Physics 130
Wave Motion, Optics and Sound
Final Examination

18 December, 2010
9:00 AM – 12:00 PM Pavilion

All Sections (Consolidated) **Course Convener: Dr. M. Heimpel**

NAME: _____ **ID #** _____

A single 8 1⁄2" x 11" formula sheet (front and back) is permitted.

Calculators without communications features are permitted. All other electronic devices are prohibited.

The exam is 3 hours (180 minutes) in length.

Attempt ALL questions.

Answers must be clearly indicated on the answer sheet using an HB pencil.

Several sheets of scratch paper are appended in the back of the exam for rough work (you may separate these extra pages), and you may write on this exam paper. At the end of the exam, turn in your answer sheet, this exam paper, and the scratch paper (but not your formula sheet). Turn everything in to the box for your section, keeping the answer sheet separate.

Rough work will not be graded.

ON THE ANSWER SHEET ENTER:
Your name (Surname followed by space then given names)
Student Identification Number

Course Section in Special Codes columns KLM:

Section	Instructor	Lecture Time	Codes
A01	Pogosyan	09:00 – 09:50 AM	JKL = 111
A02	Heimpel	10:00 – 10:50 AM	JKL = 222
A03	Heimpel	02:00 – 02:50 PM	JKL = 333
A04	Pinfold	03:00 – 03:50 PM	JKL = 444

Grading: 1 point per question.

Possibly useful constants:

Gravitational acceleration:	$g = 9.81\ m/s^2$	Kelvin temperature:	$0°C = 273.15\ K$
Speed of light in a vacuum:	$c = 3.00 \times 10^8\ m/s$	Ideal gas constant:	$R = 8.31\ J/(K \cdot mol)$
Stefan-Boltzmann constant:	$k = 5.67 \times 10^{-8}\ J/(s \cdot m^2 \cdot K^4)$	Threshold of human hearing:	$I_0 = 1.0 \times 10^{-12}\ W/m^2$

There is only one correct answer to each question. If you believe the correct answer is not listed, choose the closest matching value.

There are 16 pages with 40 questions for a maximum total of 40 points for this exam.

IF ANYTHING IS UNCLEAR, PLEASE ASK!

Question (1) What is impossible about the following situation? An object in simple harmonic motion has an equilibrium position x = 0.00 m. At some instant in time, the position of the object is +3.00 m, the velocity is -2.00 m/s, and the acceleration is +9.00 m/s^2.

(A) The numerical value of the velocity is smaller than the distance from the equilibrium position, but the numerical value of the magnitude of the acceleration is larger than the distance from equilibrium.

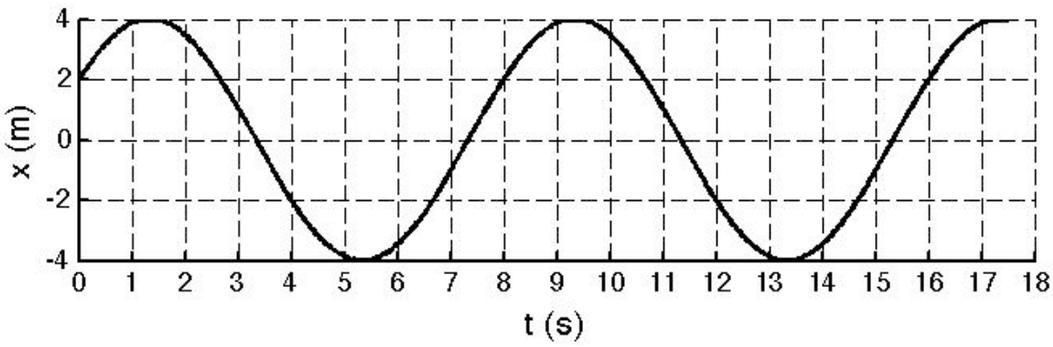
(B) The velocity is opposite in direction to the displacement.

(C) The displacement from equilibrium and the acceleration are in the same direction.

(D) The speed is less than the displacement.

(E) The acceleration is greater than the speed.

Question (2) The simple harmonic motion of an object is shown in the figure below. What is the position of the object as a function of time?



(A) $x(t) = (4.0\text{ m})\sin[(2\pi/8.0\text{ s})t + \pi/3.0]$

(B) $x(t) = (4.0\text{ m})\cos[(2\pi/8.0\text{ s})t + 2\pi/3.0]$

(C) $x(t) = (4.0\text{ m})\cos[(2\pi/8.0\text{ s})t + \pi/3.0]$

(D) $x(t) = (4.0\text{ m})\cos[(2\pi/8.0\text{ s})t - \pi/3.0]$

(E) $x(t) = (8.0\text{ m})\cos[(2\pi/8.0\text{ s})t + \pi/3.0]$

Question (3) A vertical spring has a mass hanging from it, which is displaced from the equilibrium position and begins to oscillate. At what point does the system have the least potential energy?

(A) at the highest point

(B) at one-fourth of the distance between the highest point and lowest point

(C) at the lowest point

(D) at the point where the spring is unstretched

(E) at the equilibrium point

Question (4) A pendulum 3.0 m long is oscillating through a maximum angle of 4.8°. What is its speed when the angle is 2.4°?

(A) 0.45 m/s

(B) 0.39 m/s

(C) 23 m/s

(D) 3.0 m/s

(E) 26 m/s

Question (5) A damped harmonic oscillator, with a damping force proportional to its speed, is oscillating with an amplitude of 0.500 cm at t = 0. When t = 8.20 s, the amplitude has died down to 0.400 cm. At what value of t will the oscillations have an amplitude of 0.250 cm?

(A) 18.5 s

(B) 20.5 s

(C) 16.5 s

(D) 25.5 s

(E) 5.13 s

Question (6) Consider the wave equation below, where A and B are positive constants. What is the speed of waves described by this equation?

$$A\frac{\partial^2 z(x,t)}{\partial x^2} = B\frac{\partial^2 z(x,t)}{\partial t^2}$$

(A) $\sqrt{B}$

(B) B^2/A^2

(C) $1/\sqrt{B}$

(D) $\sqrt{A}$

(E) $\sqrt{A/B}$

Question (7) The wavelengths corresponding to the harmonics of a string with fixed ends can be found by saying that the length of the string must be equal to

(A) an odd number of quarter-wavelengths.

(B) an odd number of third-wavelengths.

(C) an odd number of half-wavelengths.

(D) an integer number of half-wavelengths.

(E) an integer number of wavelengths.

Question (8) Ocean tides are waves that have a period of 12 hours and a speed of 750 km/hr. What is their wavelength?

(A) 9000 km

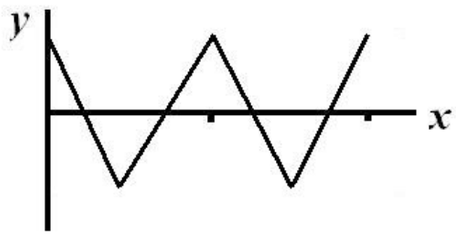
(B) 32,400 km

(C) 9000 m

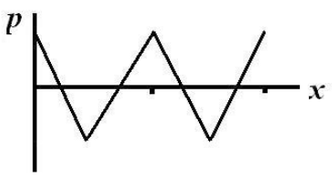
(D) 32,400 m

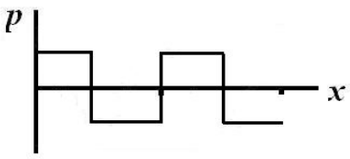
(E) 2,500 m

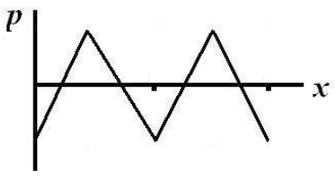
Question (9) The displacement y in a non-sinusoidal sound wave is shown in the figure below as a function of x at time $t = 0$.

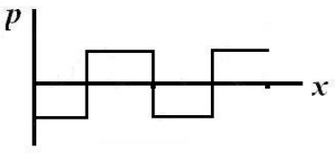


Which graph shows the pressure amplitude p in this wave as a function of x at time $t = 0$?

(A) 

(B) 

(C) 

(D) 

(E) None of the above

Question (10) A 440-Hz tone is produced by a sound wave with displacement amplitude equal to 0.045 μm. The velocity of sound in air is 344 m/s. The bulk modulus of air is 142 kPa. The intensity level of the sound waves, in decibels, is closest to:

(A) 31 dB

(B) 49 dB

(C) 65 dB

(D) 139 dB

(E) 150 dB

Question (11) A particular pipe organ can resonate at 264 Hz, 440 Hz and 616 Hz, but not at any other frequencies in between. What is the fundamental frequency of this pipe?

(A) 44 Hz

(B) 66 Hz

(C) 88 Hz

(D) 176 Hz

(E) 264 Hz

Question (12) A 0.74 m-long open pipe vibrates in the second *overtone* ($n = 3$) with a frequency of 962 Hz. In this situation, the speed of sound in air, in SI units, is closest to:

(A) 451 m/s

(B) 459 m/s

(C) 467 m/s

(D) 475 m/s

(E) 483 m/s

Question (13) You have a stopped pipe of adjustable length close to a taut 85.0-cm, 7.25-g wire under a tension of 4110 N. You want to adjust the length of the pipe so that, when it produces sound at its fundamental frequency, this sound causes the wire to vibrate in its second *overtone* (that is, $n = 3$) with very large amplitude. The speed of sound in the pipe is 344 m/s. The length of the pipe should be closest to:

(A) 7.02 cm

(B) 14.0 cm

(C) 28.6 cm

(D) 63.2 cm

(E) 70.4 cm

Question (14) A pair of speakers separated by 70.0 cm are driven in phase at a frequency of 690 Hz. An observer, originally positioned at one of the speakers, begins to walk along a line perpendicular to the line joining the two speakers. The speed of sound is 344 m/s. How far must the observer walk before reaching the first relative minimum in the intensity?

(A) 4.63 cm

(B) 22.5 cm

(C) 24.2 cm

(D) 45.1 cm

(E) 85.8 cm

Question (15) Two loudspeakers face each other at opposite ends of a long corridor. They are connected to the same source, which produces a pure tone of 440 Hz. A person walks from one speaker to the other at a speed of 1.8 m/s. Take the speed of sound equal to 344 m/s. The frequency of the beat heard by the person is closest to:

(A) 2.3 Hz

(B) 3.4 Hz

(C) 4.6 Hz

(D) 6.8 Hz

(E) 9.2 Hz

Question (16) A car on a road parallel to and right next to a railroad track is approaching a train. The car is traveling eastward at 30.0 m/s while the train is going westward at 50.0 m/s. There is no wind, and the speed of sound is 344 m/s. The car honks its horn at a frequency of 1.00 kHz as the train toots its whistle at a frequency of 1.50 kHz. The wavelength of the sound from the train's whistle, as measured by the driver of the car, is closest to:

(A) 0.263 m

(B) 0.249 m

(C) 0.196 m

(D) 0.180 m

(E) 0.229 m

Question (17) The doublet of the sodium spectrum, in the yellow band, has two constituents having lengths of 589.0 nm and 589.6 nm respectively. Light of this doublet is propagated at normal incidence through a crystal slab. The index of refraction of the crystal at these wavelengths is 1.548. The number of waves of the 589.0-nm constituent that are present in a crystal 1.3 mm thick is closest to:

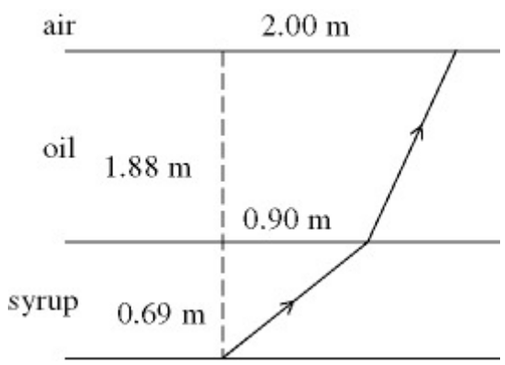
(A) 2200
(B) 2700
(C) 5300
(D) 4300
(E) 3400

Question (18) When light travels from air into water,

(A) its wavelength changes, but its velocity and frequency do not change.
(B) its velocity changes, but its frequency and wavelength do not change.
(C) its velocity and wavelength change, but its frequency does not change.
(D) its velocity, wavelength, and frequency all change.
(E) its frequency changes, but its velocity and wavelength do not change.

Question (19) A tank holds a layer of oil, 1.88 m thick, which floats on a layer of syrup that is 0.69 m thick. Both liquids are clear and do not intermix. A ray, which originates at the bottom of the tank on a vertical axis, crosses the oil-syrup interface at a point 0.90 m from the axis. The ray continues and arrives at the oil-air interface, 2.00 m from the axis and at the critical angle. In the figure below, the index of refraction of the oil is closest to:

(A) 1.94
(B) 2.02
(C) 1.96
(D) 2.00
(E) 1.98



Question (20) How far above the horizon is the Moon when its image reflected in calm water is completely polarized?

(A) 36.9°
(B) 43.2°
(C) 46.8°
(D) 53.1°
(E) 57.5°

Question (21) In the picture below, the radius of the curved part of the lens is 24.0 cm, and the refractive index of the lens material is 1.75. The focal length is closest to:

(A) +13.8 cm
(B) +32.0 cm
(C) -13.8cm
(D) -32.0 cm
(E) -16.0 cm

Question (22) Suppose you place your face in front of a concave mirror (so that your eyes are facing the mirror).

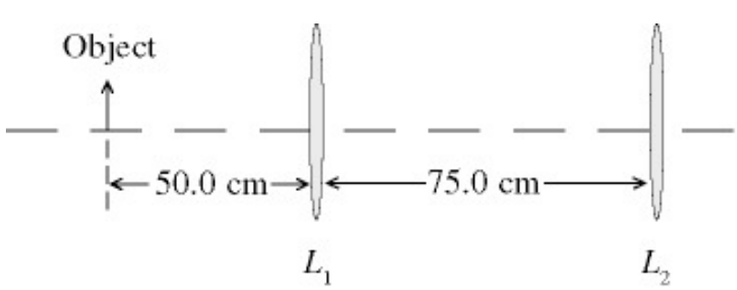
(A) Your image will be diminished in size.
(B) No matter where you place yourself, a real image will be formed.
(C) If you position yourself between the center of curvature and the focal point of the mirror, you will not see your image.
(D) Your image will always be inverted.
(E) None of these is true.

Question (23) An erect object is 50 cm from a concave mirror of radius 60 cm. The distance of the image from the mirror is closest to:

(A) 60 cm
(B) 120 cm
(C) 35 cm
(D) 19 cm
(E) 75 cm

Question (24) The figure below shows a thin double-convex lens having a focal length of magnitude 85.0 cm, and a thin double-concave lens with focal length of magnitude 40.0 cm. The location of the final image produced by this combination of lenses, relative to , is closest to:

(A) 33.2 cm to the left of L_2
(B) 290 cm to the left of L_2
(C) 30.3 cm to the left of L_2
(D) 29.1 cm to the left of L_2
(E) 21.5 cm to the left of L_2



Question (25) When an object is placed 30 cm from a converging lens, the image formed is positioned 60 cm from the lens. If the object is moved 5 cm closer to the lens, the position of the image changes by 40 cm. What is the focal length of the lens?

(A) 32 cm

(B) 20 cm

(C) 25 cm

(D) 16 cm

(E) 36 cm

Question (26) What is the minimum thickness of a soap bubble if it appears green (with a wavelength of 540 nm) at a point on the surface near the child who has just blown the bubble. Assume that the refractive index of the soap film is 1.35. Choose the value that is closest in the following options:

(A) 100 nm

(B) 200 nm

(C) 300 nm

(D) 500 μm

(E) 100 μm

Question (27) A Young's double slit apparatus has a slit separation of 2.5×10^{-5} m on which monochromatic light is directed. The resultant bright fringes on the screen 1.00 m from the double slit are separated by 2.30×10^{-2} m. What is the wavelength of incident light? Choose the answer that best agrees with your result.

(A) 373 nm

(B) 454 nm

(C) 575 nm

(D) 667 nm

(E) 725 nm

Question (28) A radio station operating at frequency 99.5 MHz broadcasts from two towers. What is the farthest distance the towers can be apart to make sure there are no "dead zones" (places where the radio signal is completely canceled out by destructive interference)?

(A) 0 m

(B) 1.5 m

(C) 3.0 m

(D) 1500 km

(E) 0.17 m

Question (29) White light shines directly on a 201 nm thick layer of oil (n = 1.25) that is floating on a pool of water (n = 1.33). Which of the following wavelengths of light is most strongly reflected?

(A) 503 nm

(B) 1005 nm

(C) 583 nm

(D) 535 nm

(E) 650 μm

Question (30) Two identical radio transmitters are placed only ten metres apart. The frequency of the waves they both radiate is 60 MHz. The intensity at a distance of 700 m in the + x-direction (corresponding to $\theta = 0$ degrees) is $I_0 = 0.020$ W/m^2. What is the intensity at the distance 700m in the direction $\theta = 4.0$ degrees.

(A) 16.0 W/m^2

(B) 0.16 W/m^2

(C) 0.032 Wcm^2

(D) 0.008 W/m^2

(E) 0.016 W/m^2

Question (31) Two clear glass microscope slides each ten 10 cm long are placed directly on top of each other. However a hair gets stuck between the plates one end. This raises one end of the top slide 0.0200 mm above the bottom plate. At the other end the plates are in contact. The situation is shown in the Figure below. What is the spacing of the interference fringes seen when light reflected of the bottom surface of the top slide interferes with light reflected off the top surface of the bottom slide, by someone looking directly down on the slides? Assume monochromatic light with a w

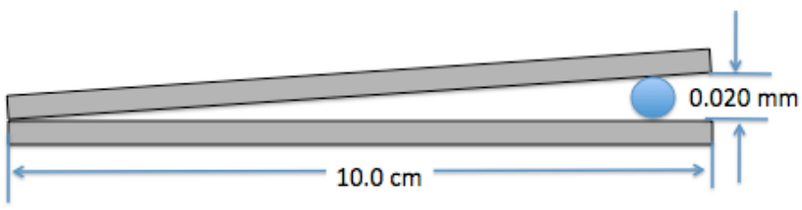
(A) 2.00 mm

(B) 1.75 mm

(C) 1.25 mm

(D) 3.20 mm

(E) 4.40 mm



Question (32) Consider a Young's double slit apparatus in which the centre-to-centre slit spacing is 0.3 mm and the slits-to-screen distance is 0.8 m. Two wavelengths of light λ_1 and λ_2 illuminate the slits simultaneously, where $\lambda_1 = 500$ nm and $\lambda_2 = 600$ nm, producing two interference patterns on the screen. Find the separation (distance) on the screen between the two third-order interference patterns produced by λ_1, λ_2.

(A) 1×10^{-3} m

(B) 2×10^{-4} m

(C) 3×10^{-5} m

(D) 8×10^{-4} m

(E) 6×10^{-5} m

Question (33) Solar cells - devices that generate electricity when exposed to sunlight – are often coated with a transparent thin film of silicon monoxide (with refractive index=1.45) to minimize reflective losses from the surface. Suppose that a silicon solar cell (with refractive index = 3.5) is coated with a thin film of silicon monoxide for this purpose as shown in the figure below. Determine the minimum film thickness that produces the least reflection at a wavelength of 550 nm, near the centre of the visible spectrum.

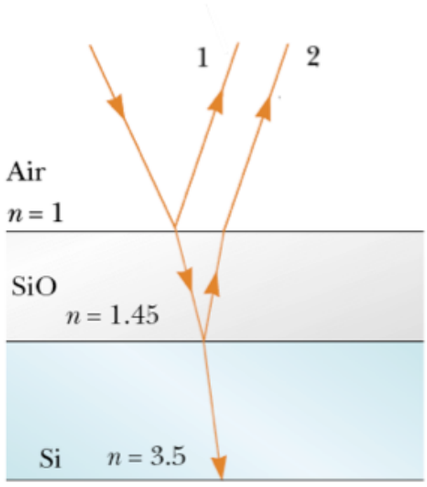
(A) 94.8 nm

(B) 128.2 nm

(C) 209.2 nm

(D) 250.0 nm

(E) 515.0 nm



Question (34) A single-slit diffraction pattern is formed on a distant screen. Assuming the angles involved are small, by what factor will the width of the central bright spot on the screen change if the slit width is doubled?

(A) It will be cut to one-quarter its original size.

(B) It will be cut in half.

(C) It will double.

(D) It will become four times as large.

(E) It will become eight times as large.

Question (35) A slit of width 0.01 mm has light of wavelength 600 nm passing through it onto a screen 60 cm away. How wide (in cm) is the central maximum?

(A) 0.12 cm

(B) 7.2 cm

(C) 1.8 cm

(D) 3.6 cm

(E) 0.9 cm

Question (36) If the 5th order minimum in the diffraction pattern is at 40°, at what angle is the 1st order minimum?

(A) 8.0°

(B) 3.4°

(C) 4.0°

(D) 7.4°

(E) 1.7°

Question (37) If the 5th order minimum in the diffraction pattern is at 40°, what is the highest order minimum in the pattern?

(A) 6

(B) 11

(C) 8

(D) 7

(E) 9

Question (38) The angular resolution of the eye is about 5×10^{-4} rad. The Moon is about 400,000 km from the earth and has a diameter of about 3500 km. What is the smallest feature on the Moon that can be resolved with the unaided eye?

(A) 400 km

(B) 1000 km

(C) 100 km

(D) 1.8 km

(E) 200 km

Question (39) A He-Ne laser (632.8 nm) is used to calibrate a grating. If the first-order maximum occurs at 20.5°, what is the grating constant (the distance between the slits)?

(A) 0.905 μm
(B) 1.81 μm
(C) 2.20 μm
(D) 3.62 μm
(E) 4.52 μm

Question (40) If the intensity of the central maximum in a single slit diffraction pattern has intensity I_0, what is the approximate intensity of the first secondary maximum?

(A) 0.22 I_0
(B) 0.25 I_0
(C) 0.50 I_0
(D) 0.045 I_0
(E) 0.090 I_0

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