SOLUTIONS

Physics 204– Second Hour Exam
Sunday, April 5, 2009
Prof. George Horton

Your name sticker

with exam code ⇒

1. The exam will last from 6:10 to 7:30 P.M. Use a #2 pencil to make entries on the answer sheet. Enter the following id information now, before the exam starts.
2. In the section labelled NAME (Last, First, M.I.) enter your last name, then fill in the empty circle for a blank, then enter your first name, another blank, and finally your middle initial.
3. Under STUDENT # enter your 9-digit Rutgers ID number.
4. Enter 204 under COURSE, and your section number under SEC.
5. Under CODE enter the exam code given above.
6. During the exam, you may use a calculator and are allowed one $8\frac{1}{2} \times 11$ inch sheet of paper with whatever you want hand-written on it. Xeroxed or printed sheets are **not permitted** and will be confiscated.
7. The exam consists of 17 multiple choice questions. For each multiple choice question mark only one answer on the answer sheet. There is no deduction of points for an incorrect answer, so even if you cannot work out the answer to a question, you should make an educated guess.
8. Turn off any cell phone or other communication device, and pack it away in a place clearly inaccessible. You may not use your cell-phone as a clock or in any other way during the exam.
9. Before starting the exam, make sure that your copy contains all 17 questions. Raise your hand if this is not the case, and a proctor will help you. Also raise your hand during the exam if you have a question.
10. A proctor will check your name sticker and your student ID when you turn in the exam. Please have them ready.
11. You are not allowed to give help to any other student, ask for help from anyone but a proctor, or change your seat without permission from a proctor. Doing so will result in a zero score for the exam.
12. Please hand in the answer sheet. You may take the question paper with you when you leave.
13. Some constants are given on the last page.

1. A flux of $4 \times 10^{-5}\ Wb$ is maintained through a coil for $0.5\ s$. What emf is induced in this coil by this flux during that time?

   a) $8 \times 10^{-5}\ V$
   b) $4 \times 10^{-5}\ V$
   c) $2 \times 10^{-5}\ V$
   d) $6 \times 10^{-5}\ V$
   → e) No emf is induced in the coil

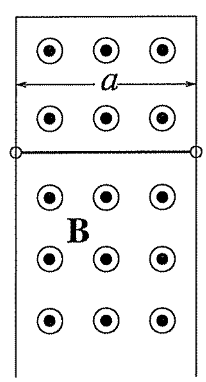
   $|\mathcal{E}| = \frac{\Delta \Phi}{\Delta t} = 0$ because flux is not changing.

2. A circular coil lies flat on a tabletop in a region where the magnetic field vector points straight up. The magnetic field gradually diminishes. When viewed from above, what is the sense of the induced current in this coil as the field diminishes?

   → a) The induced current flows counter-clockwise
   b) The induced current flows clockwise
   c) There is no induced current in the coil
   d) The induced current flows clockwise initially and then flows counter-clockwise before stopping
   e) The induced current flows counter-clockwise initially and then flows clockwise before stopping

   Induced magnetic field opposes the original flux change: Lenz's Law.

3. A wire of negligible resistance is bent into the shape shown. The long portions of the wire are vertical. A bar of length a, resistance R, and mass m can slide downwards without friction on the vertical portions. A uniform horizontal magnetic field B points out of the page. The bar is released from rest and allowed to fall under the influence of gravity. (The vertical wires are long enough that their length is of no concern). Under these conditions, how will the falling bar behave?



   a) It will continue to accelerate indefinitely
   b) It will slow down and finally come to rest in equilibrium
   c) It will reach a constant terminal velocity $mgR/2a^2B^2$
   → d) It will reach a constant terminal velocity mgR/a^2B^2
   e) It will reach a constant terminal velocity $2mgR/a^2B^2$

Motional emf $\mathcal{E} = vBa$.

Induced current $I = \frac{\mathcal{E}}{R} = \frac{vBa}{R}$ clockwise by Lenz's Law.

Magnetic force $F_{MAG} = IaB = \left(\frac{vBa}{R}\right)aB = \frac{va^2B^2}{R}$ upward

Net force $F_{NET} = \frac{va^2B^2}{R} - mg$

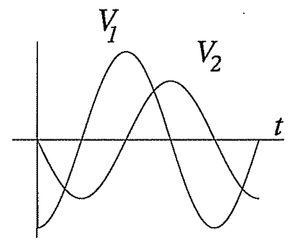
Terminal velocity when $F_{NET} = 0 \Rightarrow v = \frac{mgR}{a^2B^2}$

4. Consider a circular coil that is initially oriented with its plane perpendicular to a uniform magnetic field. Which of the following changes will NOT lead to an induced current in the coil?

All but (d) have a changing flux.

a) Decreasing the magnitude of the magnetic field
b) Deforming the circular coil into a square shape
c) Rotating the coil about a diameter
→ d) Rotating the coil about an axis through its center and perpendicular to its plane
e) Increasing the magnitude of the magnetic field

5. Compare the voltage waves shown from two different AC circuits. The absolute value of the phase difference is



a) Zero
b) 45°
→ c) 90° ↳ one-quarter of a cycle.
d) 180°
e) None of the other answers

6. A pure inductor is connected to an AC power supply. In this circuit, the current

See textbook, page 730, figure 23.7 and discussion.

a) leads the voltage by 90°
→ b) lags the voltage by 90°
c) is in phase with the voltage
d) alternates lagging and leading the voltage
e) leads the voltage by 45°

7. What size capacitor must be placed in series with a 30 Ω resistor and a 40 mH inductor so that the resonant frequency is 500 Hz?

→ a) About 2.5 μF
b) About 4.0 μF
c) About 5.5 μF
d) About 7.0 μF
e) About 8.5 μF

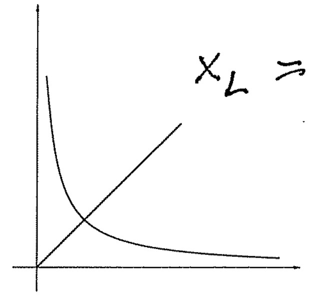
$$f = \frac{1}{2\pi\sqrt{LC}} \Rightarrow C = \frac{1}{L(2\pi f)^2}$$

$$\Rightarrow C = \frac{1}{.04(2\pi \cdot 500)^2} = 2.5 \times 10^{-6} \text{ F.}$$

8. The graph shown represents resonance if the vertical axis is reactance and the

$$X_C = \frac{1}{2\pi f C}$$

$$X_L = 2\pi f L$$



a) horizontal axis is resistance
b) straight line is capacitive reactance, the curved line is inductive reactance, and the horizontal axis is frequency
→ c) straight line is inductive reactance, the curved line is capacitive reactance, and the horizontal axis is frequency
d) horizontal axis is inductance
e) horizontal axis is capacitance

9. An argon-ion laser produces a cylindrical beam of light whose average power is 0.750 W. How much energy is contained in a 2.50 m length of the beam?

a) 1.25×10^{-9} J
b) 2.25×10^{-9} J
c) 3.25×10^{-9} J
d) 9.25×10^{-9} J
→ e) None of the other answers

This was Web Assign 7, Question 7.

$$E = \frac{PL}{c} = \frac{(0.750)(2.50)}{3\times10^{8}} = 6.25\times10^{-9}\ J.$$

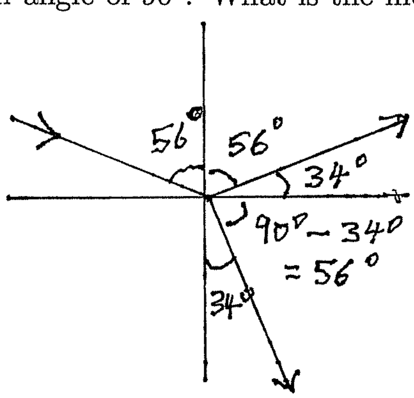
10. When a light wave enters into a medium of different optical density, for example air to glass,

a) its speed and frequency change, but not its wavelength
→ b) its speed and wavelength change, but not its frequency
c) its frequency and wavelength change, but not its speed
d) only its frequency changes
e) its speed, frequency, and wavelength all change

f depends on source, so it stays the same.
$v = \frac{c}{n}$ so it changes.
$\lambda = \frac{v}{f}$ so it changes since v changes while f stays same.

11. A beam of light travelling in air strikes a plate of transparent material at an angle of incidence of 56°. It is observed that the reflected and refracted beams form an angle of 90°. What is the index of refraction of this material?

a) 1.40
b) 1.43
c) 1.45
→ d) 1.48
e) 1.50



From geometry, angle of refraction is 34°.

$$\sin 56° = n \sin 34°$$

$$n = \frac{\sin 56°}{\sin 34°} = 1.48$$

12. A plane mirror forms an image that is

a) real and upright
→ b) virtual and upright
c) real and upside down
d) virtual and upside down
e) virtual and reduced in size

see textbook, pages 785 - 786.

13. Sometimes when you look into a curved mirror you see a magnified image (big you) and sometimes you see a reduced image (little you). If you look at the convex underside of a shiny spoon, what will you see?

a) You won't see an image of yourself because no image is formed
b) You will see little you, inverted
→ c) You will see little you, upright
d) Whether your image is upright or inverted depends on how close you are to the spoon
e) You will see big you or little you depending on how close you are to the spoon

see textbook, page 793.

14. How far from a 50 *mm* focal length lens must an object be placed if it is to form a real image magnified in size by a factor of three?

a) About 46.2 *mm*
b) About 52.2 *mm*
c) About 33.3 *mm*
d) About 57.5 *mm*
→ e) About 66.7 *mm*

$|m| = \frac{|d_i|}{d_o} = 3 \Rightarrow |d_i| = 3d_o$

Real, so $d_i = +3d_o$

So $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{3d_o} = \frac{4}{3d_o} \Rightarrow d_o = \frac{4}{3}f$

$= 66.7$ mm.

15. An object is placed at the origin. A converging lens of focal length 10 *mm* is placed at x = 40 *mm* on the x-axis. A second converging lens of focal length 20 *mm* is placed at x = 90 *mm*. The final image will be

a) real and enlarged
b) virtual and enlarged
→ c) real and reduced
d) virtual and reduced
e) the same size as the object

$\frac{1}{40} + \frac{1}{d_1} = \frac{1}{10} \Rightarrow d_1 = 13.33$ mm.

So $x_1 = 40 + 13.33 = 53.33$ mm.

Then object distance for <u>second</u> lens is

$d_{o_2} = 90 - x_1 = 90 - 53.33 = 36.67$ mm.

Then $\frac{1}{36.67} + \frac{1}{d_2} = \frac{1}{20} \Rightarrow d_2 = 44.0$ mm.

Positive, therefore real.

$$|m| = \frac{d_1}{d_{o_1}} \cdot \frac{d_2}{d_{o_2}} = \frac{13.33}{40} \cdot \frac{44.0}{36.67} = 0.40.$$

16. In a Young's double slit experiment, the seventh dark fringe is located 0.025 m to the side of the bright central fringe on a flat screen which is 1.1 m away from the slits. The separation between the slits is 1.4×10^{-4} m. What is the wavelength of the light being used?

a) 5.8×10^{-7} m
b) 5.4×10^{-7} m
→ c) 4.9×10^{-7} m
d) 4.3×10^{-7} m
e) 3.8×10^{-7} m

$\tan\theta = \frac{y}{L} = \frac{.025}{1.1} \Rightarrow \theta = 1.30°$

$\sin\theta = \left(m + \frac{1}{2}\right)\frac{\lambda}{d}$ with $m = 6$ (not 7).

$\Rightarrow \lambda = \frac{d \sin\theta}{m + \frac{1}{2}} = \frac{(1.4\times10^{-4})\sin 1.30°}{6.5} = 4.9\times10^{-7}$ m.

17. Light shining on a diffraction grating has a wavelength of 495 nm. The grating produces a second-order bright fringe whose position is defined by an angle of 9.34°. How many lines per cm does the grating have?

a) About 1608 lines per cm
b) About 1616 lines per cm
c) About 1627 lines per cm
→ d) About 1639 lines per cm
e) About 1652 lines per cm

$d = \frac{m\lambda}{\sin\theta} = \frac{(2)(495\times10^{-9})}{\sin 9.34°}$

$= 6.1\times10^{-6}$ m $= 6.1\times10^{-4}$ cm.

So $\frac{1}{d} = \frac{1}{6.1\times10^{-4}} = 1639$ lines per cm

Some Constants

acceleration due to gravity g	$9.8\ m/s^2$
electromagnetic permittivity ϵ_0	8.854×10^{-12} C^2/N-m^2
electromagnetic constant $k_e \equiv \frac{1}{4\pi\epsilon_0}$	8.9875×10^9 N-m^2/C^2
magnitude of electron charge	1.602×10^{-19} C
electron mass	9.11×10^{-31} kg
proton mass	1.67×10^{-27} kg
magnetic permeability μ_0	$4\pi \times 10^{-7}$ T·m/A
speed of light in vacuum	3×10^8 m/s
atomic mass unit	u $= 1.6605 \times 10^{-27}$ kg $= 931.5$ MeV/c^2