# Physics 158 Midterm 1 Review Package

## UBC Engineering Undergraduate Society

Attempt questions to the best of your ability. Problems are ranked in difficulty as $(*)$ for easy, $(**)$ for medium, and $(***)$ for difficult.

Solutions posted at: `http://ubcengineers.ca/tutoring/`

If you believe that there is an error in these solutions, or have any questions, comments, or suggestions regarding EUS Tutoring sessions, please e-mail us at: tutoring@ubcengineers.ca. If you are interested in helping with EUS tutoring sessions in the future or other academic events run by the EUS, please e-mail vpacademic@ubcengineers.ca.

Some of the problems in this package were not created by the EUS. Those problems originated from one of the following sources (All solutions prepared by the EUS.):

- Electricity, Magnetism, and Light / Wayne Saslow

- Exercises for the Feynman Lectures on Physics / Matthew Sands, Richard Feynman, Robert Leighton.

| Want a warm up? | Short on study time? | Want a challenge? |
|:---:|:---:|:---:|
| These are the easier problems | These cover most of the material | These are some tougher questions |
| 1,2,3,4 | 3, 5, 6, 7 | 9, 10, 11 |

## EUS Health and Wellness Study Tips

- **Eat Healthy**—Your body needs fuel to get through all of your long hours studying. You should eat a variety of food (not just a variety of ramen) and get all of your food groups in.

- **Take Breaks**—Your brain needs a chance to rest: take a fifteen minute study break every couple of hours. Staring at the same physics problem until your eyes go numb won't help you understand the material.

- **Sleep**—We have all been told we need 8 hours of sleep a night, university shouldn't change this. Get to know how much sleep you need and set up a regular sleep schedule.

**EUS**

Good Luck!

(∗)   1. In the circuit shown in the figure, with the switch $S$ open (so $S$ begins neither at $A$ nor $B$) at $t < 0$, the capacitor is uncharged.

(a) After the switch is closed at $A$, how much time $t$ does it take the voltage across the capacitor to reach 8.0 V?

(b) At the instant the voltage across the $C$ reaches 8.0 V, the switch is thrown to $B$. What is the initial value of the current $I_0$ that starts through $L$?

$R_1 = 1.0 \cdot 10^4 \ \Omega$      $R_2 = 1.0 \cdot 10^3 \ \Omega$

A      B

$V_0 = 10 \ V$

$L = 10 \ H$

$C = 1.0 \ mF$
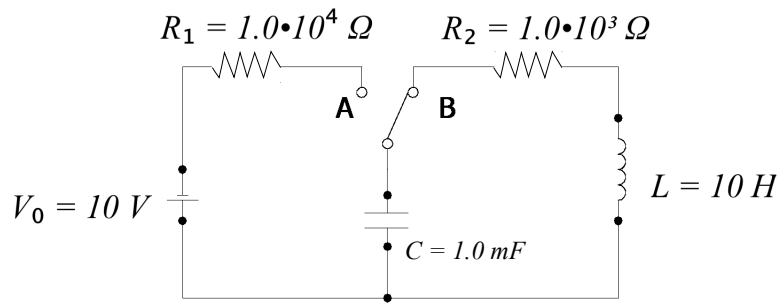
(∗)   2. The circuit shown in the figure constitutes what is called at *relaxation oscillator*. It consists of a neon bulb $N$ connected parallel to a capacitor that is charged through a resistor from an 80 V DC voltage source. The neon tube has infinite resistance as long as the voltage across it is less than 60 V. If the voltage attained exceeds this value, the neon tube breaks down and then has negligible resistance, discharging the capacitor. The neon tube then "goes out", and returns to the infinite resistance state. If $C = 0.1 \ \mu\text{F}$, $R = 10^6 \ \Omega$, and $V_0 = 80$ V, find the frequency $f$ at which the neon tube flashes.
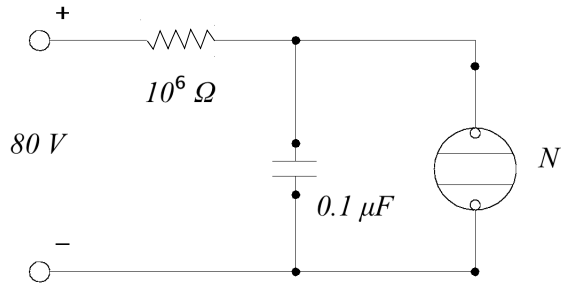
(∗)  3.  (a)  Sound of frequency 240 Hz is normally incident on a wall with two slit-like holes separated by $d$. If on the other side of the wall at a distance $D$ there is a plane for which the angular separation between the central maximum and the first minimum is 10°, determine the separation between the slits. Take $d \ll D$.

(b)  If the incident wave now has frequency 960 Hz, find the angular separation between the central maximum and third minimum.

($*$)   4. A 120 V rms, 60 Hz generator is placed across a circuit containing a resistor $R = 20\ \Omega$ and another circuit element (either a capacitor or an inductor). The phase angle is $63°$.

    (a) Identify the other element, give its reactance, and give its capacitance or inductance.

    (b) Find the average rate at which power is dissipated.

(∗∗)   5.  An unknown inductor is in series with a 12 Ω resistor. When driven at 440 Hz, the driving voltage leads the current by 0.055 ms. Find:

(a) The phase angle $\phi$ between the voltage and current.

(b) The reactance $X_L$ of the inductor.

(c) The inductance $L$ of the inductor.

(d) The impedance $Z$ of the circuit.

(∗∗)  6. In the circuit shown in the figure, originally the switch was at $A$, but at $t = 0$ it is thrown to $B$. After a long time,

(a) How much energy $\Delta E$ has been dissipated as heat in the resistor?

(b) What voltages $V_1$ and $V_2$, if any, remains on the capacitors?

Express your answers in terms of $V_0$, $C_1$, and $C_2$.
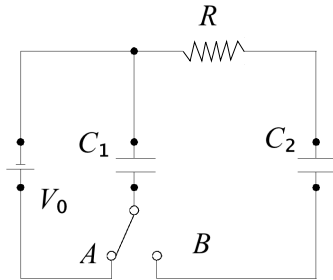
($**$)   7. An oil slick ($n_1 = 1.22$) of thickness 850 nm lies above water ($n_2 = 1.33$).

     (a) Find the colours (from 400 nm to 700 nm) that are intensified on reflection at normal incidence

     (b) Repeat for transmission

(∗∗)  8. Monochromatic light is incident on a Young's two-slit apparatus with slit separation 0.250 mm, with a screen that is 1.1 m from the slits. The third order maximum occurs at $y = 5.4$ mm.

   (a) Determine the wavelength of the light

   (b) Determine the angle $\theta$ and position $y$ on the screen of the fifth-order minimum.

   (c) Determine the highest-order maximum that can be observed.

   (d) If a flat piece of glass of index $n = 1.5$ and thickness $t = 1$ $\mu$m is put in front of one of the slits, how far from the central axis will the closest maxima be?

(∗ ∗ ∗)   9. In the circuit shown, the switch $S$ is initially closed, and steady current $I = V_0/R$ is flowing. At $t = 0$, $S$ is suddenly opened.

(a) Find a time $T$ after the switch is opened at which the voltage on the capacitor is maximum.

(b) Find the maximum voltage $V_{\text{max}}$ that is subsequently observed on the capacitor.

(c) Graph the charge on the right capacitor plate as a function of time, starting at $t = 0$. Make sure to specify any characteristic properties of the graph.
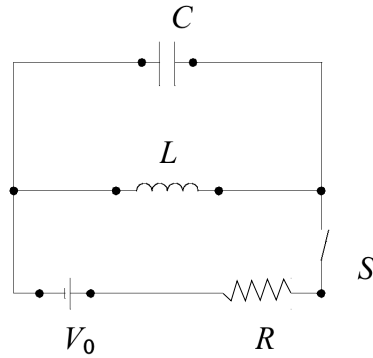
$(***)$ 10. (a) For two in-phase point sources separated by $d = 4$ cm, if $\lambda = 18$ cm, how many curves giving maxima (constructive interference) are there? Curves giving minima (destructive interference)?

(b) For $d = 4$ cm and $\lambda = 6$ cm, how many curves giving maxima are there? Curves giving minima?

(c) For $d = 4$ cm and $\lambda = 1.4$ cm, how many curves giving maxima are there? Curves giving minima?

$(* * *)$ 11. Consider a wedge formed by two optically flat glass plates, Suppose light is incident to the top glass plate as shown. At atmospheric pressure 1511 dark lines are observed across a thickness $d$ for a 690.0 nm wavelength in air. When the air pressure is increased by a factor of ten, 1519 dark lines are observed.

    (a) If the index of refraction $n$ deviates from unity only by a term linearly proportional to the pressure, find the index of refraction of air at atmospheric pressure to six decimal places.

    (b) Find the wavelength of the light in vacuum.

    (c) Find $d$.

**Remark.** *The dotted line in the figure does not denote the path of the light through the glass plate, it is there only to show the angle of incidence of light.*
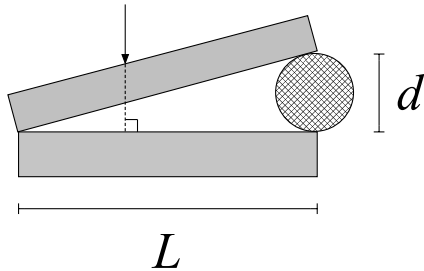
**Waves:**

$$v = \sqrt{\frac{T}{\mu}}, \; k = \frac{2\pi}{\lambda}, \; P = \tfrac{1}{2}\mu\omega^2 A^2 v, \; p_o = \rho\omega v s_0$$

$$v = \sqrt{\frac{\gamma RT}{M}}, \qquad I = \frac{P_{\text{av}}}{4\pi r^2}, \qquad \beta = 10 dB \log_{10}\left(\tfrac{I}{I_0}\right), \qquad \text{Doppler Effect } f' = f_0\left(\frac{v \pm v_L}{v \mp v_S}\right)$$

Beats: $\Delta f = f_2 - f_1, \qquad y = A\cos(kx \mp \omega t + \phi)$

Interference: $k\Delta x + \Delta\phi = 2\pi n$ or $\pi(2n+1)$, $n = 0, \pm 1, \pm 2, \pm 3, \pm 4, \ldots$

Standing Waves $f_m = \dfrac{mv}{2L}$, $m = 1, 2, 3, \ldots$, $f_m = \dfrac{mv}{4L}$, $m = 1, 3, 5, \ldots$

**Constants:**

$$k = \frac{1}{4\pi\epsilon_0} \approx 9 \times 10^9 \, \text{Nm}^2/\text{C}^2, \qquad \epsilon_0 = 8.84 \times 10^{-12} \, \text{C}^2/\text{Nm}^2, \qquad e = 1.6 \times 10^{-19} \, \text{C}$$

$$\mu_0 = 4\pi \times 10^{-7} \, \text{Tm/A}, \qquad c = \frac{1}{\sqrt{\epsilon_0\mu_0}} = 299,792,458 \, \text{m/s}$$

**Point Charge:**

$$|\mathbf{F}| = \frac{k|q_1 q_2|}{r^2}, \; |\mathbf{E}| = \frac{k|q|}{r^2}, \; V = \frac{kq}{r} + \text{Constant}$$

**Electric potential and potential energy** $\Delta V = V_a - V_b = \displaystyle\int_a^b \mathbf{E} \cdot d\mathbf{l} = -\int_b^a \mathbf{E} \cdot d\mathbf{l}$

$$E_x = -\frac{dV}{dx}, \qquad \mathbf{E} = -\nabla V, \qquad \Delta U = U_a - U_b = q(V_a - V_b)$$

**Maxwell's Equations:**

$$\int_S \mathbf{E} \cdot d\mathbf{A} = \frac{Q_{\text{enc}}}{\epsilon_0} = 4\pi k Q_{\text{enc}} \qquad \int_S \mathbf{B} \cdot d\mathbf{A} = 0$$

$$\int_C \mathbf{B} \cdot d\mathbf{l} = \mu_0 \left(I_{\text{enclosed}}\right) + \epsilon_0\mu_0 \frac{d\Phi_E}{dt} \qquad \int_C \mathbf{E} \cdot d\mathbf{l} = -\frac{d\Phi_B}{dt}$$

Where $S$ is a closed surface and $C$ is a closed curve. $\Phi_E = \displaystyle\int \mathbf{E} \cdot d\mathbf{A}$ and $\Phi_B = \displaystyle\int \mathbf{B} \cdot d\mathbf{A}$

**Energy Density:**

$u_E = \dfrac{1}{2}\epsilon_0 E^2$ and $u_B = \dfrac{1}{2\mu_0} B^2$ (energy per volume)

**Forces:**

$\mathbf{F} = q\mathbf{E} + q\mathbf{v} \times \mathbf{B}$, $\mathbf{F} = I\mathbf{L} \times \mathbf{B}$

**Capacitors:**

$q = CV$, $U_C = \dfrac{1}{2} \cdot \dfrac{q^2}{C}$, For parallel plate capacitor with vacuum (air): $C = \dfrac{\epsilon_0 A}{d}$, $C_{\text{dielectric}} = K C_{\text{vacuum}}$

**Inductors:**

$\mathcal{E}_L = -L\frac{dI}{dt}$, $U_L = \tfrac{1}{2}LI^2$, where $L = N\Phi_B/I$ and $N$ is the number of turns.

For a solenoid $B = \mu_0 n I$ where $n$ is the number of turns per unit length.

**DC Circuits:** $V_R = IR$, $P = VI$, $P = I^2 R$

(For RC circuits) $q = ae^{-t/\tau} + b$, $\tau = RC$, $a$ and $b$ are constants

(For LR circuits) $I = ae^{-t/\tau} + b$, $\tau = L/R$, $a$ and $b$ are constants

**AC circuits:** $X_L = \omega L$, $X_C = 1/(\omega C)$, $V_C = X_C I$, $V_L = X_L I$

$V = ZI$, $Z = \sqrt{(X_L - X_C)^2 + R^2}$, $P_{\text{average}} = I_{\text{rms}}^2 R$, $I_{\text{rms}} = \dfrac{I_{\text{max}}}{\sqrt{2}}$

If $V = V_0 \cos(\omega t)$, then $I = I_{\text{max}} \cos(\omega t - \phi)$, where $\tan\phi = \dfrac{X_L - X_C}{R}$, $P_{\text{av}} = V_{\text{rms}} I_{\text{rms}} \cos\phi$

**Additional Equations:** $d\mathbf{B} = \dfrac{\mu_0}{4\pi} \cdot \dfrac{I d\mathbf{l} \times \mathbf{r}}{r^3}$

LRC Oscillations: $q = A_0 e^{-\frac{Rt}{2L}} \cos(\omega t + \phi)$, where $\omega = \sqrt{\omega_0^2 - \left(\frac{R}{2L}\right)^2}$ and $\omega_0^2 = \frac{1}{LC}$