PHYSICS 1C - Waves, Optics, and Modern Physics
Summer Session I, 2012
Midterm 2, Version A

Instructor: Grigor Aslanyan
July 25, 2012

Please read carefully before beginning!

- You have 80 minutes to complete the exam.
- Fill in your name, student ID, 3-digit code number, and the test version on your scantron.
- You are not allowed to have any materials other than a scantron, a pen and/or a pencil, and a calculator. Equations are provided below.
- Each problem is worth 1 point.

Best of luck!

Useful equations:

Simple harmonic motion:
\[
\begin{align*}
\frac{d^2x}{dt^2} &= -\omega^2 x \\
v_x &= -\omega A \sin(\omega t + \phi) \\
a_x &= -\omega^2 A \cos(\omega t + \phi) \\
E &= \frac{1}{2} kA^2
\end{align*}
\]
Mass attached to a spring:
\[\omega = \sqrt{\frac{k}{m}}\]

Simple pendulum:
\[\omega = \sqrt{\frac{g}{l}}\]

Physical pendulum:
\[\omega = \sqrt{\frac{mgd}{I}}\]

Damped oscillations:
\[x(t) = A e^{-\frac{b}{2m}t} \cos(\omega t + \phi)\]
\[\omega = \sqrt{\omega_0^2 - \left(\frac{b}{2m}\right)^2}\]

Forced oscillations:
\[x(t) = A \cos(\omega t + \phi)\]
\[A = \frac{F_0/m}{\sqrt{(\omega^2 - \omega_0^2)^2 + (\frac{b\omega}{m})^2}}\]

Waves:
\[y(x, t) = A \sin(kx - \omega t)\]
\[v_y = -\omega A \cos(kx - \omega t)\]
\[a_y = -\omega^2 A \sin(kx - \omega t)\]
Linear wave equation:
\[\frac{\partial^2 y}{\partial x^2} = \frac{1}{v^2} \frac{\partial^2 y}{\partial t^2}\]

Waves on strings:
\[v = \sqrt{\frac{T}{\mu}}\]

Energy transfer:
\[P = \frac{1}{2} \mu \omega^2 A^2 v\]

Sound waves:
\[s = s_{\text{max}} \sin(kx - \omega t)\]
\[v = 331 m/s + (0.6 m/s \cdot ^\circ C) T_C\]
\[v(20^\circ C) = 343 m/s\]
Doppler effect: \[ f' = f \frac{v_0 + v_a}{v_0} \]

Interference: \[ y = (2A \cos \phi) \sin (kx - \omega t + \phi) \]
constructive: \[ \phi = 0, 2\pi, 4\pi, ... \]
destructive: \[ \phi = \pi, 3\pi, 5\pi, ... \]
Standing waves: \[ y = (2A \sin kx) \cos \omega t \]

In strings: \[ f_n = \frac{n \pi}{2L} \sqrt{\frac{T}{\mu}} \]
In air columns:
open both ends: \[ f_n = \frac{n \pi}{4L} \]
one end closed: \[ f_n = \frac{n \pi}{2L} \]
Beats: \[ y = [2A \cos 2\pi \left( \frac{f_1 - f_2}{2} \right) t] \cos 2\pi \left( \frac{n + f_2}{2} \right) t \]

Displ. current: \[ i_d = \frac{d\Phi}{dt} \]
Maxwell’s eq’s:
\[ \oint \mathbf{E} \cdot d\mathbf{A} = \frac{q}{\epsilon_0} \]
\[ \oint \mathbf{B} \cdot d\mathbf{s} = \mu_0 I \]
EM waves: \[ c = \frac{1}{\sqrt{\mu_0 \epsilon_0}} = 3 \times 10^8 \text{m/s} \]
\[ \epsilon_0 = 8.85 \times 10^{-12} \frac{C^2}{N \cdot m^2} \]
Doppler effect: \[ f' = f \sqrt{\frac{v + v_a}{v}} \]

\[ LC \text{ circuit:} \quad \omega = \frac{1}{\sqrt{LC}} \]
\[ \mathbf{S} = \frac{1}{\mu_0} \mathbf{E} \times \mathbf{B} \]

Intensity: \[ I = S_{avg} = \frac{E_{max}B_{max}}{2\mu_0} = \frac{E_{max}^2}{2\mu_0 c} = \frac{cB_{max}^2}{2\mu_0} \]
Energy dens.: \[ u_E = \frac{\epsilon_0 E^2}{2} \]
\[ u_{avg} = \frac{\epsilon_0 E_{max}^2}{2} = \frac{B_{max}^2}{2\mu_0} \]

Momentum: \[ p = \frac{E}{c} \]
Pressure: \[ P = \frac{S}{c} \]
Polarization: \[ I = I_0 \cos^2 \theta \]
Reflection: \[ \theta' = \theta \]
Refraction: \[ n = \frac{c}{v} \]
Tot. int. refl.: \[ \sin \theta_c = \frac{n_2}{n_1} \]

Mirrors: \[ \frac{1}{p} + \frac{1}{q} = \frac{1}{f} \]
Signs: \[ p > 0 \text{ obj. in front (real)} \]
\[ h' > 0 \text{ image upright} \]
Refr. surface: \[ \frac{n_2}{p} + \frac{n_1}{q} = \frac{n_2 - n_1}{R} \]
Signs: \[ p > 0 \text{ obj. in front (real)} \]
\[ h' > 0 \text{ image upright} \]
Lenses: \[ \frac{1}{p} + \frac{1}{q} = \frac{1}{f} \]
Signs: \[ p > 0 \text{ obj. in front (real)} \]
\[ h' > 0 \text{ image upright} \]
Magnification: \[ M = h'/h = -\frac{2}{p} \]

\[ v_o, v_a \] positive when moving toward\n\[ \Delta r = \frac{\phi}{2\pi} \lambda \]
distance between (anti)nodes: \[ \lambda/2 \]

\[ n = 1, 2, 3, ... \]

\[ n = 1, 2, 3, ... \]

\[ n = 1, 3, 5, ... \]

\[ f_0 = |f_1 - f_2| \]

\[ f \] positive when approaching

\[ S = E \mathbf{B} = E^2 \mu_0 = \frac{cB^2}{\mu_0} \]

\[ u_B = \frac{p^2}{2\mu_0} \]
\[ I = cu_{avg} \]

for complete absorption
\[ I = \frac{I_0}{2} \] for unpolarized

\[ n_1 \sin \theta_1 = n_2 \sin \theta_2 \]
\[ \lambda_{1R_1} = \lambda_{2R_2} \]
for \( n_2 < n_1 \)
\[ f = \frac{R}{2} \]
\[ q > 0 \] image behind (real)
\[ R > 0 \] center behind
\[ \frac{1}{f} = (n - 1) \left( \frac{1}{R_1} - \frac{1}{R_2} \right) \]
\[ q > 0 \] image behind (real)
\[ R_1, R_2 > 0 \] center behind
Problem 1  *In an electromagnetic wave:*

(A) $E$ and $B$ fields oscillate parallel to each other and parallel to the direction of propagation.

(B) $E$ and $B$ fields oscillate perpendicular to each other and perpendicular to the direction of propagation.

(C) $E$ and $B$ fields oscillate parallel to each other and perpendicular to the direction of propagation.

(D) $E$ and $B$ fields oscillate parallel to each other, and propagation is in the direction of $\vec{E} \times \vec{B}$.

Problem 2  *A concave spherical mirror has a radius of curvature of $20\text{ cm}$. An object is at a distance of $20\text{ cm}$ in front of the mirror. The image is:*

(A) in front of the mirror at a distance of $20\text{ cm}$, it is real and inverted.

(B) behind the mirror at a distance of $20\text{ cm}$, it is real and inverted.

(C) in front of the mirror at a distance of $20\text{ cm}$, it is real and upright.

(D) at infinity.

Problem 3  *At what distance from a $100\text{ W}$ electromagnetic wave point source does $E_{\text{max}} = 15\text{ V/m}$?*

(A) $7.30\text{ m}$

(B) $3.65\text{ m}$

(C) $10.33\text{ m}$

(D) $5.16\text{ m}$

Problem 4  *Unpolarized light passes through two Polaroid sheets. The axis of the first is vertical and that of the second is at $45^\circ$ to the vertical. What fraction of the incident light is transmitted?*

(A) none

(B) $1/4$

(C) $1/2$

(D) $1/\sqrt{2}$
**Problem 5** A light ray enters water from air. The index of refraction of water is 1.33. Which of the following statements is false? (There is only one wrong statement)

(A) The speed of light is reduced by a factor of 1.33.
(B) The wavelength is reduced by a factor of 1.33.
(C) The frequency is reduced by a factor of 1.33.
(D) The angle of incidence is greater than the angle of refraction.

**Problem 6** Find the focal length of the combination of two converging lenses placed right next to each other, each of which has a focal length of 50 cm. **Hint:** Find the image of an object placed at infinity (i.e. parallel light rays coming in) through the first lens, then think of that image as the object of the second lens and find the new image. This will be at the focal point.

(A) infinity
(B) 1 m
(C) 50 cm
(D) 25 cm

**Problem 7** What is the critical angle for total internal reflection for light going from glass \((n = 1.5)\) into water \((n = 1.33)\)?

(A) 27.5°
(B) 41.8°
(C) 48.8°
(D) 62.5°
Problem 8  A pool is 1 m deep and is filled with water. How deep does it appear to an observer from outside? The index of refraction of water is 1.33.

(A) 1.33 m  
(B) 1 m  
(C) 75 cm  
(D) 57 cm

Problem 9  A bright star is emitting light of wavelength 400 nm toward the earth. The observed wavelength on the earth is 800 nm. What is the speed of the star relative to the earth?

(A) $1.8 \times 10^8$ m/s approaching  
(B) $1.8 \times 10^8$ m/s going away  
(C) $1 \times 10^8$ m/s approaching  
(D) $1 \times 10^8$ m/s going away

Problem 10  The amplitude of the electric field in an electromagnetic wave is 3 V/m. What is the amplitude of the magnetic field?

(A) $9 \times 10^{16}$ T  
(B) 3 T  
(C) 1.5 T  
(D) $1 \times 10^{-8}$ T