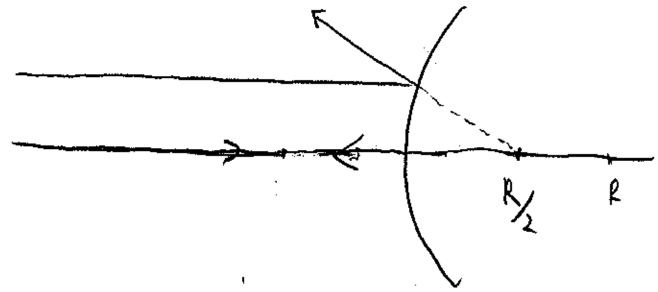
Practice Final Exam Solutions

(1.)

a.)



I should have specified a convex mirror geometry ☆

b.) $\frac{1}{s'} + \frac{1}{s} = \frac{1}{f}$ for a spherical mirror

$f = -R/2$

$s = \infty$

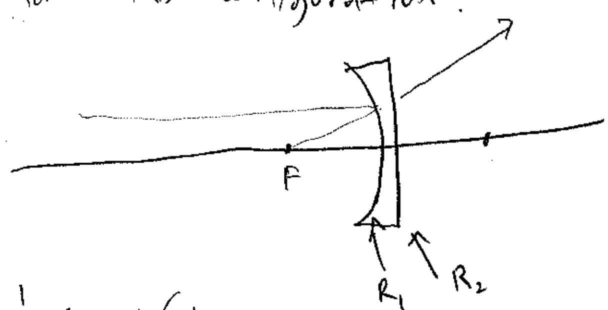
$s' = f = -R/2$

c.) $f = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$ for the planar surface

$R \to \infty$

From sign rules, R is positive when center of curvature is on outgoing side,

for this configuration:



$R_1 = -R$ ← assuming same R as in mirror.

$R_2 = \infty$

$\frac{1}{f} = (n-1)\left(\frac{1}{-R} - 0\right)$

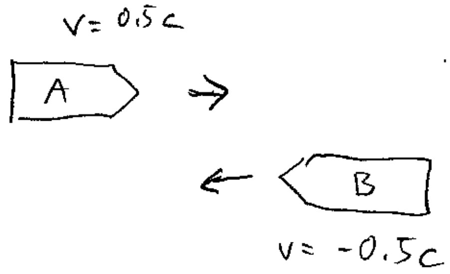
$\frac{1}{f} = -\frac{(n-1)}{R}$ so $n = 3$

Images are infinitely small, but in the limit:

d.) mirror: $m = -s'/s$ $m > 0$ erect, virtual

lens: $m = -s'/s$ $m > 0$ erect, virtual

(2.)



a) this is velocity addition

$$v_x' = \frac{v_x - V}{1 - \frac{V v_x}{c^2}}$$

take spaceship A to be new ref. frame.

velocity of B in new ref. frame is then

$$v_x' = \frac{(-0.5c) - (0.5c)}{1 - \frac{(0.5c)(-0.5c)}{c^2}} = \frac{-c}{1 + .25}$$

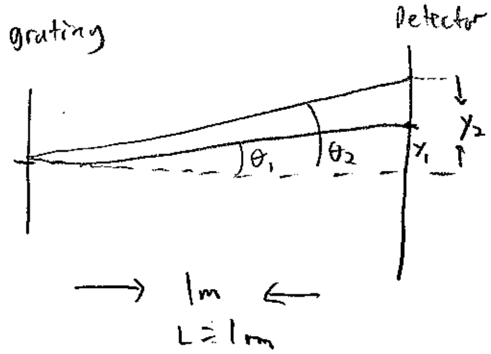
$$v_x' = -\frac{4}{5}c$$

b.) 10 m/s is insignificant compared to $\frac{4}{5}c$

$$v_{baseball} \approx \frac{4}{5}c$$

$$K = (\gamma - 1) mc^2 = \left(\frac{1}{\sqrt{1 - \frac{16}{25}}} - 1\right)(0.1\ kg)\left(3 \times 10^8\ m/s\right)^2$$

3.



take

$m = 1$

$$D = \frac{1\,cm}{10^4} = \frac{10^7\,nm}{10^4} = 10^3\,nm = 10^{-6}\,m$$

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

$$\theta_1 = \sin^{-1}\left[\frac{\lambda_1}{D}\right]$$

$$\theta_2 = \sin^{-1}\left[\frac{\lambda_2}{D}\right]$$

$$\tan\theta_1 = \frac{y_1}{L}$$

$$\tan\theta_2 = \frac{y_2}{L}$$

$$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

for λ_1

$n_i = 3 \quad n_f = 2$

$$\frac{1}{\lambda_1} = R\left(\frac{1}{4} - \frac{1}{9}\right) = R\,\frac{5}{36}$$

for λ_2

$$\frac{1}{\lambda_2} = R\left(\frac{1}{4} - \frac{1}{16}\right) = R\,\frac{3}{16}$$

$$\lambda_1 = \frac{36}{5R} \qquad \lambda_2 = \frac{16}{3R}$$

Spacing of detector is

$$y_2 - y_1 = L\left(\tan\theta_2 - \tan\theta_1\right) = L\left\{\tan\left[\sin^{-1}\left(\frac{36}{5RD}\right)\right] - \tan\left[\sin^{-1}\left(\frac{16}{3RD}\right)\right]\right\}$$

if we make a (not very good in this case since $\lambda \sim D$) small angle approximation

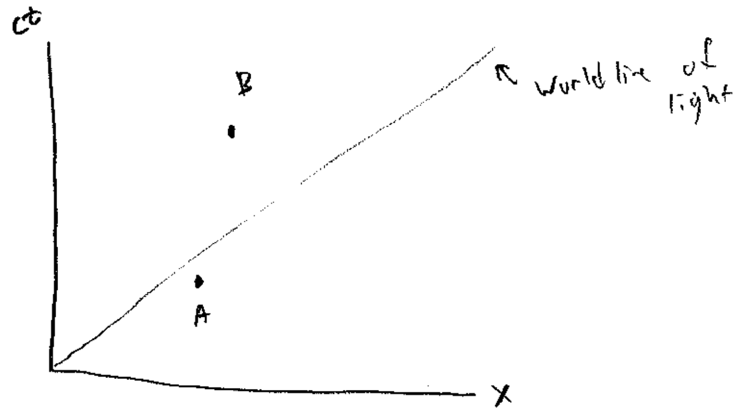
$\sin\theta \approx \tan\theta \approx \theta$

$$y_2 - y_1 = \frac{L}{RD}\left[\frac{36}{5} - \frac{16}{3}\right] \approx \frac{1\,m}{(1.1\times10^{7}\,m^{-1})(10^{-6}\,m)}\left[7 - 5\right] \approx 0.2\,m$$

(4.)

If Δs is real, then the interval is

<u>time like</u>



It is not possible for time like events to reverse order in other frames.

(5.)

For the Bohr model

$$L = n\hbar \quad , n = 1, 2, 3$$

So the lowest energy level, $n = 1$

$$L = \hbar$$

From the schrödinger solution

$$\ell = 0, 1, \dots n-1$$

So for $n = 1$

$$\ell = 0$$

$$L = \sqrt{\ell(\ell+1)}\,\hbar = 0$$

Schrödinger solution gives correct orbital angular momentum.

(6.)

$I = \sigma T^4$

$P = AI = 4\pi R^2 \sigma T^4$

take $T \sim 300\ K$

$\sigma = 5.67 \times 10^{-8}\ J\ s^{-1}\ m^{-2}\ K^{-4}$

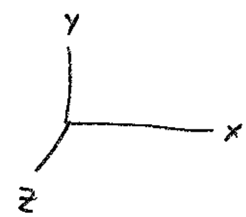
$P = 4\pi \left(6.4 \times 10^6\ m\right)^2 \left(5.67 \times 10^{-8}\ \frac{J}{s\,m^2 K^4}\right)\left(300\ K\right)^4$

$= 2.4 \times 10^{12}\ W$

(7.)

$\vec{E} = E_{max} \sin(kx - wt)\ \hat{k}$

$\vec{B} = \frac{-E_{max}}{c} \sin(kx - wt)\ \hat{j}$



(8.)

$4s \to 3s$ not allowed by selection rule $\Delta l = \pm 1$, here $\Delta l = 0$

$4s \to 3p$ OK,

$4p \to 3s$ O.k,

$4d \to 1s$ $\Delta l = 2$, not allowed