18. 13



$f = 32\text{cm}$

Want s' to be at wall

So $s + s' = 2\text{m} = 200\text{cm}$

$\Rightarrow s' = 200\text{cm} - s$

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

$$\Rightarrow \frac{1}{s} + \frac{1}{200\text{cm} - s} = \frac{1}{32\text{cm}} \Rightarrow \frac{(200-s)\cdot 1}{(200-s)\,s} + \frac{s \cdot 1}{s(200-s)} = \frac{1}{32}$$

(I'm dropping units!)

$$\Rightarrow \frac{200 - \cancel{s} + \cancel{s}}{(200-s)\,s} = \frac{1}{32} \Rightarrow \frac{200}{(200-s)s} = \frac{1}{32} \Rightarrow 200(32) = (200-s)s$$

$$\Rightarrow 6400 = 200s - s^2 \Rightarrow \text{QUADRATIC}$$

$$\Rightarrow +s^2 - 200s + 6400 = 0 \Rightarrow s = \frac{200 \pm \sqrt{200^2 - 4(1)(6400)}}{2(1)}$$

$$s = \frac{200 \pm \sqrt{14400}}{2} = \frac{200 \pm 120}{2} \Rightarrow s = 160\text{cm AND } 40\text{cm}$$

Two places work

for $s = 40\text{cm}$ $s' = 160\text{cm}$

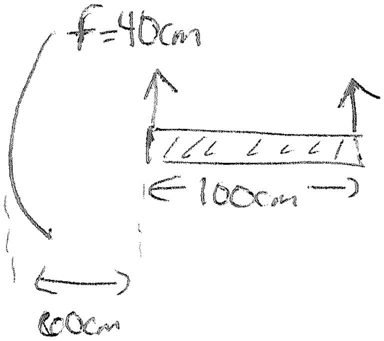
$$\Rightarrow m = -\frac{s'}{s} = \frac{-160}{40} = -4 \quad m = \frac{h'}{h} \Rightarrow h' = mh = -4(4\text{cm}) = -16\text{cm}$$

FOR $s = 160\text{cm}$, $s' = 40\text{cm}$

$$\Rightarrow m = -\frac{40}{160} = -\frac{1}{4} \Rightarrow h' = -\frac{1}{4}\left(\overset{4\text{cm}}{\cancel{2\text{cm}}}\right) = -1\,\text{cm}$$

BOTH INVERTED. ONE with 160cm height, the other 1cm

18.73



How long is image?

We can imagine two objects. One at front, the other at the back..

The distance between the images for these two is the image length.

Concave Mirror $\Rightarrow f = +40cm$

$S_1 = 600cm \qquad \frac{1}{S_1} + \frac{1}{S_1'} = \frac{1}{f} \Rightarrow \frac{1}{600cm} + \frac{1}{S_1'} = \frac{1}{40cm} \Rightarrow \frac{1}{S_1'} = \frac{1}{40cm} - \frac{1}{600cm}$

$\Rightarrow \frac{1}{S_1'} = 0.00833\ldots \Rightarrow S_1' = \frac{1}{0.00833\ldots} = 120cm$

$S_2 = 600cm + 100cm = 1600cm \Rightarrow \frac{1}{1600cm} + \frac{1}{S_2'} = \frac{1}{40cm} \Rightarrow \frac{1}{S_2'} = \frac{1}{40cm} - \frac{1}{1600cm}$

$\Rightarrow \frac{1}{S_2'} = 0.01875 \Rightarrow S_2' = \frac{1}{0.01875} = 53.333cm$

So $S_1' - S_2' = 120cm - 53.333cm = 66.667cm = 67cm$

Note: Mastering Physics uses different isotopes. Here's the original Examples.

30.22 Identify unknown:

$^{234}U \rightarrow X + \alpha$

α Decays $\Rightarrow$ Loses 2 protons and 4 Nucleons $\Rightarrow 234 - 4 = 230$

U has $Z = 92 \Rightarrow$ X has $Z = 90 \Rightarrow$ Th

$\Rightarrow {}^{230}Th$

$^{32}P \rightarrow X + e^-$

β Decay $\Rightarrow$ Loses one neutron, gains one proton $\Rightarrow N = 32$ stays the same $\Rightarrow Z$ increases by 1

P has $Z = 15 \Rightarrow$ X has $Z = 16 \Rightarrow$ S

$\Rightarrow {}^{32}S$

$X \rightarrow {}^{30}Si + e^+$

Did you read the Book? This is "Beta plus" Decay where one of the protons turns into a Neutron and emits a positively charged particle called a positron. $\Rightarrow N = 30$ stays the same but during the decay Z decreases by 1 $\Rightarrow$ X must have Z+1

Si has $Z = 14 \Rightarrow$ X has $Z = 15 \Rightarrow P \Rightarrow {}^{30}P$

$^{24}Mg \to X + \gamma$ No change in Nucleus during gamma decay $\Rightarrow$ $X = {}^{24}Mg$

30.25 Using Appendix D, find Energy in MeV when ^{238}Np undergoes Beta Decay.

Beta Decay $\Rightarrow$ $^{238}Np \rightarrow {}^{238}Pu + \beta^-$

$Z=93$ $\quad Z=94$

From Appendix D: $M_{Np} = 238.050\,946\,u$

$M_{Pu} = 238.049\,555\,u$

Mass of electron : $M_e = 0.000549\,u$

So $\Delta M = M_{Np} - M_{Pu} - M_e = 0.000842\,u$

$\Delta E = \Delta M c^2$ and use $1u = 931.5\,MeV/c^2$

$\Rightarrow \Delta E = (0.000842)\left(\frac{931.5\,MeV}{\cancel{c^2}}\right)\cancel{c^2} = 0.78\,MeV$

3.) Same Thing for Alpha Decay ^{238}Pu

Alpha Decay $\Rightarrow$ $^{238}Pu \rightarrow {}^{234}U + \alpha$

$Z=94$ $\quad Z=92$

Appendix D: $M_{Pu} = 238.049\,555\,u$

$M_U = 234.040\,946\,u$

Alpha Particle: $M_{He} = 4.0026\,u$

$\Delta M = M_{Pu} - M_U - M_{He} = 0.006009\,u$

$\Delta E = \Delta M c^2 = (0.006009)(931.5\,\frac{MeV}{\cancel{c^2}})\cancel{c^2}$

$= 5.59738\,MeV = 5.6\,MeV$

30.63 $\quad {}^{40}K \rightarrow {}^{40}Ar + \beta^+$ OCCURS 10.9% of the time.

STRANGE, β^+ DECAY which I didn't talk about in class

start with No ${}^{40}Ar$. After sometime $\frac{N_{Ar}}{N_K} = 2.6\times10^{-4}$

A.) ~~what~~ $\frac{N_K}{N_{0,K}} = ?$ IN THE EQN, $N = N_0 \left(\frac{1}{2}\right)^{t/t_{1/2}}$

N_0 IS the ORIGINAL # of SOME Nucleus AND N IS the # of that SAME Nucleus REMAINING!

$\Rightarrow N_K = N_{0,K} \left(\frac{1}{2}\right)^{t/t_{1/2}}$ DOES NOT have Argon IN IT AT All.

We have to be tricky! The TOTAL # of Nuclei IS staying the SAME. It's just that they ARE different types.

$\Rightarrow$ the # of K AND the # of Other Stuff Must still ADD to be No

$\Rightarrow N_K + N_{other} = N_{0,K} \Rightarrow N_{other} = N_{0,K} - N_K$

of those other Nuclei 10.9% of them Are Argon (The rest are Calcium) $\Rightarrow N_{Ar} = .109\, N_{other} \Rightarrow N_{Ar} = 0.109\,(N_{0,K} - N_K)$

we know

$$\frac{N_{Ar}}{N_K} = 2.6\times10^{-4} \Rightarrow \frac{0.109(N_{0,K}-N_K)}{N_K} = 2.6\times10^{-4}$$

$$\Rightarrow \frac{N_{0,K}-N_K}{N_K} = \frac{2.6\times10^{-4}}{0.109} = 0.002385 \Rightarrow \frac{N_{0,K}}{N_K} - \frac{N_K}{N_K} = 0.002385$$

$$\Rightarrow \frac{N_{0,K}}{N_K} - 1 = 0.002385 \Rightarrow \frac{N_{0,K}}{N_K} = 1.002385$$

$$\Rightarrow \frac{N_K}{N_{0,K}} = \frac{1}{1.002385} = \underline{0.99762}$$

b.) How many millions of years old is the rock (and therefore the fossil)

Now, we use $N_K = N_{0,K}\left(\frac{1}{2}\right)^{t/t_{1/2}} \Rightarrow \frac{N_K}{N_{0,K}} = \left(\frac{1}{2}\right)^{t/t_{1/2}}$

$t_{1/2} = 1.28\times10^{9}$ years $= (1.28\times1000)\times10^{6}$ years $= 1280$ million years

billion

$$\therefore 0.99762 = \left(\frac{1}{2}\right)^{t/1280} \Rightarrow \ln(0.99762) = \ln\left(\frac{1}{2}^{t/1280}\right) = \frac{t}{1280}\ln(0.5)$$

$$\therefore \frac{t}{1280} = \frac{\ln(0.99762)}{\ln(0.5)} \Rightarrow t = \frac{1280(-0.002382)}{(-0.69315)} = \underline{4.4 \text{ million yrs}}$$

30.59 $R_0 = 115mCi = 115(1\times10^{-3})Ci = 0.115Ci$

16 hours later $R = 95mCi = 0.095Ci$

lowest usable amount is $10mCi = 0.01Ci$

a) what is half life?

$R = R_0 (\frac{1}{2})^{t/t_{1/2}}$ so Actually we can use any unit

for R & R_0

$\Rightarrow 95mCi = 115mCi \, (\frac{1}{2})^{16h/t_{1/2}} \Rightarrow (\frac{1}{2})^{16h/t_{1/2}} = \frac{95mCi}{115mCi} = 0.826$

You can use either, but I'll use ln to solve

$\ln\left(\frac{1}{2}^{16h/t_{1/2}}\right) = \ln(0.826) \Rightarrow \frac{16h}{t_{1/2}} \ln(\frac{1}{2}) = \ln(0.826)$

$\Rightarrow \frac{16h}{t_{1/2}} = \frac{\ln(0.826)}{\ln(0.5)} = \frac{-0.191}{-0.693} = 0.2756$

$\Rightarrow t_{1/2} = \frac{16h}{0.2756} = 58h$

b) How long after delivery?

Now let $R_0 = 95mCi$ AND $R = 10mCi$

$$R = R_0\left(\tfrac{1}{2}\right)^{t/t_{1/2}} \Rightarrow 10mCi = 95mCi\left(\tfrac{1}{2}\right)^{t/58h}$$

$$\Rightarrow \left(\tfrac{1}{2}\right)^{t/58h} = \frac{10mCi}{95mCi} = 0.105$$

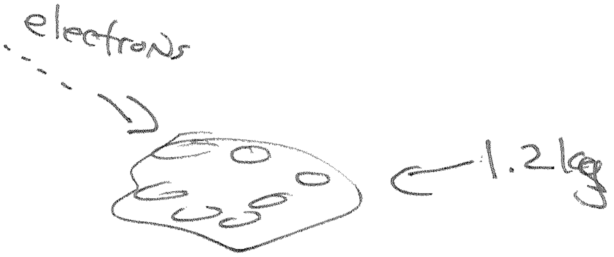
$$\Rightarrow \ln\left[\left(\tfrac{1}{2}\right)^{t/58h}\right] = \ln(0.105) \Rightarrow \frac{t}{58h} \cdot \ln\left(\tfrac{1}{2}\right) = \ln(0.105)$$

$$\Rightarrow t = 58h\,\frac{\ln(0.105)}{\ln(0.5)} = 58h\left(\frac{-2.25}{-0.693}\right)$$

$$= 58h(3.2486) = \underline{\underline{188h}} = 188h \times \frac{day}{24h} = 7.85\,day$$

about a week

30.67 GROUND BEEF IRRADIATED WITH High Energy electrons



4.5 KGy in 40 s

a) How much energy deposited in Kilojoules.

GRAY (Gy) is the unit of DOSE, $\text{Dose} = \frac{\text{Energy}}{\text{MASS}}$ i.e. $D = \frac{\Delta E}{m}$

ΔE = Energy deposited $\therefore \Delta E = Dm$

A Gray is J/kg $\Rightarrow D = 4.5\,\text{KGy} = 4500\,\text{Gy}$

AND $\Delta E = (4500\,\text{J/kg})(1.2\,\text{kg}) = 5400\,\text{J} \times \frac{\text{kJ}}{1000\,\text{J}} = \underline{5.4\,\text{kJ}}$

I probably should have been smart AND Noticed that

$\text{KGy} = 1000 \cdot \frac{\text{J}}{\text{kg}} = \frac{\text{kJ}}{\text{kg}}$ so $(4.5\,\text{KGy})(1.2\,\text{kg}) = 5.4\,\text{kJ}$

b) what is avg. rate (in Watt) of energy deposit.

Power

Power, $P = \frac{\Delta E}{\Delta t}$

$\Delta t = 40\,\text{s}.$

ΔE must be in Joules AND Δt in seconds to get Watts.

so $P = \frac{5400J}{40s} = \underline{135 \text{ watt}}$ ← just slightly more than a lightbulb

C.) Estimate temp. Increase. Assume all energy turned into heat. Heat and temp. change in a solid ⇒

$Q = mc\Delta T$

$C = 3/4$ of water ⇒ $C = \frac{3}{4}(4190 J/kg \cdot C^\circ) = 3142.5 J/kg \cdot C^\circ$

All energy turned into heat ⇒

$Q = \Delta E = 5400J$, $m = 1.2kg$

$\Delta T = \frac{Q}{mc}$ (Notice that $\frac{Q}{m} = \frac{\Delta E}{m} = D = 4500 Gy$

so another way to figure out the temp. change is $\Delta T = \frac{D}{c}$)

Either way $\Delta T = \frac{4500 J/kg}{3142.5 J/kg C^\circ} = \underline{1.43^\circ C}$

So for about the same amount of Power as a lightbulb, we can produce enough energy to kill of DANGEROUS pathogens ~~AND~~ without raising the temp. too much ⓐ using irradiation.

30.53 75Kg patient swallows 30μCi beta emitter

~~...~~ $t_{1/2} = 5$days, RBE = 1.6

Beta particles have $E_\beta = 0.35$MeV, 90% of which is absorbed by body.

A: How many particles initially?

From the activity and the halflife, we can determine the #.

$R = \frac{N \ln(2)}{t_{1/2}}$. We know that when swalled $R_0 = 30\mu Ci$

$\Rightarrow R_0 = \frac{N_0 \ln(2)}{t_{1/2}} \Rightarrow N_0 = \frac{R_0 t_{1/2}}{\ln(2)}$

have to use Bq = decays per second and $t_{1/2}$ in seconds

~~1Bq~~ $1\ Ci = 3.7 \times 10^{10}\ Bq$

$\Rightarrow 30\mu Ci = 30(10^{-6})\ Ci \times \frac{3.7\times10^{10}\ Bq}{1\ Ci} = 1{,}110{,}000\ Bq$

$t_{1/2} = 5\text{days} \times \frac{24h}{day} \times \frac{3600s}{h} = 432\,000s$

$\therefore N_0 = \frac{(1{,}110{,}000\ Bq)(432000s)}{\ln(2)} = \underline{6.918\times10^{11}}$

(No unit since solving for a number)

B.) How many Nuclei Remain after a week?

Now use $N = N_0 \left(\frac{1}{2}\right)^{t/t_h}$

We can use any for t and t_h as long as they are the SAME! A week ⇒ t = 7 days, & t_h = 5 days

$\therefore N = 6.918 \times 10^{11} \left(\frac{1}{2}\right)^{7/5} = \underline{2.621 \times 10^{11}}$

C) How many Decays? Each Decay Removes (decreases the # of) one of the ~~RA initial type~~ RADIOACTIVE Nuclei

$\Rightarrow N_D = N_0 - N = 6.918 \times 10^{11} - 2.621 \times 10^{11} = \underline{4.297 \times 10^{11}}$

D) Each Decay Deposits 90% of 0.35 MeV

$\Rightarrow .9(0.35\,\text{MeV}) = 0.315\,\text{MeV} = 0.315(10^6)\,\text{eV} = 3.15 \times 10^5\,\text{eV}$

$3.15 \times 10^5\,\text{eV} \times \frac{1.6 \times 10^{-19}\,\text{J}}{\text{eV}} = 5.04 \times 10^{-14}\,\text{J}$

So the total Energy is 5.04×10^{-14} J times the # of decays!

$\Delta E = (5.04 \times 10^{-14}\,\text{J})(4.297 \times 10^{11}) = \underline{0.0217\,\text{J}}$

E) DOSE EQUIVALENT IN mSV?

$$\text{DOSE} = \frac{\Delta E}{m} = \frac{0.0217\,J}{75\,Kg} = 2.89\times10^{-4}\,Gy$$

J/kg = Gray

$$\text{DOSE EQUIVALENT} = \text{DOSE} \times \text{RBE} = (2.89\times10^{-4}\,Gy)(1.6)$$
$$= 4.62\times10^{-4}\,Sv$$

Different unit to distingush

$$4.62\times10^{-4}\,Sv \times \frac{1000\,mSv}{Sv} = 0.462\,mSV = \underline{0.46\,mSV}$$

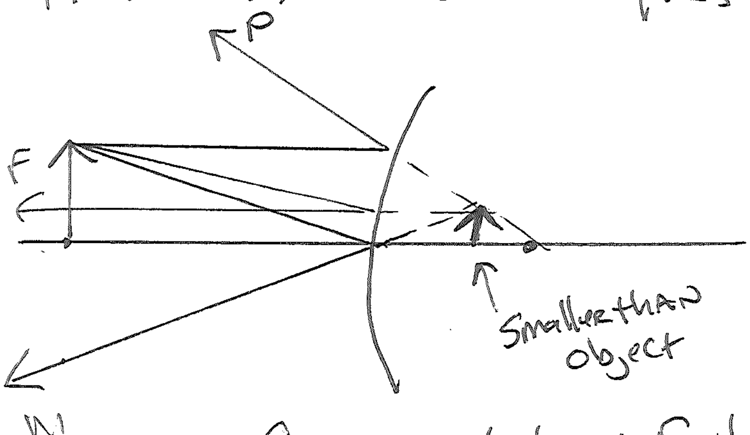
Written Question #1:

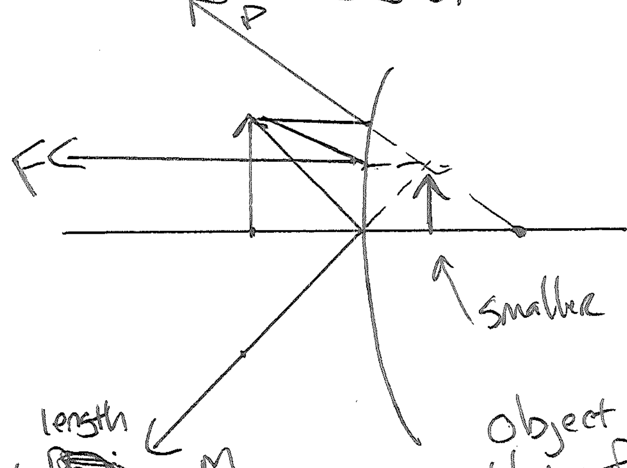
I know the instructions say to use graph paper, but it doesn't scan well. So I'm doing this on regular paper. You, however, have to use graph paper.

Dentist wants mirror to give upright virtual image with $m = 1.8$ when object is 2 cm away.

What type of mirror?

Both concave and convex mirrors can give virtual images. Convex mirrors always give virtual images but their images always have magnification less than 1. Two examples are shown below.

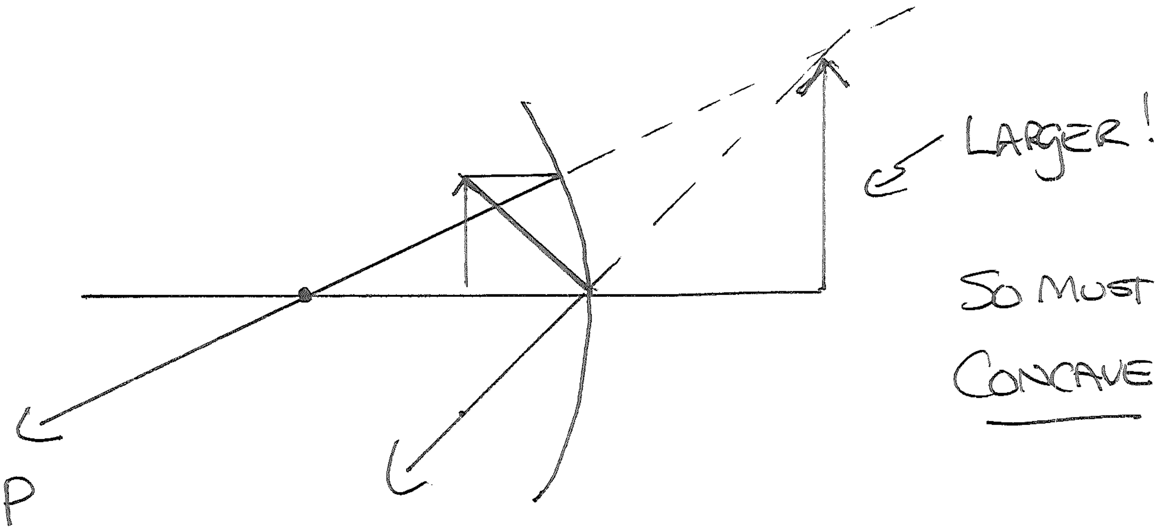




Convex w/ object farther than focal length

object closer than focal length

HOWEVER, WHEN WE put AN Object CLOSER THAN THE FOCAL LENGTH of A CONCAVE MIRROR, WE get AN VIRTUAL image whose magnification is LARGER THAN 1!



SO MUST BE A CONCAVE MIRROR.

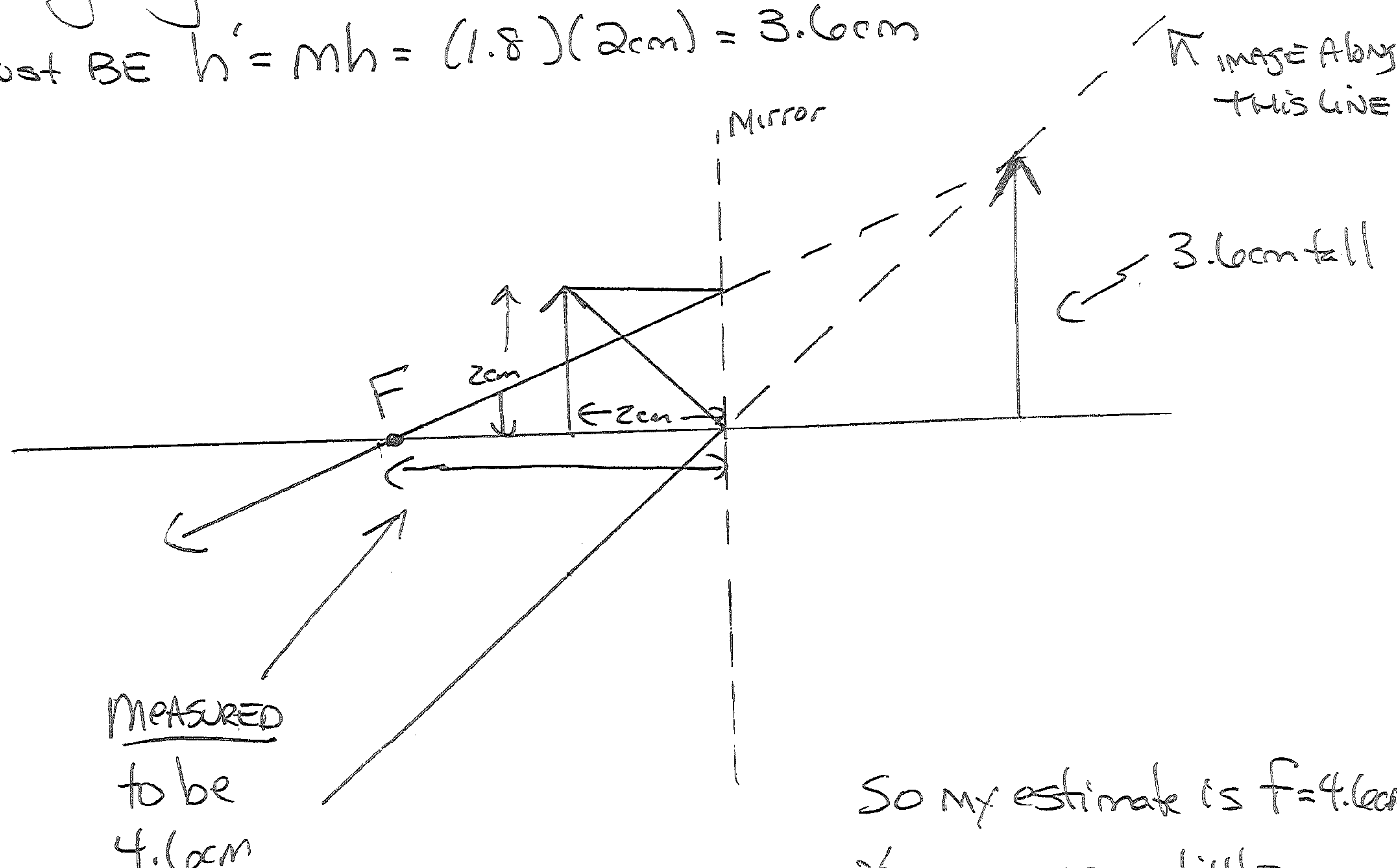
ESTIMATE FOCAL LENGTH:

WITHOUT KNOWING the FOCAL LENGTH, WE CAN ONLY DRAW THE M-RAY. BUT WE CAN TRACE ~~TREAT~~ IT BACKWARDS TO find the LINE THAT THE top of IMAGE MUST BE ON. USING THE magnification WE KNOW how tall THE image MUST BE, SO We'll USE THAT LINE AND THE Height to find the image. We'll then finish By DRAWING the F-RAY, "BACKWARDS" MEANING We'll DRAW from the object to the mirror, From there we'll TRACE BACKWARDS to the (cont.)

IMAGE, THEN WE REVERSE THAT LINE TO FIND THE REFLECTED RAY. Where THE REFLECTED RAY PASSES THROUGH THE OPTICAL AXIS IS OUR ESTIMATE OF THE FOCAL LENGTH.

Also SINCE WE DON'T KNOW THE FOCAL LENGTH, WE DONT KNOW how CURVED TO MAKE THE MIRROR. SO JUST DRAW A VERTICAL LINE to REPRESENT IT. (THAT'S REALLY WHAT YOU'RE SUPPOSED TO DO WITH MIRROR DIAGRAMS ANYWAY.

I'M going TO MAKE MY Object 2cm tall, SO THE IMAGE height must BE $h' = mh = (1.8)(2cm) = 3.6cm$



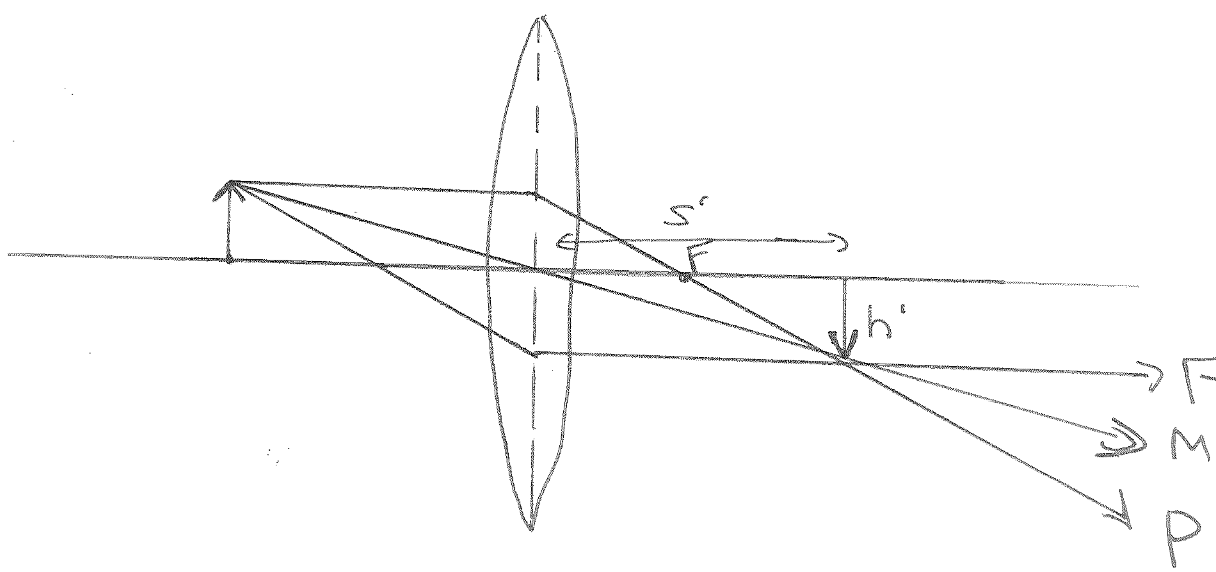
So my estimate is $f = 4.6cm$.
YOURS MAY BE A little Different

Bonus Question #1

$h = 5cm$, $s = 20cm$, $f = 10cm$ converging

To fit on page, I'll have to scale everything.

I'll scale by 5 $\Rightarrow$ h = 1 space, s = 4 spaces, f = 2 spaces



I measure s' to be 4.1 spaces and h' to be 1 space

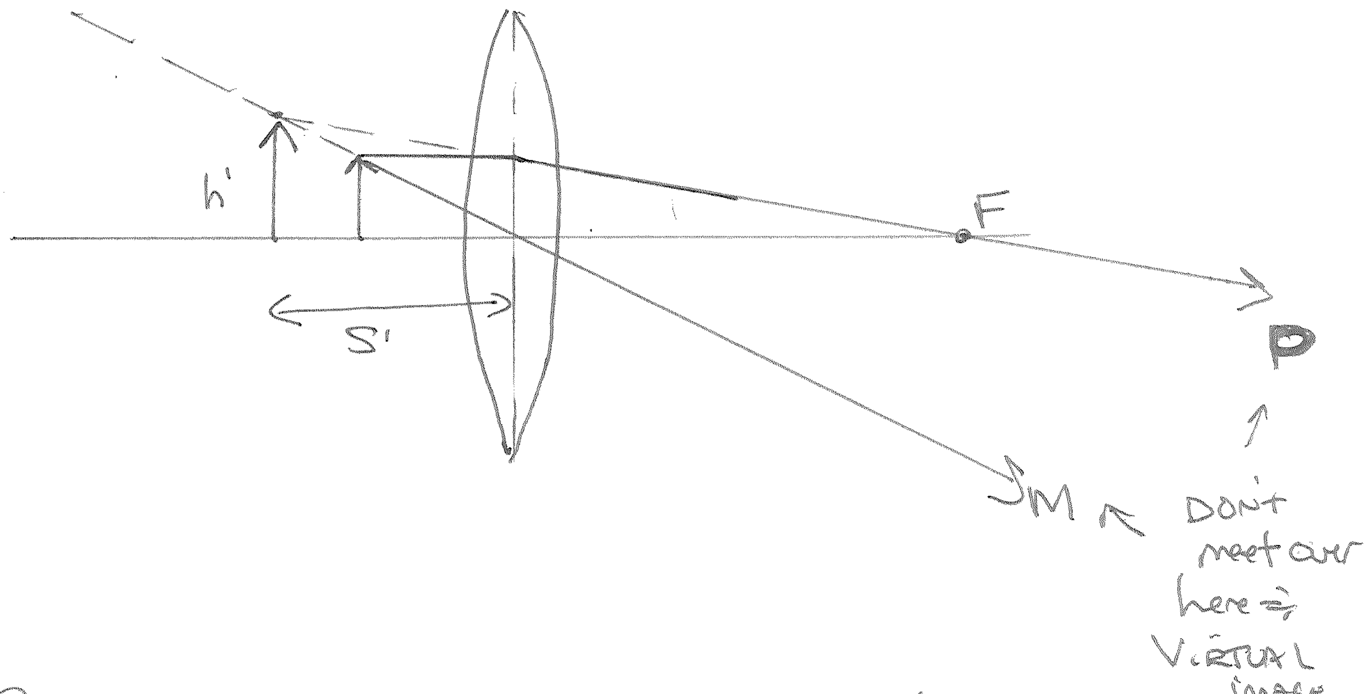
$4.1(5) = 20.5$ $\quad 1(5) = 5$

So my estimates are $s' = 20.5cm$, $h' = 5cm$

Bonus Question #2

$h = 10\text{cm}$ $s = 20\text{cm}$, $f = 60\text{cm}$ CONVERGING

THIS TIME I'll SCALE by 10 $\Rightarrow h = 1, s = 2, f = 6$



CAN'T DRAW F-RAY HERE SINCE Object IS CLOSER THAN FOCAL Length, SO just USE P AND M to FIND IMAGE

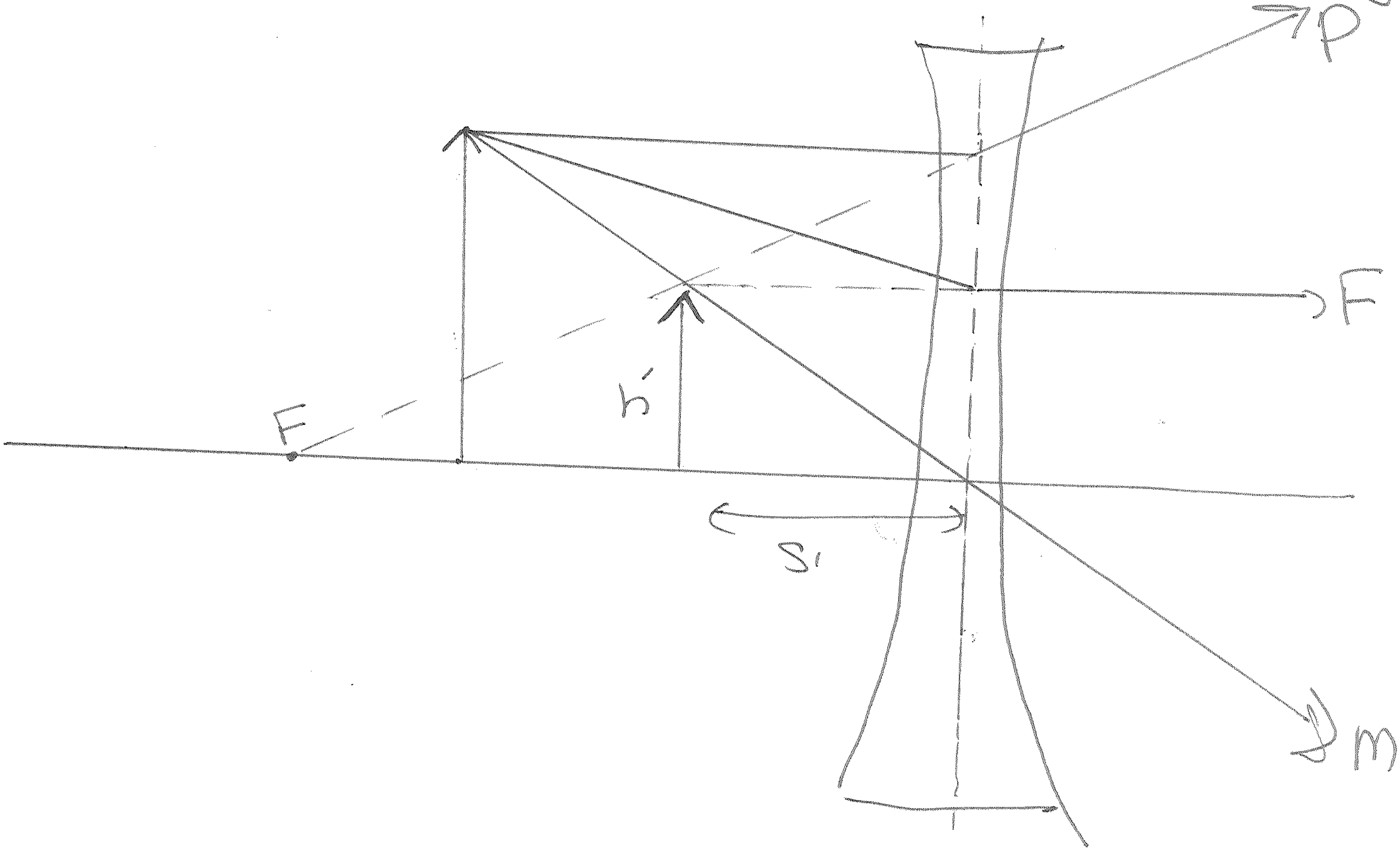
MEASURE s' to be 3.1 SPACES (to left) $\Rightarrow s' = -31\text{cm}$ (Negative ⇒ VIRTUAL)

h' to be 1.7 SPACES $\Rightarrow h' = 17\text{cm}$

Bonus Question #3

$h = 5cm$, $s = 7.5cm$, $f = 10cm$ DIVERGING ($f = -10cm$ if doing math)

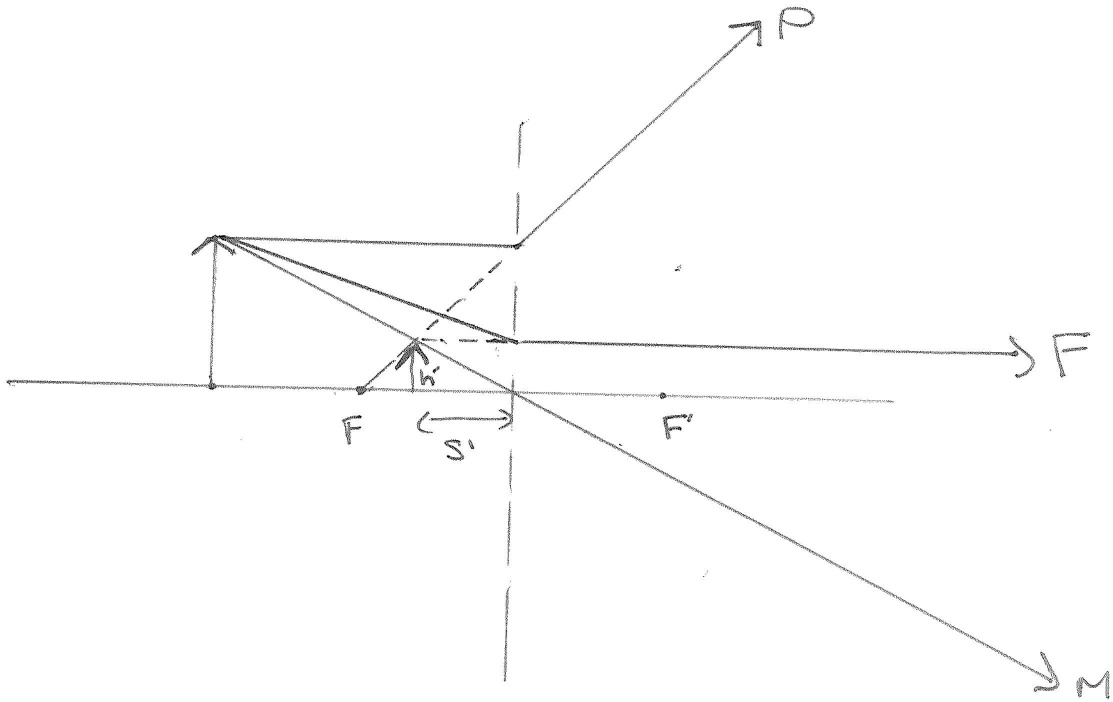
It will be big, but I think I can fit this without scaling!



P, F, M DON'T MEET ON RIGHT SIDE ⇒ VIRTUAL IMAGE.
TRACING BACK AND MEASURING (NO NEED TO SCALE) ⇒
$s' = -4.3cm$ $h' = 2.7cm$

Bonus Question #4 $h = 50cm$, $s = 100cm$, $f = 50cm$
diverging

Let's scale by 25 $\Rightarrow h = 2$, $s = 4$, $f = 2$



I MEASURE $s' = -1.4 \Rightarrow s' = -1.4(25) = -35cm$

$h' = 0.75 \Rightarrow h' = 0.75(25) = 18.75cm$

Notice Bonus Questions #3 AND #4 show us THAT THERE IS NO ~~DIFFERENCE~~ CHANGE IN IMAGE TYPE FOR object DISTANCES CLOSER OR FARTHER AWAY THAN FOCAL LENGTH FOR DIVERGING lenses.

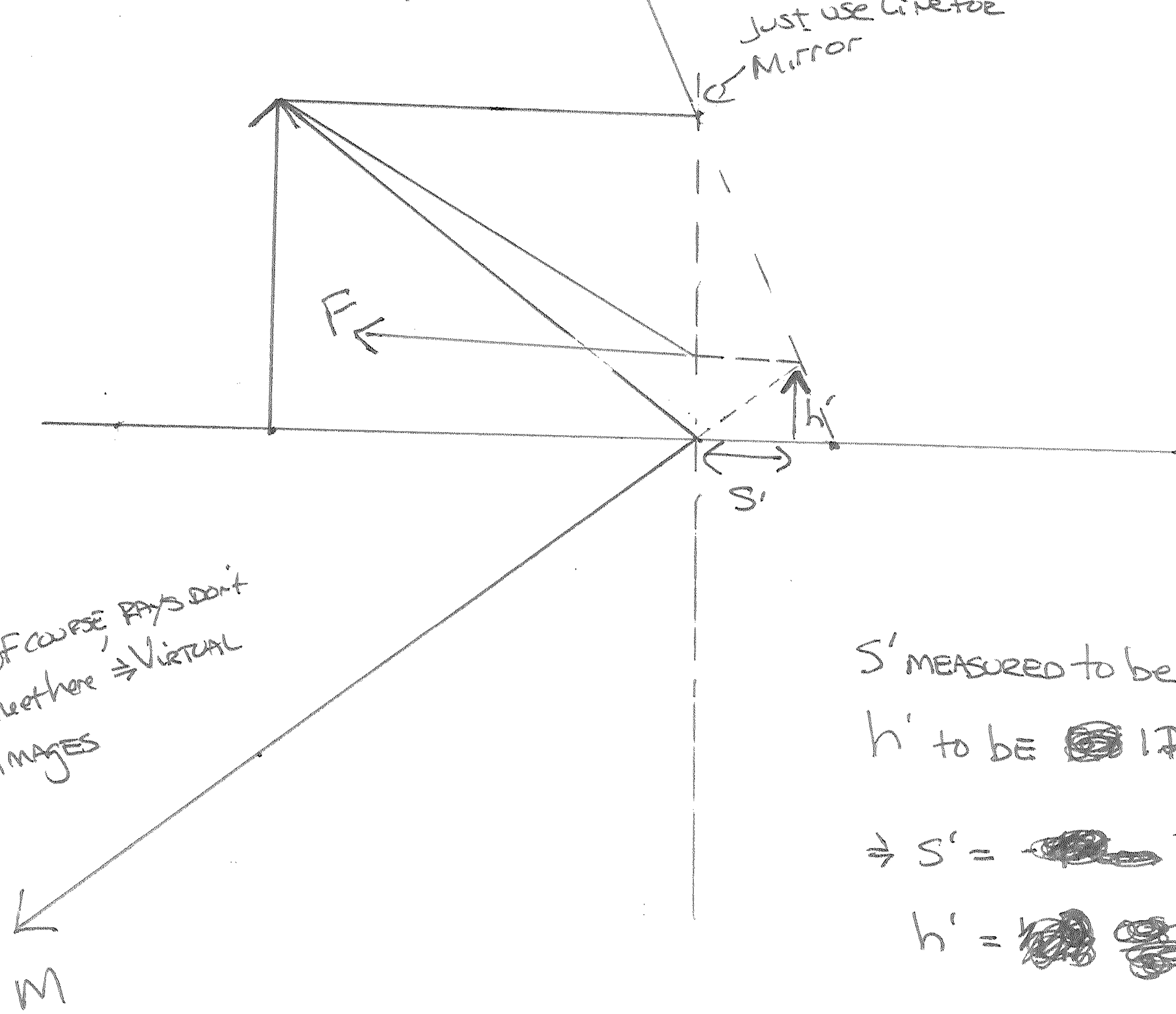
#1 AND #2 show us (AGAIN) that FOR CONVERGING lenses, images BECOME VIRTUAL when objects ARE placed closer THAN focal length.

Bonus Question #5 $h = 1.60\,m$, $s = 2\,m$ $f = 2/3\,m$ for

Convex mirror

($f = -2/3$ in math)

Let's scale this by 3 $\Rightarrow h = 4.8$ spaces, $s = 6$ spaces, $f = 2$ spaces



S' measured to be -1.4

h' to be 1.2

$\Rightarrow S' = \frac{-1.4}{3} = -0.467\,m$

$h' = \frac{1.2}{3} = 0.4\,m$