Physics 130
Wave Motion, Optics and Sound
Final Examination

17 December, 2009
9:00 AM – 12:00 PM Pavilion

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

NAME: ______________________________ ID # ____________________

A single 8 ½" 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 minute) 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	Isaac	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	MacDonald	03:00 – 03:50 PM	JKL = 444

Grading: 1 point per question.

Possibly useful constants:

Gravitational acceleration: $g = 9.81$ m/s^2
Speed of light in a vacuum: $c = 3.00 \times 10^8$ m/s
Stefan-Boltzmann constant: $k = 5.67 \times 10^{-8}$ J/(s·m^2·K^4)
Kelvin temperature: 0°C = 273.15 K
Ideal gas constant: $R = 8.31$ J/(K·mol)
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 17 pages with 42 questions for a maximum total of 42 points for this exam.

IF ANYTHING IS UNCLEAR, PLEASE ASK!

Question (1) A particle is in simple harmonic motion along the x axis with a period of 7.7 s and an amplitude of 0.51 m. The equilibrium position of the particle is at $x = 0$. At time $t = 0$, the particle is at $x = +0.36$m and it is moving in the negative x–direction. The x–component of the acceleration (in units of m/s^2), at time $t = 0$, is closest to:

(A) −0.24

(B) 0.24

(C) −0.34

(D) 34

(E) zero

Question (2) Increasing the amplitude of a mass–and–spring system causes what kind of change in the resonant frequency of the system? (Assume no other changes in the system.)

(A) The frequency increases.

(B) The frequency decreases.

(C) There is no change in the frequency.

(D) The frequency depends on the displacement, not the amplitude.

Question (3) When a mass is attached to a vertical spring and lowered to its equilibrium position, it is found that the spring extends 12 cm. If the mass is now displaced from its equilibrium position, what is the period of the resulting oscillations?

(A) 2.2 s

(B) 3.7 s

(C) 0.69 s

(D) 9.0 s

(E) 1.5 s

Question (4) A pendulum that was originally erected by Foucault at the Pantheon in Paris for the Paris Exhibition in 1851 was restored in 1995. It has a 28.0 kg sphere suspended from a 67.0–m light cable. If the amplitude of the swing is 5.00 m, what is the maximum speed of the sphere?

(A) 3.57 m/s

(B) 3.65 m/s

(C) 13.1 m/s

(D) 4.16 m/s

(E) 1.91 m/s

Question (5) Two wave pulses with equal positive amplitudes pass each other on a string, one is traveling toward the right and the other toward the left. At the point that they occupy the same region of space at the same time

(A) constructive interference occurs.

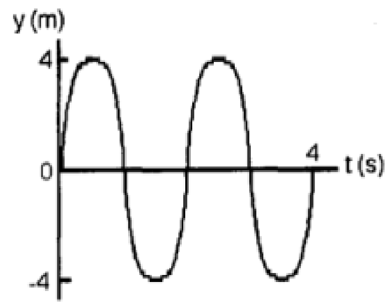
(B) destructive interference occurs.

(C) a standing wave is produced.

(D) a traveling wave is produced.

(E) a wave pulse is produced.

Figure for Question (6)



Question (6) In the figure to the right, the wavelength is

(A) 8 m.

(B) 4 m.

(C) 2 m.

(D) 1 m.

(E) cannot be determined from the given information.

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) A 60.0 cm long string is fixed at both ends with a mass 8.00 g and has tension of 200 N. What is the fundamental frequency of this string?

(A) 38.7 Hz

(B) 1500 Hz

(C) 56.7 Hz

(D) 102 Hz

(E) 3.75 Hz

The following two questions pertain to the situation described here: A stopped pipe (closed at one end), 0.90 m long, resonates with a tone whose wavelength is 0.72 m.

Question (9) The number of the harmonic for this resonant wavelength is:

(A) 2

(B) 3

(C) 4

(D) 5

(E) 6

Question (10) The distance between a node and an adjacent antinode, in the standing wave pattern in the pipe in SI units is closest to:

(A) 0.18

(B) 0.22

(C) 0.27

(D) 0.36

(E) 0.45

Question (11) Two loud speakers S_1 and S_2, placed 5.0 m apart, are driven in phase by an audio oscillator. A boy stands at point P, which is 12.0 m from S_1 and 13.0 m from S_2. A right triangle is formed by S_1, S_2 and P. The wave from S_2 arrives at point P 2.00 periods later than the wave from S_1. The speed of sound is 350 m/s. The frequency of the oscillator, in SI units, is closest to:

(A) 350

(B) 500

(C) 700

(D) 1000

(E) 1400

Question (12) In order for two sound waves to produce audible beats, it is essential that the two waves have

(A) the same amplitude

(B) the same frequency

(C) the same number of harmonics

(D) slightly different amplitudes

(E) slightly different frequencies

A train is approaching a signal tower at a speed of 40.0 m/s. The train engineer sounds a 1000 Hz whistle and a switchman in the tower responds by sounding a 1200 Hz siren. The air is still and the speed of sound is 340 m/s.

Question (13) The wavelength of the train whistle tone reaching the switchman, in SI units, is given by:

(A) 0.30

(B) 0.32

(C) 0.34

(D) 0.36

(E) 0.38

Question (14) The frequency of the train whistle tone, heard by the switchman, in SI units, is given by:

(A) 1000

(B) 300/340 x 1000

(C) 340/300 x 1000

(D) 340/380 x 1000

(E) 380/340 x 1000

Question (15) The wavelength of the tower siren tone, reaching the engineer, in SI units, is closest to:

(A) 0.18

(B) 0.22

(C) 0.25

(D) 0.28

(E) 0.32

Question (16) The frequency of the tower siren tone, heard by the engineer, in SI units, is given by:

(A) 1200

(B) 300/340 x 1200

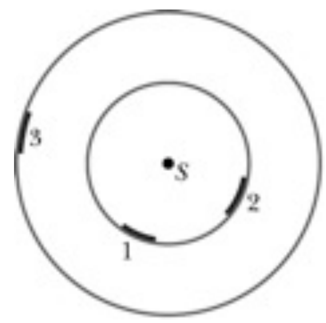
(C) 340/300 x 1200

(D) 340/380 x 1200

(E) 380/340 x 1200

The figure below shows three small patches 1, 2, and 3 (which may or may not be of the same size) that lie on the surfaces of two imaginary spheres; the spheres are centered on an isotropic point-like sound source (S). The rates at which energy is transmitted through the three patches by the sound waves are equal. Rank the patches according to:

Figure for Questions (17) and (18)



Question (17) The intensity of the sound on them:

(A) $I_1 > I_2 > I_3$

(B) $I_1 < I_2 < I_3$

(C) $I_1 = I_2 = I_3$

(D) $I_1 = I_2 < I_3$

(E) $I_3 < I_2 = I_1$

Question (18) Their area:

(A) $A_1 = A_2 = A_3$

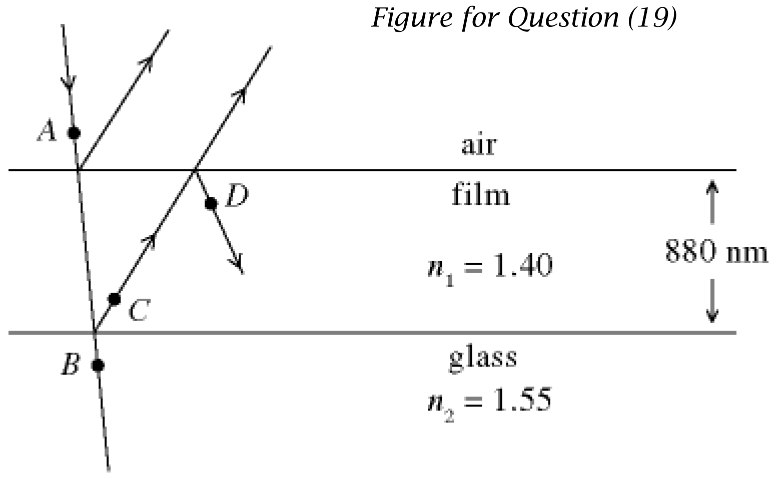
(B) $A_1 = A_2 < A_3$

(C) $A_3 < A_1 < A_2$

(D) $A_3 < A_1 = A_2$

(E) None of the above

Figure for Question (19)



Question (19) A film of 880–nm thickness and refraction index $n_1 = 1.40$, is on the surface of a glass plate, of index $n_2 = 1.55$. A ray of monochromatic light, of 500 nm wavelength, is incident normally upon the air–film interface, and undergoes reflections and transmissions. Consider points *A*, *B*, *C*, and *D* as being at a negligible distance from their nearest interfaces, respectively. In the figure above, the phase difference in the wave at *D*, with respect to the wave at *A*, is closest to *[Hint: subtract any phase shift or shifts associated with reflection]:*

(A) 28 rad

(B) 29 rad

(C) 30 rad

(D) 31 rad

(E) 33 rad

Question (20) Two radio antennas are 130 m apart on a north–south line. The two antennas radiate in phase at a frequency of 4.7 MHz. All radio measurements are made far from the antennas. Point *A* is due east of the antennas and point *B* is 30° north of east from the antennas. Both points *A* and *B* are at the same large distance from the antennas. The ratio of the intensity of the radio signal at *B* to that at *A* is closest to:

(A) 1.0

(B) 0.50

(C) 1.5

(D) 2.0

(E) 3.0

Question (21) At most, how many bright fringes can be formed on one side of the central bright fringe (not counting the central bright fringe) when light of 625 nm falls on a double slit whose spacing is 2.81×10^{-6} m?

(A) 2

(B) 3

(C) 4

(D) 5

(E) 6

Question (22) A pair of narrow slits, separated by 1.8 mm, is illuminated by a monochromatic light source. Light waves arrive at the two slits in phase. A fringe pattern is observed on a screen 4.8 m from the slits. Monochromatic light of 450 nm wavelength is used. The angular separation between adjacent dark fringes on the screen, measured at the slits, is closest to:

(A) 0.15×10^{-3} rad

(B) 0.20×10^{-3} rad

(C) 0.25×10^{-3} rad

(D) 0.30×10^{-3} rad

(E) 0.36×10^{-3} rad

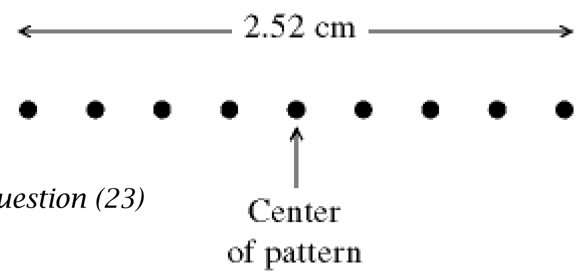


Figure for Question (23)

Question (23) Coherent monochromatic light of wavelength 632.8 nm passes through a pair of thin parallel slits. The figure above shows the central portion of the pattern of bright fringes viewed on a screen 1.40 m beyond the slits. For the two slits corresponding to the pattern shown in the figure above, the distance between the slits is closest to:

(A) 0.0703 mm

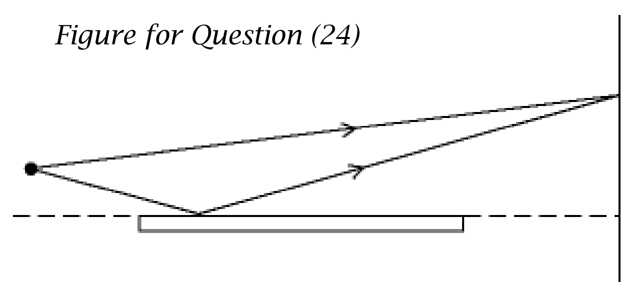
(B) 0.281 mm

(C) 0.141 mm

(D) 0.562 mm

(E) 0.633 mm

Figure for Question (24)



Question (24) In the figure above, Lloyd's Mirror is an apparatus that can be used to form interference fringes using a single source. Light from the source is reflected off a plane mirror and viewed on a screen. A reflected ray and a direct ray can interfere to form a fringe pattern on the screen. In the arrangement drawn here, the screen is 2.4 m from the source, and the separation between fringes on the screen is 1.3 mm. The light has wavelength 580 nm. How high above the reflecting plane is the source positioned?

(A) 1.64 mm

(B) 0.54 mm

(C) 1.08 mm

(D) 1.22 mm

(E) 0.27 mm

Question (25) Light of wavelength 425.0 nm in air falls at normal incidence on an oil film that is 850.0 nm thick. The oil is floating on a water layer 1500 nm thick. The refractive index of water is 1.33, and that of the oil is 1.40. The number of wavelengths of light that fit in the oil film is closest to:

(A) 2.00

(B) 2.66

(C) 2.80

(D) 3.53

(E) 4.69

Question (26) As in the previous question, light of wavelength 425.0 nm in air falls at normal incidence on an oil film that is 850.0 nm thick. The oil is floating on a water layer 1500 nm thick. The refractive index of water is 1.33, and that of the oil is 1.40. You want to add oil so that light reflected off of the top of the oil film will be canceled. The minimum amount by which you should increase the thickness of the oil film is closest to:

(A) 60.7 nm

(B) 75.9 nm

(C) 106 nm

(D) 121 nm

(E) 152 nm

Question (27) An electromagnetic wave has a wavelength equal to 393 nm in benzene (index of refraction $n = 1.50$). When this wave passes from benzene to ethyl alcohol (index of refraction $n = 1.36$), the wavelength in ethyl alcohol is closest to:

(A) 262 nm

(B) 356 nm

(C) 393 nm

(D) 433 nm

(E) 590 nm

Question (28) A point source of light is submerged 3.5 m below the surface of a lake and emit rays in all directions. Assuming that $n_{water} = 1.33$, what is the radius of the largest circle, at the surface of water, over which light from the source can escape from the water?

(A) 1.1 m

(B) 2.3 m

(C) 2.6 m

(D) 3.1 m

(E) 4.0 m

Question (29) Three polarizing filters are stacked, with the polarizing axis of the second and third filters at 25.0° and 60.0°, respectively, to that of the first. If unpolarized light is incident on the stack, the light has intensity 80.0 W/cm^2 after it passes through the stack. What is the intensity of the incident light; that is, the intensity of the light before it enters the first filter?

(A) 145 W/cm^2

(B) 216 W/cm^2

(C) 290 W/cm^2

(D) 390 W/cm^2

(E) 779 W/cm^2

Question (30) During a laboratory experiment with an object placed in front of a concave mirror, the image distance, *s*', is determined for several different values of object distance, *s*. How could the focal distance, *f*, of this mirror be determined from a graph of the data?

(A) Plot $1/s'$ versus $1/s$; y - intercept = $1/f$

(B) Plot s' versus s ; y - intercept = $1/f$

(C) Plot $1/s'$ versus $1/s$; slope = $1/f$

(D) Plot s' versus s ; slope = $1/f$

(E) Plot $1/s'$ versus $1/s$; y - intercept = f

Question (31) A cylindrical glass rod (n_{glass} = 1.52) is immersed in ethanol ($n_{ethanol}$ = 1.36). One end is ground to a convex hemispherical surface with radius of curvature R = 7.00 cm. The lateral magnification of the image produced by a small object located at 12.0 cm out of the rod is closest to:

(A) 4.44×10^{-3}

(B) 0.832

(C) 1.25

(D) 1.56

(E) 9.21

Question (32) You are asked to design a thin converging lens made of lanthanum glass (n = 1.80) with a focal length of 30.0 cm (when immersed in air). If the lens is symmetric (i.e. both sides have the same curvature), what radius of curvature is needed?

(A) –208 cm

(B) –48.0 cm

(C) 30.0 cm

(D) 48.0 cm

(E) 208 cm

Question (33) If a real object is placed between the first focal point and the vertex of a diverging lens, the image formed by the lens is

(A) Real, upright, and reduced

(B) Virtual, upright, and reduced

(C) Real, inverted, and reduced

(D) Virtual, upright and magnified

(E) Real, inverted, and magnified

Question (34) A converging lens ($|f| = 4.0$ cm) is 12 cm to the left of a diverging lens ($|f| = 2.0$ cm). If the final image, produced by the diverging lens, is 4.0 cm to the left of the diverging lens, the position of the initial object (i.e. the object of the converging lens), with respect to the converging lens, is closest to

(A) 2.7 cm to the left of the converging lens
(B) 5.3 cm to the left of the converging lens
(C) 5.7 cm to the left of the converging lens
(D) 6.4 cm to the left of the converging lens
(E) 8.0 cm to the left of the converging lens

Question (35) A shark with a laser on its head is swimming underwater. The wavelength of the laser light in air is 500 nm. The shark shoots its laser at an underwater diffraction grating, which has 3300 lines/cm. The diffraction grating is 5 m away from the shark. The index of refraction of water is 1.333. What is the angle of the third order diffraction for the laser beam?

(A) 0.166 rad
(B) 0.518 rad
(C) 21.8 rad
(D) 0.124 rad
(E) 0.371 rad

Question (36) A single slit forms a diffraction pattern with monochromatic light. The 6th minimum of the pattern occurs at an angle of 23º from the central maximum. The number of bright bands on either side of the central band is closest to:

(A) 17
(B) 13
(C) 14
(D) 19
(E) 16

Question (37) When monochromatic light passes through a pair of identical thin parallel slits, you observe on a distant screen that the eighth-order bright fringe due to double-slit interference is missing because it was cancelled by the third-order single-slit dark fringe. The ratio of the width of the slits to the distance between them is closest to:

(A) 0.750
(B) 2.67
(C) 5.33
(D) 0.375
(E) 0.188

Question (38) The Ninjas are designing a large camera for aerial surveillance of the Pirates. The maximum diameter of the circular aperture (opening) of the camera lens is 30 cm. Assume light of 550 nm wavelength is used and that the resolution of the camera is limited solely by diffraction. The angular resolution of the camera at maximum aperture is closest to:

(A) 2.2×10^{-6} rad

(B) 3.2×10^{-6} rad

(C) 6.3×10^{-6} rad

(D) 4.5×10^{-6} rad

(E) 1.6×10^{-6} rad

Question (39) A diffraction grating has 450 lines per mm. What is the highest order that contains the entire visible spectrum from 400 nm to 700 nm?

(A) $m = 2$

(B) $m = 5$

(C) $m = 3$

(D) $m = 6$

(E) $m = 4$

Question (40) The variable *m* is used to label the dark fringes in a single-slit diffraction pattern. What is the complete set of allowed values of *m*?

(A) 1, 2, 3, ...

(B) 0, 1, 2, 3, ...

(C) ±1, ±2, ±3, ...

(D) 0, ±1, ±2, ±3, ...

(E) Any rational number.

Question (41) Diana, Duck of Science, sets up a standard double-slit diffraction experiment, with a slit spacing of 0.500 mm. She shines a laser through the slits and observes the usual series of maxima and minima in the interference pattern on the screen. Then, using her Absurdly Sharp Knife, she creates a *third* slit 0.500 mm to the left of the first one. She shines the laser through the triple slit and observes the interference pattern. Are there any points between the maxima of the original two slits where light from all three slits interferes constructively? If so, what are they?

(A) No.

(B) Yes, halfway between the original maxima.

(C) Yes, at intervals one-third of the distance between the original maxima.

(D) Yes, halfway between every second pair of maxima.

(E) Yes, halfway between every third pair of maxima.

Question (42) A single slit, 2300 nm wide, forms a diffraction pattern when illuminated by monochromatic light of 660 nm wavelength. At an angle of 10º from the central maximum, the ratio of the intensity to that of the central maximum is closest to:

(A) 0.37

(B) 0.41

(C) 0.25

(D) 0.33

(E) 0.29

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