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)

The Sun delivers about 1000W/m^2 of energy to the Earth's surface.
a) Calculate the total power incident on a roof of dimensions 8m x 20m. Explain.
b) Determine the radiation pressure and radiation force on the roof assuming the roof covering is a perfect absorber. Explain.

Problem 2 (15 points)

Two thin converging lenses of focal lengths f_1=10cm and f_2=20cm 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. Explain.

b) Is the final image inverted or upright? Virtual or real? Explain your reasoning.

c) Find the magnification of the final image. Explain.

Problem 3 (5 points)

Why does a clear stream always appear to be shallower than it actually is? (We're looking for a physics explanation!)

Problem 4 (5 points)

A classic science-fiction story, “The Invisible Man”, tells of a person who becomes invisible by changing the index of refraction of his body to that of air. This story has been criticized by students who have studied how the eye works; they claim the invisible man would be unable to see. On the basis of your knowledge of the eye, could he see or not? Explain.

Problem 5 (10 points)

The drawing shows a crown glass (n=1.5) slab with a rectangular cross section. A laser beam strikes the upper surface at an angle of 60 degrees.
a) If the glass is surrounded by air, determine where part of the beam first exits the glass, at point A, B, or C. Explain.
b) If the glass is surrounded by water, determine where part of the beam first exits the glass, at point A, B, or C. Explain.

Problem 6 (10 points)

A nearsighted person has a far point located only 220cm from her eyes. Determine the focal length of contact lenses that will enable her to see distant objects clearly. If needed, you can assume that her eyes are 2.5cm in diameter. Explain.