PHY303L Useful Formulae for Test 3

EMF in a moving conductor $\mathcal{E} = lvB$

Faraday's Law of Induction $\mathcal{E} = -N\frac{d\Phi_B}{dt}$ Induced EMF $\mathcal{E} = \oint \vec{E} \cdot d\vec{s}$

Definition of Inductance $L = \frac{N\Phi_B}{i}$

Inductance of a solenoid $L = \mu_0 n^2 Al$

Induced EMF on an inductor $\mathcal{E} = -L\frac{di}{dt}$

Energy stored in an inductor $U_B = \frac{1}{2}Li^2$

Magnetic field energy density $u_B = \frac{B^2}{2\mu_0}$

Mutual inductance $M_{12} = N_1\frac{\Phi_{12}}{I_2} = N_2\frac{\Phi_{12}}{I_1}$

Simple R-L circuit (current rise) $i = \frac{\mathcal{E}}{R}\left(1 - \exp^{-tR/L}\right)$

Simple R-L circuit (current decay) $i = i_0 \exp^{-tR/L}$

Capacitive reactance $X_C = 1/\omega C$ Inductive reactance $X_L = \omega L$

Impedance in an LRC series circuit $Z = \sqrt{R^2 + (X_L - X_C)^2}$

Resonance frequency in an LC or LRC series circuit $\omega = \frac{1}{\sqrt{LC}}$

Transformer relations $\mathcal{E}_2 = \mathcal{E}_1\frac{N_2}{N_1}$ $I_2 = I_1\frac{N_1}{N_2}$

EM wave amplitude relation $c = \frac{E}{B} = \frac{1}{\sqrt{\mu_0\epsilon_0}}$

EM wave energy flow, Poynting vector $\vec{S} = \frac{1}{\mu_0}\vec{E} \times \vec{B}$

EM wave energy $I = \langle S \rangle = \frac{1}{c\mu_0}E^2_{\text{rms}}$

Malus' polarization law $I = I_0 \cos^2\theta$

Index of refraction $n = \frac{c}{v}$

Snell's law or refraction $n_1 \sin\theta_1 = n_2 \sin\theta_2$

Critical angle for total internal reflection $\sin\theta_c = \frac{n_2}{n_1}$

Brewster's angle for polarization by reflection $\tan\theta_B = \frac{n_2}{n_1}$

Constructive interference in Young's double slit $d\sin\theta = m\lambda$

Intensity in a two slit experiment $I = 4I_0\cos^2\frac{\phi}{2}$

Constants and Conversion factors:

Magnetic permeability constant, $\mu_0 = 1.26\text{x}10^{-6}$ T·m/A

Couloumb's law constant: $k_e = \frac{1}{4\pi\epsilon_0} = 8.89\text{x}10^9$ N·m^2/C^2

PHY303L Test 3 May 6, 2009 Name:

Instructions: the test starts with 10 multiple choice questions worth 2 points each. Then work 4 of the 5 longer questions (20 points each) and clearly indicate which problem you are skipping.

(1) Clearly mark one answer to each of the following or write a brief answer. On the multiple choice questions, if you think more than one answer is correct, pick the best answer.

(1.1) Colors seen in an oil slick are an example of (a) refraction. (b) reflection. (c) dispersion. (d) polarization. (e) interference.

(1.3) A conducting loop is rotated about an axis perpendicular to a magnetic field. For what position of the loop is the rate of change of the flux a maximum? (a) the normal to the loop is in the direction of B. (b) the normal to the loop is at an angle of 45 degrees to B. (c) the normal to the loop is perpendicular to B. (d) the normal to the loop is at an angle of 135 degrees to B. (e) the normal to the loop is opposite to the direction of B.

(1.4) A conducting loop is rotated about an axis parallel to a magnetic field. For what position of the loop is the flux of the magnetic field a maximum? (a) the normal to the loop is perpendicular to the direction of B. (b) the flux through the loop is constant and nonzero. (c) the flux through the loop is constant and zero.

(1.5) A wavefront (a) is a surface of constant phase of an EM wave. (b) is spherical for a point source. (c) travels through empty space at the speed of light. (d) is a concept useful for EM waves in vacuum or in matter. (e) all of these.

(1.6) A light ray propagates in a high index material (n_1) and reaches an interface to a lower index one (n_2). If the ratio of n_1 to n_2 is large, the incident angle at which total internal reflection occurs (a) is small, that is close to the normal. (b) is large, that is close to glancing. (c) is a constant independent of either index of refraction. (d) is not applicable, you get TIR when going from a low index material to a high index material.

(1.7) When a pulse of white light is incident on a piece of glass, the first color to emerge is (a) red. (b) orange. (c) green. (d) violet. (e) they all emerge at the same time.

(1.8) Which of the following change when light enters matter from vacuum. (a) the frequency. (b) the speed. (c) the wavelength. (d) the frequency and the speed. (e) the wavelength and the speed. (f) the frequency, the wavelength and the speed.

(1.9) Which of the following change when light reflects from a surface. (a) the frequency. (b) the speed. (c) the wavelength. (d) the wavenumber. (e) the period. (f) the direction of propagation.

(1.2) What do the A and F in AM and FM stand for? Which is longer wavelength?

(1.10) Order the following in terms of increasing frequency and decreasing wavelength: X-rays, infrared, radio, microwave, γ-rays, visible, ultraviolet.

(2) A thin film of material with index of refraction 1.3 is applied to the surface of a glass (n = 1.52) optic. What is the minimum thickness that the film can have be to give minimize reflection at a wavelength of 632.8 nm? The wave is incident in air.

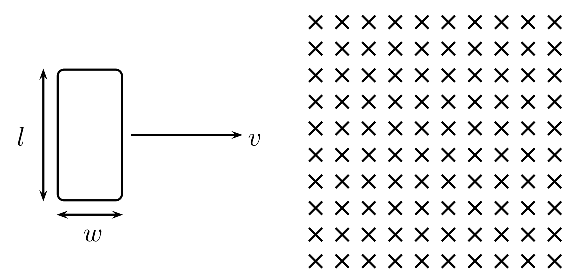
(3) You are initially given an optical setup with two crossed linear polarizers, through which no light is transmitted. A third linear polarizer is placed between the first two. Write an expression for the intensity of light transmitted as a function of the angle of the middle polarizer, keeping the outer two fixed. Be sure to define the angle appearing in your result. Bonus: (leave this part until the end of the test) what angle results in the maximum transmission? You must prove your answer.

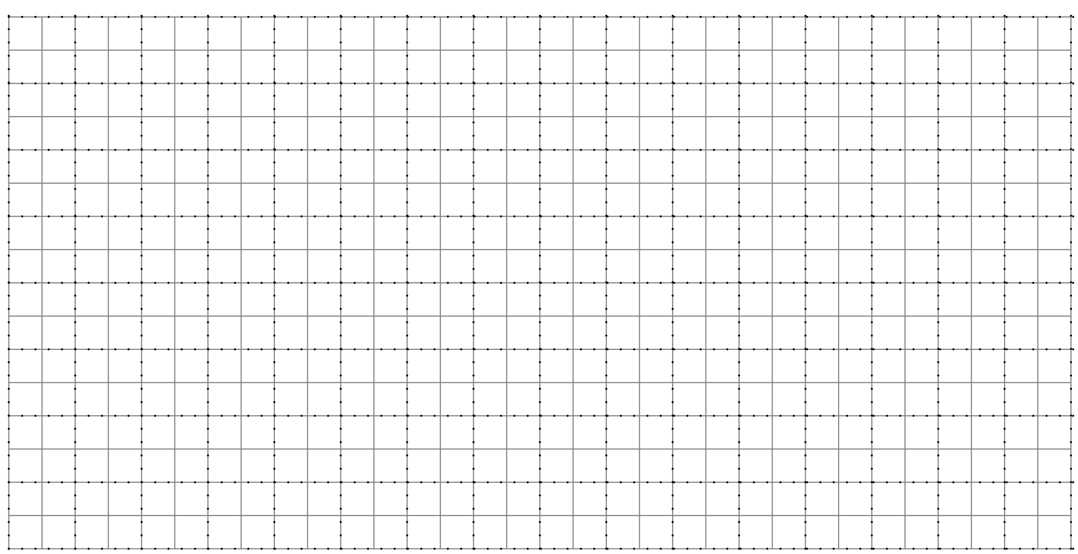
(4) A magnetic field of constant magnitude B is in a direction perpendicular to the plane of the diagram below. It is nonzero in the region from $x = -L$ to $+L$. A rectangular loop of wire of dimensions l by w oriented in a plane perpendicular to the direction of B moves at a constant velocity v in the positive x-direction. Both l and w are less than L.

(a) On the graph, sketch the EMF induced around the loop as a function of time.

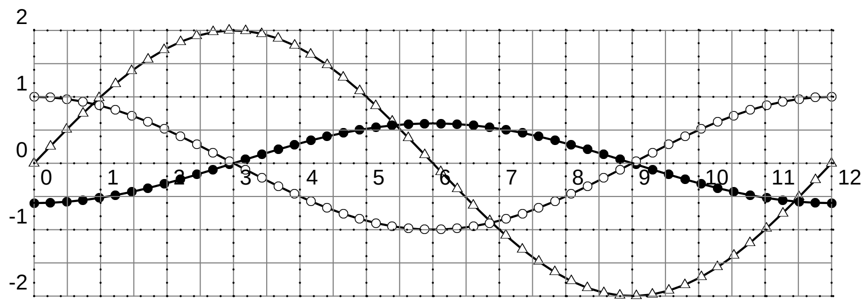
(b) On the same graph, sketch the induced EMF around the loop if it is rotated by 90 degrees in the plane of the paper before it passes through the magnetic field.

(c) Which of the specified quantities (B, L, l, w and v) does the maximum EMF induced in the loop depend on?





(5) Shown are the voltage as a function of time across 3 elements in a series LRC circuit driven by a AC source of EMF.



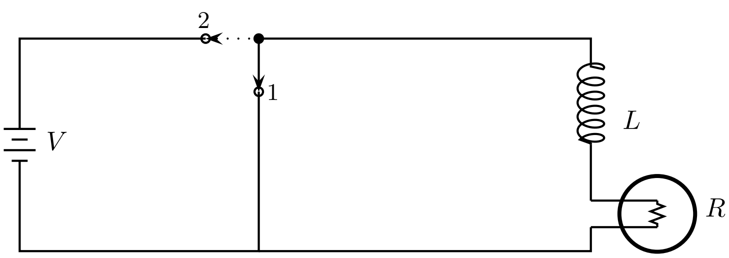
(a) Which curve corresponds to which element (L, C, and R)?

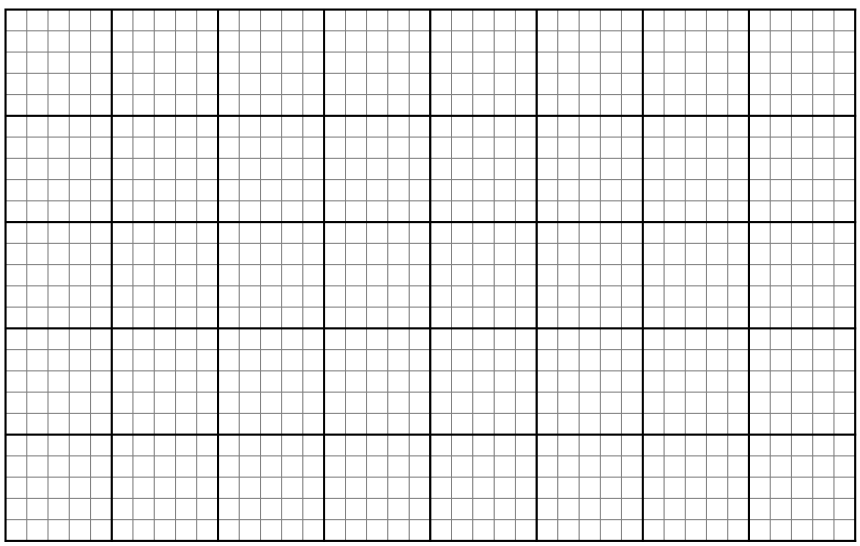
(b) is the frequency of the source below, equal to or above resonance? Justify your answer.

(c) if the frequency of the source were made much, much higher, how would the plot change?

(Bonus) Does this circuit have a relatively large or relatively small Quality factor? Why?

(6) The switch in the circuit below been at position 1 for a very long time. The resistor (light bulb R) has resistance of 1 kΩ, the inductor has inductance of L = 500 mH and the battery supplies a voltage of V = 5 volts. At time zero the switch is moved to position 2.





(a) Sketch the current through the resistor as a function of time. Scale the time and current axes in units determined from the constants given (some combination of R, L and/or V).

(b) How long before the power dissipated in the resistor reaches one half its maximum value?

(c) How long before the energy stored in the inductor reaches one half its maximum value?