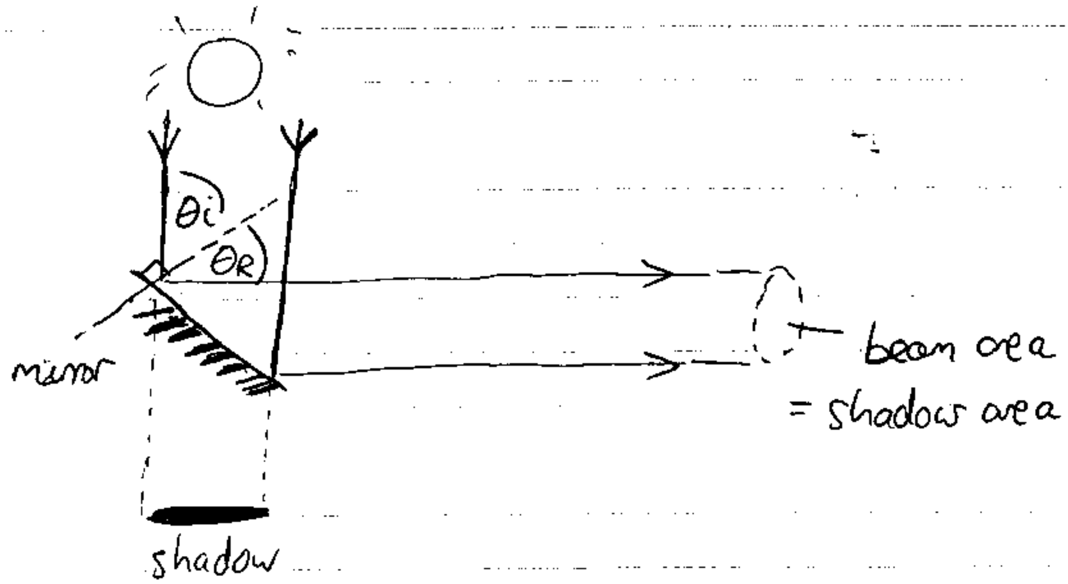
Physics 1C Quiz 1 Solutions

1a) Time to reach Earth = $\frac{\text{distance}}{\text{speed}} = \frac{150 \times 10^9 \text{ m}}{3 \times 10^8 \text{ m/s}} = \underline{500 \text{ s}}$ (~8 min)

[By the way: sun's power $P = 4\pi r^2 I$ with r = distance $= 2.96 \times 10^{26}$ W].

b)



To reflect sunlight through $\theta_i + \theta_R = 90°$ (vertical → horizontal)

using $\theta_i = \theta_R \Rightarrow \theta_i = \theta_R = \underline{45°}$

c) Mirror has area 0.12 m^2, but tilted at 45°

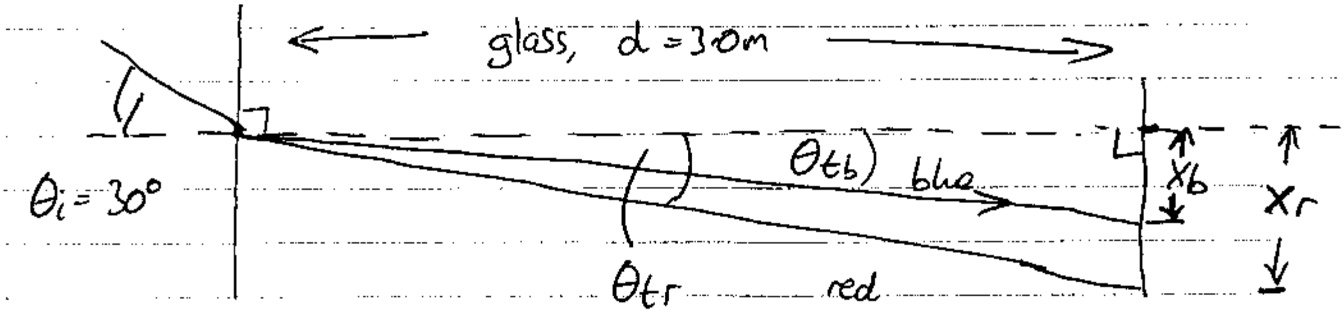
$\Rightarrow$ shadow under mirror has area $0.12 \text{ m}^3 \cos 45°$
$= 0.0845 \text{ m}^2$

(note: does not depend on shape of mirror, can use squares to make any shape).

So mirror intercepts and reflects a power $P_M = I \times 0.0845 \text{ m}^2$
$= 1.05 \times 10^3 \text{ W/m}^2 \times 0.0845 \text{ m}^2$
$= \underline{89.1 \text{ W}}$

similar power to light bulb, but collimated in parallel beam (not isotropic)

2.



Blue light "sees" higher refractive index so is bent more (towards normal)

a) Inside block, wavelength $\lambda = \frac{v}{f} = \frac{c}{nf} = \frac{\lambda_0}{n}$ ← vacuum

So red : $\lambda_0 = 700\,\text{nm},\ n = 1.25 \rightarrow \quad \lambda = 560\,\text{nm}$
blue : $\lambda_0 = 400\,\text{nm},\ n = 2.0 \rightarrow \quad \lambda = 200\,\text{nm}$.

b) From Snell's law, $\sin\theta_t = \frac{n_i}{n_t}\sin\theta_i = \frac{1 \times \sin 30^\circ}{n} = \underline{\frac{0.5}{n}}$

red: $\theta_{tr} = \sin^{-1}\left(\frac{0.5}{1.25}\right) = 23.58^\circ$ blue: $\theta_{tb} = \sin^{-1}\left(\frac{0.5}{2}\right) = \cancel{28.58}^\circ$

Over block length $d = 3.0\,\text{m}$, each beam is deflected by a distance from normal $x = d\tan\theta_t$
So separation of beams $x_r - x_b = d\,(\tan\theta_{tr} - \tan\theta_{tb})$
$= 3.0(\tan 23.58 - \tan 14.47)$

$\underline{\Delta x = 0.535\,\text{m}}$

c) Time for beam inside block = $\frac{\text{distance}}{\text{speed}}$. speed $v = c/n$
distance $= d/\cos\theta_t \Rightarrow$ time $= \frac{dn}{c}\cos\theta_t$

$\therefore$ time delay $\Delta t = t_r - t_b = \frac{d}{c}\left(\frac{n_b}{\cos\theta_{tb}} - \frac{n_r}{\cos\theta_{tr}}\right) = 7.0$
$\underline{= 7.016\,\text{ns}}$

d) For $n_B = 2.0,\ n_W = 1.33,\ n_{air} = 1.0$

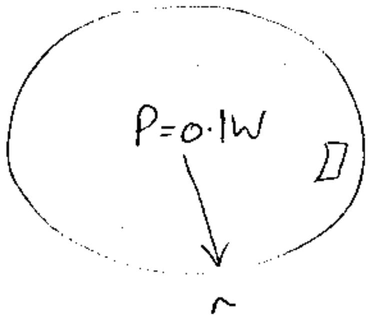
$\theta_c\ (\text{air}) = \sin^{-1}\left(\frac{1}{2}\right) = 30^\circ \quad \theta_c\ (\text{water}) = \sin^{-1}\left(\frac{1.33}{2.0}\right) = 41.68^\circ$

note: no total internal reflection for red light underwater

3. Antenna length $\frac{\lambda}{4} = \frac{c}{4f} = \frac{3 \times 10^8 m/s}{4 \times 2.4 \times 10^9 Hz} = 0.03125m$

or $\underline{3.125cm}$

b) Emitting 0.1W over a sphere with radius $r = 15m$



$$I = \frac{P}{4\pi r^2} = \frac{0.1}{4\pi (15)^2}$$

$$= 35.37 \mu W/m^2$$

c) Using $I = \frac{1}{2} c \varepsilon_0 E_0^2 = 35.37 \times 10^{-6} W/m^2$

$$E_0 = \sqrt{\frac{2I}{c\varepsilon_0}} = 0.1632 \quad V/m$$

$\Rightarrow$ potential diff. in antenna $\Delta V = E_0 \times$ length

$= 0.1632 \times 0.03125 = 0.0051 V$

or $\underline{5.1 mV}$.