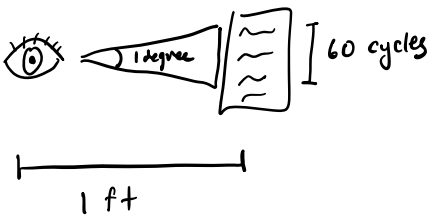
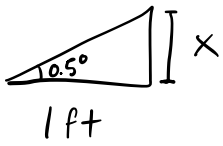
12.1 a) Assume metal-halide lamp, 100 lm/W

$1000\ \text{lm} \cdot \frac{1\ \text{W}}{100\ \text{lm}} = \boxed{10\ \text{W}}$

b) Eye can resolve 60 cycles per degree

Assume book held 1 ft from face




$\tan(0.5\ \text{deg}) = \frac{x}{1\ \text{ft}} \rightarrow x = 2.66\ \text{mm}$

60 cycles in 5.32 mm → 11.3 cycles per mm

→ $\boxed{88.7\ \mu\text{m per cycle}}$

**12.2** a) $U = \frac{8\pi h\nu^3}{c^3(e^{h\nu/kT}-1)}$

$\frac{dU}{d\nu} = \frac{8\pi h}{c^3} \cdot \left( \frac{-\nu^2\left(\left(\frac{h\nu}{kT}-3\right)\cdot e^{h\nu/kT}+3\right)}{(e^{h\nu/kT}-1)^2} \right) = 0$

$\hookrightarrow -\nu^3\left(\left(\frac{h\nu}{kT}-3\right)\cdot e^{h\nu/kT}+3\right) = 0$

$\hookrightarrow \left(\frac{h\nu}{kT}-3\right)e^{h\nu/kT} = -3$

Human temp = 310 K $\rightarrow \frac{h}{kT} = 1.55\times10^{-13}$

$\rightarrow \nu_{pk} = \boxed{1.82\times10^{13}\ Hz}$

Cosmic background = 2.74k $\rightarrow \frac{h}{kT} = 1.75\times10^{-11}$

$\rightarrow \nu_{pk} = \boxed{1.61\times10^{11}\ Hz}$

b) red light = 700nm

$\nu = \frac{c}{\lambda} = \frac{3\times10^8\ m/s}{700\times10^{-9}\ m} = 4.29\times10^{14}\ Hz$

$\frac{h\nu}{k} = 2.06\times10^4 \rightarrow T = \boxed{7290\ K}$

c) $T = 310k$

Area = $1.7m^2$

$R = 5.67\times10^{-8}\ T^4\ W/m^2\ |_{T=310k} = 524\ W/m^2$

$524\ W/m^2 \cdot 1.7m^2 = \boxed{890\ W}$

**12.3** a) $\begin{pmatrix} E_{slow} \\ E_{fast} \end{pmatrix}' = \begin{pmatrix} e^{-i\delta} & 0 \\ 0 & e^{i\delta} \end{pmatrix} \begin{pmatrix} E_{slow} \\ E_{fast} \end{pmatrix}$

phase shift after thickness $d = \delta$

$\delta = (n_{slow} - n_{fast}) \frac{\omega d}{2c}$

For 90° rotation, $\delta = \frac{\pi}{2}$

$(n_{slow} - n_{fast}) \frac{\omega d}{2c} = \frac{\pi}{2}$

Calcite w/ 600 nm light: $d = \frac{\pi c}{\omega} \cdot \frac{1}{n_{slow} - n_{fast}}$

$= \frac{\pi \lambda}{2\pi c/\lambda} \cdot \frac{1}{n_{slow} - n_{fast}}$

$= \frac{\lambda}{2} \cdot \frac{1}{n_{slow} - n_{fast}}$

$= \frac{600 \times 10^{-9}\ m}{2 \cdot .172}$

$= \boxed{1.74\ \mu m}$

b) ?

**12.4** Phase difference $= \frac{1}{c}\, \omega n_0^3\, r_{63}\, V$

$n_0 = 1.51$, $r_{63} = 10.6 \times 10^{-12}\ m/V$

$$\frac{1}{c}\, 2\pi \frac{c}{\lambda}\, n_0^3\, r_{63} V = \pi$$

$$V = \frac{\pi \cdot \lambda}{2\pi n_0^3 r_{63}} = \boxed{9.59\ kV}$$

**12.5** a) $\lambda = 2d \sin\theta$

Internet: $d = 1.73 \times 10^{-10}\ m$

$$\theta = \sin^{-1}\left(\frac{\lambda}{2d}\right) = \sin^{-1}\left(\frac{700 \times 10^{-9}}{2 \cdot 1.73 \times 10^{-10}}\right) = ?$$

b) $$\frac{I_{diff}}{I_{incident}} = \sin^2\left(\frac{\pi \ell \sqrt{M I_{acoustic}}}{\lambda \sqrt{2}}\right)$$

$\ell = 1\ mm$, $\lambda = 700\ nm$, $M = 1.53 \times 10^{-6}$, $I_{acoustic} = \frac{1\ W}{1\ mm^2} = 10^6\ \frac{W}{m^2}$

$S = \boxed{.95}$

c) ?