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- The images and the pictures in this lecture are provided by the CDs accompanied by the books
  1. University Physics, Bauer and Westfall, McGraw-Hill, 2011.
  2. Principles of Physics, Halliday, Resnick, and Walker, Wiley, 8th and 9th Ed.
- The rest is made by me.

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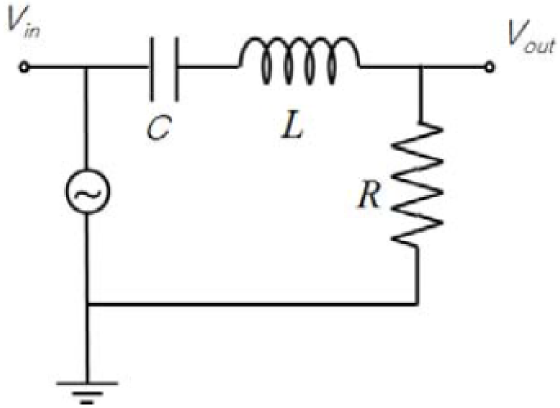
Problem 3. (25 points) The impedance Z of a series RLC circuit is $Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$ and the phase difference ϕ between $V_{in}(t)$ and $I(t)$ is $\phi = \tan^{-1}\left(\frac{\omega L - (\omega C)^{-1}}{R}\right)$. Assume that $V_{in} = V_0 \sin(\omega t)$ and $I(t) = I_0 \sin(\omega t - \phi)$ is the time-varying current along the circuit.

(a) If we remove the capacitor (i.e., $C = \infty$), the remaining circuit can be viewed as a RL low-pass filter of the input $V_{in}(t)$, yielding $V_{out}(t)$. For what value of ω, $V_{out}/V_{in} = 1/\sqrt{2}$? Draw V_{out}/V_{in} as a function of ω, schematically.

(b) Then, consider the case in which C, R and L all are finite. For what value of ω the current $I(t)$ will have the maximum amplitude $I_{\max}$? What will be the maximum $I_{\max}$ and the corresponding phase difference $\phi_{\max}$?

(c) When R becomes 0 (while C and L are kept finite), what will become ϕ?



<Fig. 3>

Problem 1-A. (25 points) Suppose the electric field of a plane electromagnetic wave is given by $\overrightarrow{E}(z,t)=E_0\cos(kz-wt)\hat{i}$. Find the following quantities:

(a) The direction of wave propagation.
(b) The speed of wave propagation c.
(c) The corresponding magnetic field $\overrightarrow{B}$. [Make sure to use Faraday's law.]

Problem 2. (25 points) To determine the work function Φ of a metal sample, you measured the maximum kinetic energy $K_{\max}$ of the photoelectrons to be $0.5\ \mathrm{eV}$ corresponding to a certain wavelength λ. Later on you cut down the wavelength by $50\ \%$ and found $K_{\max}$ to be $3.5\ \mathrm{eV}$ From this information determine

(a) work function Φ, and

(b) the original wavelength λ.

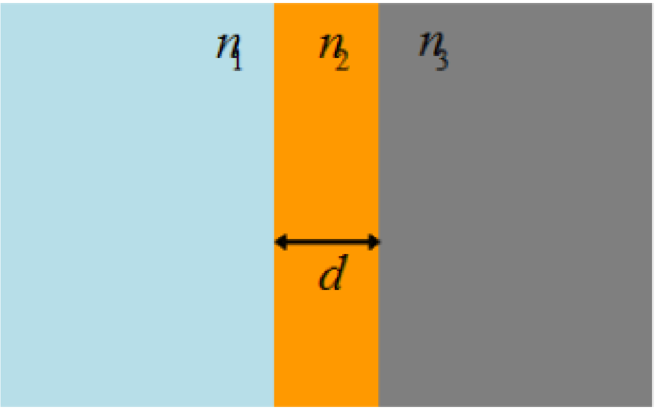
(c) What will be the de Broglie wavelength of the photoelectrons carrying $K_{\max}$ when the light of wavelength λ was used?

Problem 3. (25 points) A uniform thin film (with thickness d and index of refraction n_2) is sandwiched between two different materials having a different index of refraction n_1 and n_3, respectively. When $n_1 > n_2 > n_3$, answer the following questions :

(a) When a coherent monochromatic light (wavelength λ in vacuum) is incident normally from the right-hand, what will be the condition for the complete destructive interference of the reflected lights?

(b) Answer the same question above when the incoming light is from the left, instead.

(c) In the case of (b), what will be the minimum thickness of d when $\lambda = 560\ \mathrm{nm}$ and $n_2 = 1.4$?



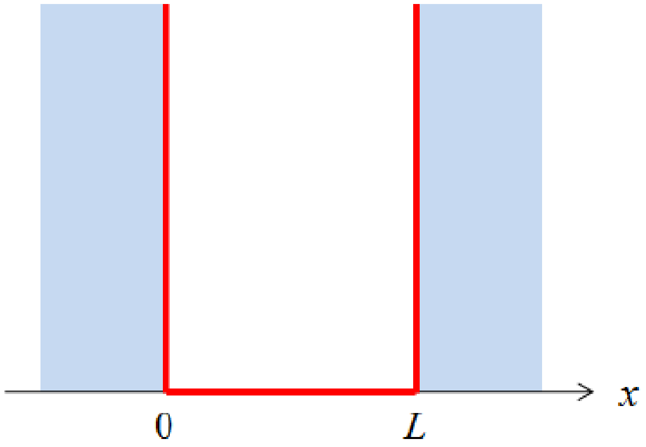
<Fig. 2>

Problem 4. (25 points) An electron is trapped in an infinite potential well as shown in the figure 4 $(0 < x < L)$. [normalization condition : $\int_{-\infty}^{+\infty} |\Psi_n(x)|^2 dx = 1$]. Answer the following questions:

(a) What will be the wave function $\Psi_n(x)$ corresponding to the n th quantized state, when $n = 0$ represents the ground state?

(b) When the electron is in the $n = 2$ (excited) state, what will be the probability of the electron being found in $0 < x < L/3$?

(c) If the electron of (b) `jumps' to the ground state, what will be its energy loss?



<Fig. 4>

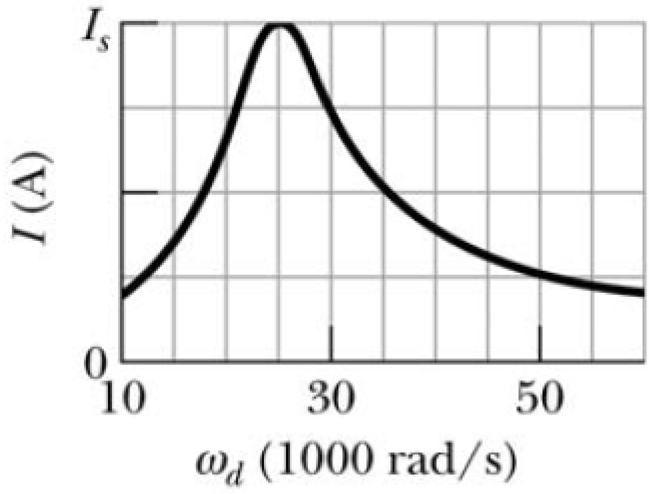
Problem 3. (25 points) The current amplitude I versus driving angular frequency ω_d for a driven RLC circuit (connected in series) is given in Fig. 3, where the vertical axis scale is set by $I_s = 4.00\ \mathrm{A}$. The inductance $L = 200\ \mu\mathrm{H}$, and the emf amplitude V_m is $8.0\ \mathrm{V}$.

(a) What is C?

(b) What is R?

(c) When $L \neq 0$ but $R = C = 0$, what will be the phase difference ϕ [when $V_{emf}(t) = V_m \sin(\omega_d t)$ and $I(t) = I_m \sin(\omega_d t - \phi)$].

(d) When $L \neq 0$, $C \neq 0$, but $R = 0$, draw the phase difference $\phi(\omega_d)$ as a function of ω_d.



<Fig. 3>

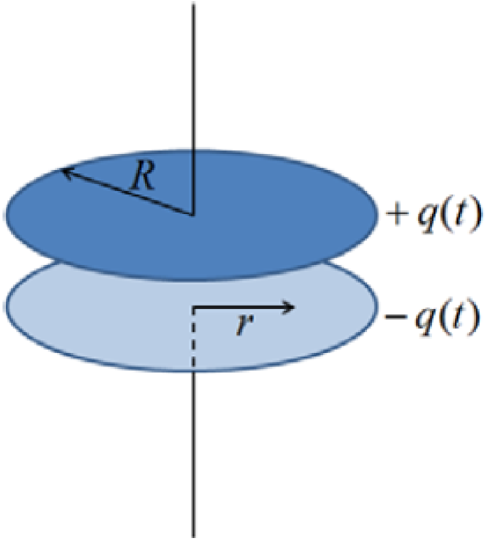
Problem 4. (25 points) A thin parallel-plate capacitor with circular plates of radius R is being charged with a constant rate α [i.e., charge $q(t) = \alpha t$].

(a) Derive an expression for the electric field $E(t)$ between the two circular plates. (Assume that the field is uniform inside the capacitor and zero outside.)

(b) Derive an expression for the displacement current $i_d(r)$ as a function of r (for both $r \leq R$ and $r > R$), where r is the radial distance from the center of the capacitor.

(c) Derive an expression for the induced magnetic field $B(r)$ as a function of r (for both $r \leq R$ and $r > R$).

(d) Draw the functions, $B(r)$ and $i_d(r)$.

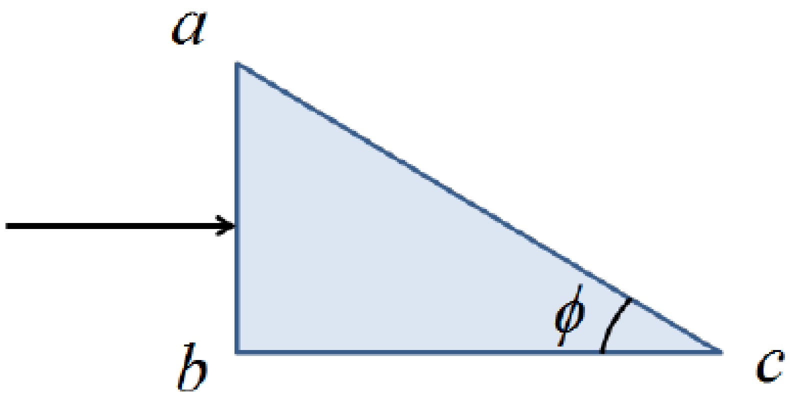


<Fig. 4>

Problem 1. (25 points)

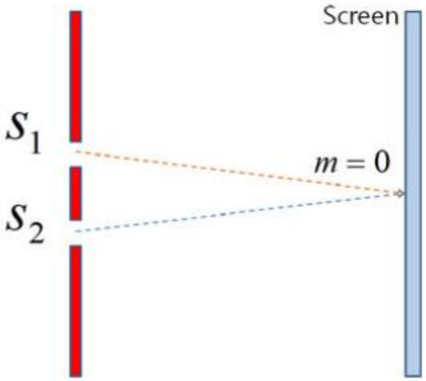
(a) A ray of light is perpendicular to the face ab of a glass prism ($n_{glass} = 1.52$) as shown in Fig. 1. Find the largest value for the angle ϕ so that the ray is totally reflected at face ac if the prism is in air ($n_{air} = 1.00$).

(b) White light, with a uniform intensity across the visible range of 400 to $690\ \mathrm{nm}$, is perpendicularly incident on a thin water film, of index of refraction $n_{water} = 1.30$ and thickness $L = 300\ \mathrm{nm}$, that is suspended in air ($n_{air} = 1.00$). At what wavelength λ is the light reflected by the water film brightest to an observer?

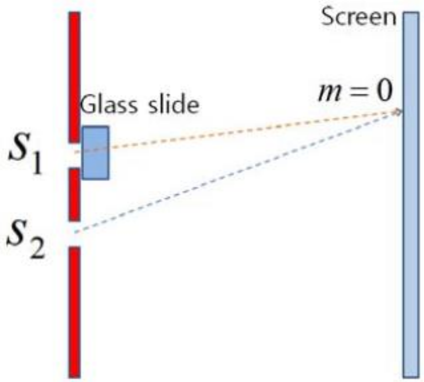


<Fig. 1>

Problem 2. (25 points) In a double-slit experiment, laser light of wavelength $633\ \mathrm{nm}$ produced an interference pattern on a screen placed at some distance from the slits. When one of the slits was covered with a thin glass slide of thickness $12.0\ \mu\mathrm{m}$, the new central fringe matched the point occupied earlier by the 10th dark fringe (see Fig. 2). What is the refractive index of the glass slide? (Assume that the distance to the screen is much larger than the thickness of the glass slide.)



without the glass slide



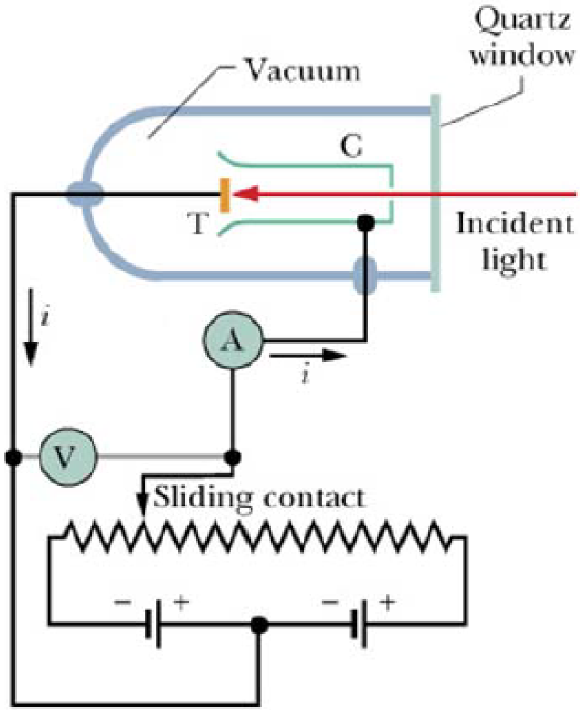
with the glass slide

<Fig. 2>

Problem 3. (25 points) Suppose you are using a circuit depicted in Fig. 3 and you have a photosensor with an unknown material (T). When using light of wavelength $250\ \mathrm{nm}$, you find that you have to apply a stopping potential of $2.86\ \mathrm{V}$ to eliminate the current. When using light of wavelength $400\ \mathrm{nm}$, you measure a value of $1.00\ \mathrm{V}$ for the stopping potential.

(a) Based on the given information, estimate the charge of a single electron.

(b) What is the critical value of wavelength beyond which no current will be produced at all?



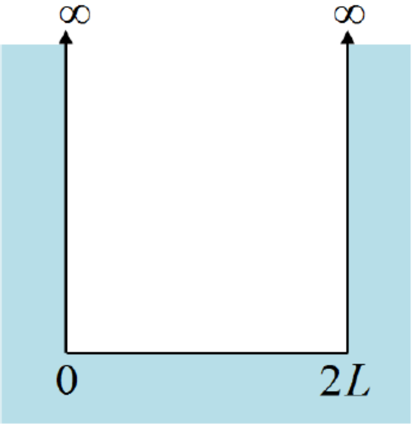
<Fig. 3>

Problem 4. (25 points) Figure 4 shows two infinite potential wells, each on an x axis.

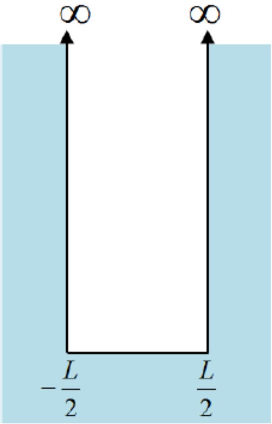
(a) Determine the wave functions $\Psi(x)$ of an electron (mass m) in its ground state and in the 1st excited state trapped in each well, and draw them on the figures.

(b) Determine the 1st excited state energies for each well.

(c) Determine the wavelength of the photon emitted during the transition from 1st excited state to the ground state for the well of CASE Ⅱ.



[CASE Ⅰ]



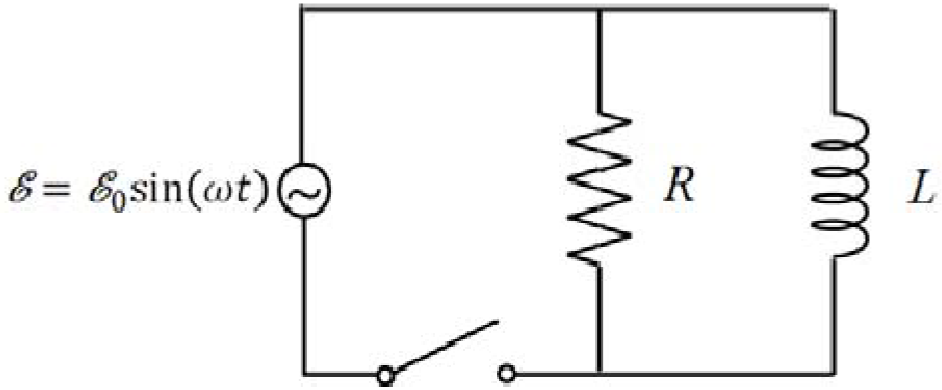
[CASE Ⅱ]

<Fig. 4>

Problem 4. (20 points) A resistor (resistance R) and an inductor (inductance L) are connected in parallel to an AC electromotive force $\mathcal{E} = \mathcal{E}_0 \sin(\omega t)$. The Kirchhoff's two rules can be applied to find a current. $\omega = R/L$ is chosen. There was no current when the switch was open. $\sin\alpha + \sin\beta = 2\sin\left(\frac{\alpha+\beta}{2}\right)\cos\left(\frac{\alpha-\beta}{2}\right)$.

(a) When the resistance $R = \infty$, the current can be expressed by $I = I_0 \sin(\omega t - \phi)$. Find I_0 and ϕ.

(b) When the resistance $R \neq \infty$, the current can be expressed by $I = I_0 \sin(\omega t - \phi)$. Find I_0 and ϕ.



<Fig. 4>

Problem 2. (30 points) A slit is added to the setup of Young's experiment to perform three slit interference experiment as shown in Fig 2-1. Suppose the phase difference caused by the path difference between the upper two rays is ϕ. Then the phase difference between the second and third rays is ϕ too. The electric field components of those three waves at a point on a screen can be written as

$$E_1 = E_m \sin(\omega t)$$
$$E_2 = E_m \sin(\omega t + \phi)$$
$$E_3 = E_m \sin(\omega t + 2\phi),$$

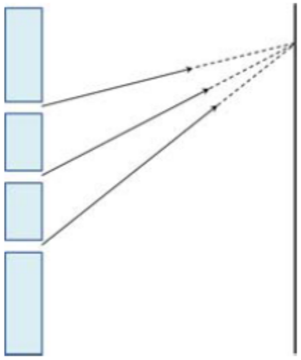
where ω is angular frequency and t is time. Resultant wave can be written as $E = E_\theta \sin(\omega t + \theta)$. To compute E_θ and θ, phasors are drawn in Fig. 2-2.

(a) Find θ as a function of ϕ.

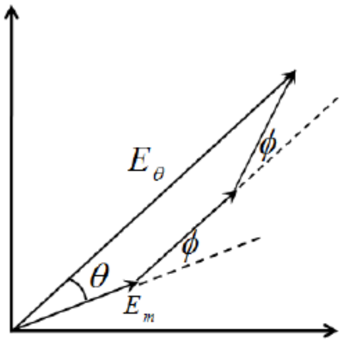
(b) Find E_θ as a function of θ and E_m.

(c) Find intensity I as a function of I_m and ϕ. The intensity of each ray E_1, E_2, and E_3 is I_m.

(d) Plot $I(\phi)$ graphically.



<Fig. 2-1>



<Fig. 2-2>

Problem 3. (25 points) The intensity of sun light is $0.9\ \mathrm{kW/m^2}$. Suppose the sun light is made up of photons of only two wavelengths $600\ \mathrm{nm}$ and $400\ \mathrm{nm}$ and they always have population ratio $3:2$. $h = 6\times10^{-34}\ \mathrm{J\cdot s}$, $e = 1.5\times10^{-19}\ \mathrm{C}$, $c = 3\times10^{8}\ \mathrm{m/s}$.

(a) Find the number of photons incident on $1\ \mathrm{m}^2$ per unit time.

(b) Suppose the sun light is illuminated to a metal of $1\ \mathrm{m}^2$ and work function $2.8\ \mathrm{eV}$. Find the maximum kinetic energy of the electrons coming out of the metal.

(c) Suppose all electrons in (b) are collected by a detector. Find the current at the detector. Every photon that satisfies an energy condition is absorbed.