Physics 1C Spring 2018 Second Midterm

Timothy Rediehs

TOTAL POINTS

83 / 100

QUESTION 1

1 1a **12 / 15**

- ✓ + **4 pts** **Correct magnitude for B.**
- ✓ + **4 pts** **Correct direction for B.**
- + **7 pts** Correctly and convincingly show alpha = 1/c^2.
- ✓ + **4 pts** **Display moderate understanding of material in solving for alpha.**
- + **0 pts** No points.

QUESTION 2

2 1b **6 / 6**

- ✓ + **2 pts** **Correctly express the time-averaged magnitude of the Poynting vector <S> in terms of E_0 and constants.**
- ✓ + **2 pts** **Correctly express <S> in terms of the time-averaged radiated power <P>, r, and constants.**
- ✓ + **2 pts** **Correctly solve for E_0.**
- + **2 pts** Miscellaneous partial credit.
- + **0 pts** No points.

QUESTION 3

3 1c **15 / 15**

- ✓ + **8 pts** **Write a somewhat correct expression for the force on the sail due to radiation.**
- ✓ + **5 pts** **Correctly solve for the area of the sail (up to a factor of 2).**
- ✓ + **2 pts** **Correctly solve for the area of the sail.**
- + **3 pts** Miscellaneous partial credit.
- + **0 pts** No points.

QUESTION 4

4 2a **5 / 5**

- ✓ + **5 pts** **Correct**
- + **2 pts** Partial credit: Correct show that Vc lags behind Vr by 90 degree.
- + **3 pts** Partial credit: Correct show that V0=vector sum of Vc and Vr.
- + **1 pts** nice try
- + **0 pts** No points

QUESTION 5

5 2b **5 / 5**

- ✓ + **2 pts** **current leads voltage or voltage lags current**
- ✓ + **3 pts** **clearly explain why current leads voltage or voltage lags current.**
- + **0 pts** no points

QUESTION 6

6 2c **13 / 16**

- ✓ + **5 pts** **Correct Vout/Vin**
- + **3 pts** Correct limit value of ratio at small omega, from your expression of Vout/Vin.
- ✓ + **3 pts** **Correct limit value of ratio at large omega, from your expression of Vout/Vin.**
- ✓ + **3 pts** **Decide if this is high pass or low pass correctly according to your limit values.**
- ✓ + **2 pts** **Explain why**
- + **0 pts** no points

QUESTION 7

7 2d **10 / 10**

- ✓ + **3 pts** **Correct expression of Vout/Vin for the first circuit.**
- ✓ + **2 pts** **Determine if the first circuit is high or low pass according to your Vout/Vin correctly and explain.**
- ✓ + **3 pts** **Correct expression of Vout/Vin for the second circuit.**
- ✓ + **2 pts** **Determine if the second circuit is high or**

low pass according to your Vout/Vin correctly and explain.

+ **0 pts** No points

QUESTION 8

8 3a 5 / 5

✓ + **5 pts** **Correct**

+ **0 pts** Incorrect

QUESTION 9

9 3b 12 / 15

✓ + **4 pts** **Correct expression for Brewster's angle.**

✓ + **4 pts** **Correct expression for critical angle.**

✓ + **4 pts** **Recognize that one angle must be taken for "internal" reflection (air to n) and the other "externally" (n to air). Or recognize that the naive approach to this problem leads to nonsensical values of n.**

+ **3 pts** Correct expression for n (with a non-zero solution).

+ **0 pts** No points.

QUESTION 10

10 3c 0 / 8

+ **8 pts** Correct (or very almost correct) analytic expression for n.

+ **4 pts** Valiant algebraic or geometric attempt in solving for n.

✓ + **0 pts** **No points**

Note to others: This problem was stupid and bad and even the professor admitted it. Don't waste your time.

Physics 1C – Spring 2018: Midterm 2

Name Tim Redrehi [redacted]

This exam is closed book and closed notes. Electronics are not permitted, except for one calculator. Please show your full solution in the boxes provided (where the scanners can pick them up). Your solutions will be graded on correctness and coherence; results given with no details will receive zero credit. There is additional scratch paper attached so you can collect your thoughts first. Academic dishonesty is reported to the Office of the Dean of Students.

Problem 1. You have designed a solar space craft of mass m that is accelerated by the force due to the 'radiation pressure' from the sun's light that falls on a perfectly reflective circular sail that is oriented face-on to the sun. The time averaged radiative power of the sun is $< P >$. The gravitational constant is G. The mass of the sun is m_s The speed of light is c. Model the sun's light as a plane electromagnetic wave with the electric field given by $\vec{E}(z,t) = E_0\cos(kz - \omega t)\hat{i}$. (Recall, Newton's universal law of gravitation: $F = \frac{Gmm_s}{r^2}$)

a. (8 pts) What is the magnetic field associated with this electric field? (7 pts) One of Maxwell's equations in vacuum has the form: $\vec{\nabla} \times \vec{B} = \alpha\frac{d\vec{E}}{dt}$. Using your expression for $\vec{B}$, determine what the constant α on the right hand side must be in terms of c, the speed of light. (Compute it; just writing down the correct answer will receive no credit.) Does your expression for $\vec{B}$ lead you to the correct constant?

$\vec{E} = c\vec{B}$ $\quad \vec{B}(t) = \frac{E_0}{c}\cos(kz-\omega t)\hat{j}$

$\vec{\nabla}\times\vec{B} = \frac{\partial}{\partial x}B(t)\hat{k} - \frac{\partial}{\partial z}B(t)\hat{i}$

$= 0 + \frac{E_0}{c}\cdot k\sin(kz-\omega t)\hat{i}$

$\begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ 0 & B(t) & 0 \end{vmatrix}$

$\frac{\partial\vec{E}}{\partial t} = E_0\omega\sin(kz-\omega t)$ $\quad k = \frac{2\pi}{\lambda}$

$E_0\sin(kz-\omega t) = \frac{\partial\vec{E}}{\partial t}\cdot\frac{1}{\omega}$ $\quad \omega = 2\pi f$

$\vec{\nabla}\times\vec{B} = \frac{k}{c}\cdot\frac{1}{\omega}\frac{\partial\vec{E}}{\partial t} = \frac{1}{c}\cdot\frac{2\pi}{\lambda}\cdot 2\pi f\cdot\frac{\partial\vec{E}}{\partial t}$ $\quad c = \lambda f$, $\lambda = \frac{c}{f}$

$\alpha = \frac{1}{\lambda f}\cdot\frac{2\pi}{\lambda}\cdot 2\pi f = 4\pi^2\cdot\frac{1}{\lambda^2} = \boxed{\frac{4\pi^2 f^2}{c^2}}$ NO

b. (2 pts) What is the magnitude of the time averaged Poynting vector, $<\vec{S}>$, associated with this wave. (4 pts) Use it to find the amplitude of the electric field at your starting point, a distance r from the sun. Constants that may appear in your answer: m , $<P>$, c, m_s, G, k, π, μ_0, ϵ_0 and ω as necessary.

$$I = |\langle \vec{S} \rangle| = c\varepsilon_0 E_{rms}^2 = \frac{1}{2} c \varepsilon_0 E_0^2$$

$$\langle P \rangle = I \cdot 4\pi r^2 = \frac{1}{2} c \varepsilon_0 E_0^2 \cdot 4\pi r^2$$

$$E_0 = \sqrt{\frac{\langle P \rangle}{2 c \varepsilon_0 \pi r^2}}$$

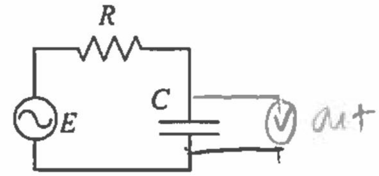
c. (15 pts) What is the minimum area for the sail in order to exactly balance the gravitational attraction from the sun? Constants that may appear in your answer: m , $<P>$, c, m_s, G, k, π,μ_0, ϵ_0 and ω as necessary.

Presure, Area

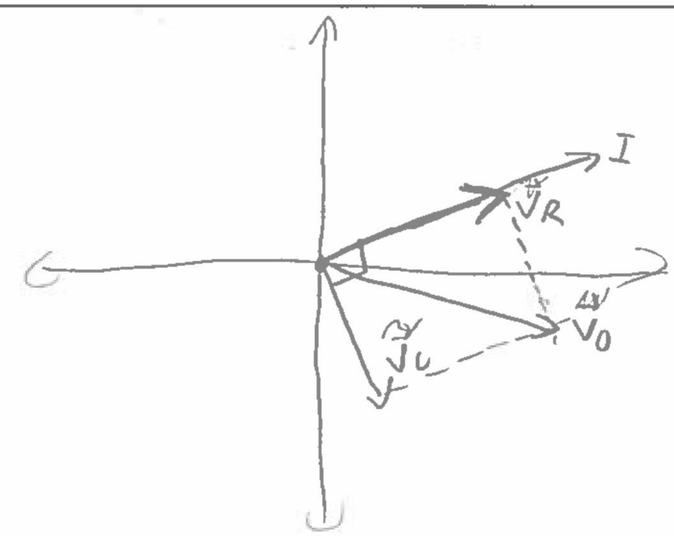
$$G\frac{m m_s}{r^2} = \left(2 \cdot \frac{I}{c}\right) \cdot A \qquad I = \frac{\langle P \rangle}{4\pi r^2}$$

$$A = \frac{G m m_s c}{2 I r^2} = \frac{G m m_s c}{2 r^2 \langle P \rangle} \cdot 4\pi r^2 = \frac{2 G m m_s c \pi}{\langle P \rangle}$$

Problem 2. The circuit shown has an AC generator $V_{in} = V_0 \sin(\omega t)$ connected in series with a resistor R and a capacitor C.



a. (5 pts) Draw a phasor diagram for this circuit, showing the relative phases of the voltages V_R, V_C, and V_0.



b. (5 pts) Does the current lag or lead the voltage? Explain.

The current leads the voltage because the voltage in the capasitor responds to the current (Capacitor voltage lags by 90°)

c. (5 pts) What is the ratio of the magnitudes of the output signal amplitude to the input signal amplitude $\frac{V_{out,0}}{V_{in,0}}$ if the output is measured across the capacitor only? (3 pts) What is the limiting value of this ratio at very small values of ω? (3 pts) What is the limiting value of this ratio at very large values of ω? (5 pts) Decide if this is a high pass or low pass filter. (Recall that a low pass filter blocks high frequencies.)

$V_c = I X_C = -\omega)$

$I = \frac{V_0 \sin(\omega t)}{\sqrt{R^2 + (\frac{1}{\omega C})^2}}$

$V_{cap} = \frac{V_0 \cdot \frac{1}{\omega C}}{\sqrt{R^2 + (\frac{1}{\omega C})^2}}$

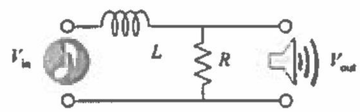
$V_{cap}^2 = \frac{V_0^2 (\frac{1}{\omega C})^2}{R^2 + (\frac{1}{\omega C})^2}$

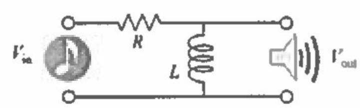
Small ω: $V_{cap} \to V_0$

Big ω: $V_{cap} \to 0$

Low pass filter

d. (10 pts) Low-pass and high-pass filters can also be constructed using inductors rather than capacitors. Determine which of these two circuits would provide a low-pass filter and which would provide a high-pass filter. Explain your answer.





Top: $V_R = I X_R$

$I_{amp} = \frac{V_0}{\sqrt{R^2 + (\omega L)^2}}$

$V_R = \frac{V_0 R}{\sqrt{R^2 + \omega^2 L^2}}$

$\omega \to \infty$ $V_R \to 0$

$\omega \to 0$ $V_R \to V_0$

Low pass filter because it kills high frequency

Bottom

$V_L = I X_L = \frac{V_0 \omega L}{\sqrt{R^2 + \omega^2 L^2}}$

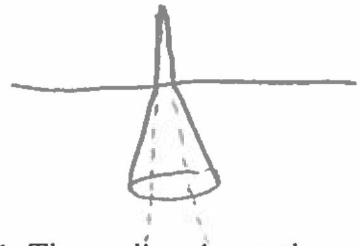
$\omega \to \infty$ $V_L \to V_0$

$\omega \to 0$ $V_L \to 0$

High pass filter because it kills low frequency

Problem 3. Consider an object immersed in an unknown fluid such that its apparent depth is **larger** than its actual depth when viewed from an observer located outside of the fluid. What can you say about the index of refraction of the fluid? (note: the fluid is not necessarily surrounded by air.) (5 pts)

a. $n_{fluid} > n_{outside}$
b. $n_{fluid} < n_{outside}$
c. $n_{fluid} = n_{outside}$
d. not possible to tell



Now consider an air-medium interface in which $n_{air} = 1$. The medium is not the one from above.

a. (15 pts) Determine an expression for the value of n of the medium for which Brewsters angle is equal to the critical angle.

$\sin(\theta_p) = n$ $\quad\quad$ $\sin(\theta_p) = n\cos(\theta_p)$

$n = n\sqrt{1-n^2}$

$1 = \sqrt{1-n^2}$

$1-n^2 = 1$

$n = 0$

$\cos(\theta_p) = \sqrt{1-\sin^2(\theta_p)} = \sqrt{1-n^2}$

$\theta_B = \tan^{-1}(n)$ $\quad\quad$ $\theta_B = \sin^{-1}(n)$

$\tan^{-1}(n) = \sin^{-1}(n)$

$n = 0$

b. (8 pts) Solve your expression from part a for n. (Hint: Use similar triangles. Does your value of n make physical sense? If not, you should reconsider the problem.)

Scratch paper