Formulae: (You may not need all of these!)

$$\vec{F} = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}\hat{r} \qquad \vec{E} = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r^2}\hat{r} \qquad \vec{\tau} = \vec{p}\times\vec{E} \qquad p = qd$$

$$\varepsilon_0\Phi = \varepsilon_0\oint \vec{E}\bullet d\vec{A} = q_{enc} \qquad E = \frac{\lambda}{2\pi\varepsilon_0 r} \qquad \Delta V = \frac{\Delta U}{q} = -\int_i^f \vec{E}\bullet d\vec{s}$$

$$\vec{F} = q\vec{E} + q\vec{v}\times\vec{B} \qquad V = \sum_{i=1}^{n} V_i = \frac{1}{4\pi\varepsilon_0}\sum_{i=1}^{n}\frac{q_i}{r_i} \qquad \left|\vec{A}\times\vec{B}\right| = AB\sin\theta$$

$$q = CV \qquad C = \frac{\varepsilon_0 A}{d} \qquad C = 2\pi\varepsilon_0\frac{L}{\ln(b/a)} \qquad C = 4\pi\varepsilon_0\frac{ab}{b-a} \qquad U = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$$

$$i = \frac{dq}{dt} \qquad i = \frac{V}{R} \qquad P = iV = i^2R = \frac{V^2}{R}$$

$$R_{eq} = \sum R_i \qquad R_{eq} = \frac{1}{\frac{1}{R_1}+\frac{1}{R_2}+\cdots} \qquad qvB = \frac{mv^2}{r} \qquad \vec{F}_B = i\vec{L}\times\vec{B} \qquad \vec{\tau} = \vec{\mu}\times\vec{B}$$

$$\mu_0 = 4\pi\times10^{-7}\,T\cdot m/A$$

$$B = \frac{\mu_0 i}{2\pi R} \qquad \oint \vec{B}\bullet d\vec{s} = \mu_0 i_{enc} \qquad B = \mu_0 in \qquad B = \frac{\mu_0 iN}{2\pi}\frac{1}{r}$$

$$\Phi_B \equiv \int \vec{B}\cdot d\vec{A} = BA \qquad \oint \vec{E}\cdot d\vec{s} = emf = -\frac{d\Phi_B}{dt} = -N\frac{d\Phi_B}{dt}$$

$$L \equiv \frac{N\Phi_B}{i} \qquad L = \mu_0 n^2 Al \qquad V = L\frac{di}{dt} \qquad U = \frac{1}{2}Li^2$$

$$V(t) = L\frac{di(t)}{dt} \qquad i(t) = \frac{1}{L}\int V(t)dt \qquad V(t) = \frac{1}{C}\int i(t)dt \qquad i(t) = C\frac{dV(t)}{dt}$$

$\varepsilon_0 = 8.85\times10^{-12}\,\mathrm{N}^2/\mathrm{C}$

$\mu_0 = 1.26\times10^{-6}\,\mathrm{H/m}$

charge on an electron $= -1.6\times10^{-19}C$

$$E = E_m \sin(kx - \omega t) \qquad B = B_m \sin(kx - \omega t) \qquad c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} \qquad \vec{S} = \frac{1}{\mu_0} \vec{E} \times \vec{B} \qquad S = \frac{1}{c\mu_0} E^2$$

$$I = \frac{1}{c\mu_0} E_{RMS}^2 \qquad I = \frac{P_s}{4\pi r^2} \qquad p_r = \frac{I}{c} \qquad p_r = \frac{2I}{c} \qquad I = I_0 \cos^2 \theta$$

$$n = c/v \qquad n_2 \sin\theta_2 = n_1 \sin\theta_1$$

$$f = \frac{1}{2} r \qquad \frac{1}{f} = (n-1)\left(\frac{1}{r_1} - \frac{1}{r_2}\right) \qquad \frac{1}{p} + \frac{1}{i} = \frac{1}{f} \qquad |m| \equiv \frac{h'}{h} \qquad m = -\frac{i}{p}$$

Angle (degrees)	**Sin**
0	0.0
15	0.26
30	0.50
37	0.60 = 1/1.667
42	0.67 = 1/1.5
45	0.71
53	0.80 = 1/1.25
60	0.87
75	0.97
90	1.0

Problem 1 (10 points)

A point source of electromagnetic radiation has an average power output of 800W.
a) Calculate the average power received by a surface of area A that is a distance D meters from the source. Make sure to explain your calculation.
b) Calculate the maximum values of the electric and magnetic fields at a point 3.5m from the source. Explain.

Problem 2 (15 points)

Two thin lenses of focal lengths f_1=30cm and f_2=-10cm are separated by 20cm as shown. An object is placed 15cm to the left of the first lens.

a) Find the position of the final image seen when looking through both lenses. Explain.

b) Find the magnification of the final image. Explain your calculation.

c) Is the final image inverted or upright? Is it a virtual or real image? Explain your reasoning.

Problem 3 (5 points)

Explain why a fish in a spherical goldfish bowl appears larger than it really is.

Problem 4 (5 points)

In a Jules Verne novel, a piece of ice is shaped to form a magnifying lens to focus sunlight to start a fire. Is this possible? Explain.

Problem 5 (10 points)

The drawing shows an optical fiber that consists of a core made of flint glass (n=1.667) surrounded by a cladding made of crown glass (n=1.5). A beam of light enters the fiber from air at an angle θ_1 with respect to the normal.

a) What is θ_1 if the light strikes the core-cladding interface at the critical angle θ_c? Explain.

b) If the cladding has an index of refraction n=1.33, would a ray of light at the θ_1 angle leave the fiber, or be reflected internally? Explain you reasoning.

Problem 6 (10 points)

A farsighted person has a near point that is 67cm from her eyes. She wears contact lenses that are designed to enable her to read a newspaper held at a distance of 25cm from her eyes. Find the focal length of the contact lenses. If needed, you can assume that her eyes are 2.5cm in diameter. Explain.