Physics 130
Optics, Wave Motion and Sound
Final Examination
8 December, 2006
2:00 PM – 5:00 PM Main Gym

All Sections (Consolidated) Course Convenor: Dr. James Pinfold

NAME:_____ **ID #** _____

A single 8 1/2" x 11" formula sheet is permitted. This is of the two official formula sheets available on WebCT. Students may add their own notes to both the front and back of this sheet. This sheet must be handed in with the exam.
Calculators without communications features are permitted.
The exam is 3 hours (180 minutes) in length.
Do ALL questions.
Answers must be clearly indicated on the answer sheet using an HB pencil.
Use the provided exam booklets for rough work.
At the end of the exam, turn in this exam paper, your answer sheet, your formula sheet and the exam booklet(s). Enclose all in the exam booklet, and turn in to the box for your section.

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

Course Section in Special Codes:

Section	Instructor	Lecture Time	Code
A01	Pinfold	09:00 – 09:50 AM	J = 1
A02	Soluk	10:00 – 10:50 AM	J = 2
A03	Fuite	02:00 – 02:50 PM	J = 3
A04	Lawrie	03:00 – 03:50 PM	J = 4

Grading:
2 choice questions: 2 points for correct answer, no partial credit
3 choice questions: 3 points for correct answer, no partial credit
5 choice questions: 5 points for the correct answer if no other answers selected
3 points if 2 answers selected, one of which is correct.
1 point if 3 answers selected, one of which is correct.

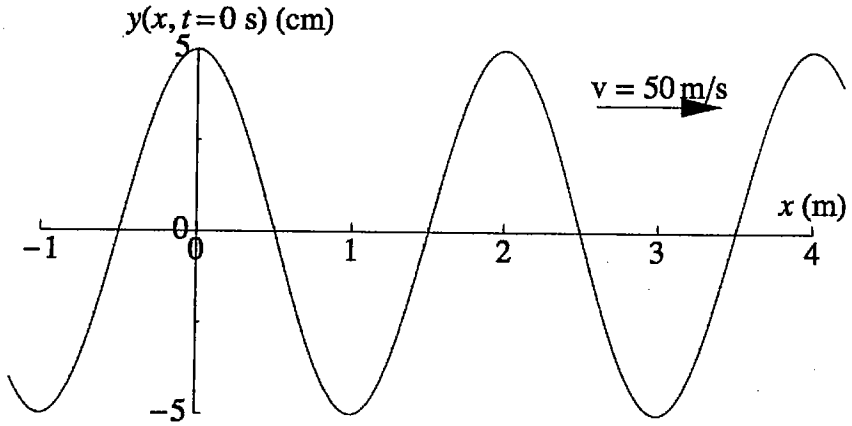
There is only one correct answer to each question. If you believe the correct answer is not listed, choose the closest matching value. There are 14 pages with 40 questions for a maximum total of 150 points for this exam.

IF ANYTHING IS UNCLEAR, PLEASE ASK!

1. Which of the following is the most accurate statement?
   A. A system like a vibrating string has only one resonant frequency.
   B. In order for a singer to break a wine glass by singing, she must adjust the amplitude of the sound she makes so that it is exactly equal to the amplitude of the vibration of the wine glass.
   C. The sound intensity level in decibels is directly proportional to $1/r^2$, where r is the distance from the source to the listener.
   D. A change of 9 dB in the sound intensity level, β, implies a factor of 8 change in the sound intensity, I.
   E. When an oscillatory system is driven by a sinusoidal force, the response amplitude of the system will be the same as the amplitude of the driving force.

The next two questions refer to the following situation:

The figure below shows a periodic, sinusoidal wave on a string, traveling to the right at 50 m/s, at a time $t = 0$ s.



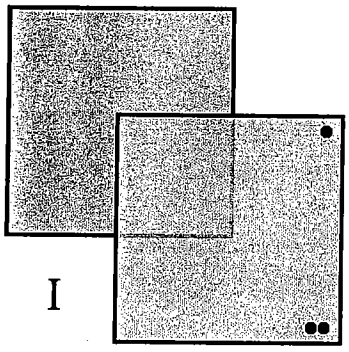
2. What is the wave equation that best describes the displacement, $y(x,t)$, of this string?

   A. $y(x,t) = (5\text{ cm})\cos[\pi x + 50\pi t]$
   B. $y(x,t) = (5\text{cm})\cos(2x - 50t)$
   C. $y(x,t) = (5\text{ cm})\cos[\pi x - 50\pi t]$
   D. $y(x,t) = (5\text{ cm})\cos(2x + 50t)$
   E. $y(x,t) = (5\text{cm})\cos[2\pi(x - 50t)]$

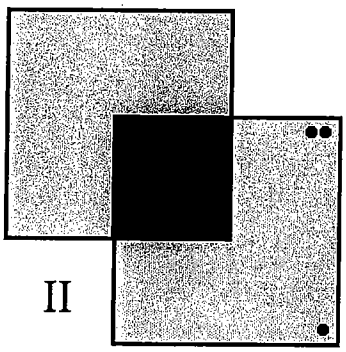
3. What is the tension in the string if it has a total length of 25 m and a total mass of 25 g?

   A. 2500 N
   B. 25 N
   C. 2.5 N

4. Two polarizing sheets are stacked so they partially overlap as shown below (I). The top sheet is marked • & ••, and this does not necessarily indicate the polarization axis. Initially, light passes through these two polarizing filters (I). When the top sheet is flipped upside down, no light is transmitted in the overlapping region (II).

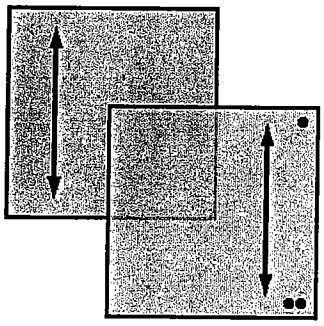


I

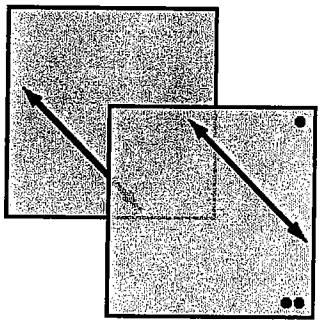


II

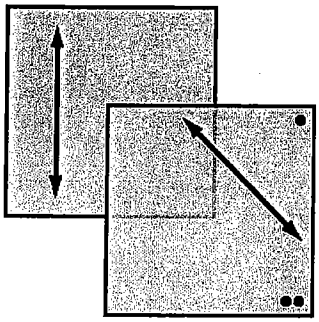
What was the most likely initial orientation of the polarizing axes for the two sheets?



A



B



C

5. An object is undergoing SHM with maximum displacement A. The relationship between the potential energy U and the kinetic energy K when the object has a displacement of A/2 is given by:

   A. U = K
   B. U = 1/2 K
   C. U = 1/3 K

6. A concave spherical mirror can produce a real or a virtual image depending on the distance of the object to the focal point of the mirror.

   A. True
   B. False

The next two questions refer to the following situation:

A single slit with a width of 50.0 μm is illuminated by parallel light rays with a wavelength of 632 nm. The far field diffraction pattern is observed on a screen that is a distance of 2.30 m from the slit. The intensity at the middle of the central maximum is I_0.

7. What is the width of the central bright maximum on the screen?

   A. 2.91 cm
   B. 5.81 cm
   C. 38.7 cm

8. What is the intensity at a point on the screen defined by an angle of 1.00° from the centre of the pattern?

   A. 0.00609 I_o
   B. 0.0123 I_o
   C. 0.0460 I_o
   D. 0.405 I_o
   E. 0.500 I_o

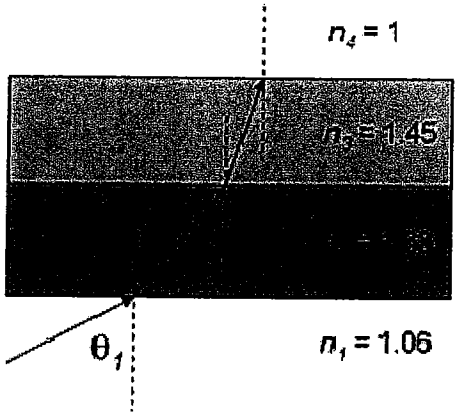
9. Musician Bob has 3 tuning forks. One fork marked "A" produces a 440Hz tone. The other forks are marked "X" and "Y" and their frequencies are not known. Bob wants to determine the unknown frequencies. He notes that frequency of fork Y is less than the frequency of fork X. When forks A and X are sounded together, a beat frequency of 4 Hz is heard. For forks A and Y, the beat frequency is 7 Hz. For forks X and Y, the beat frequency is 3 Hz. The unknown frequencies of forks X and Y are closest to:

   A. X = 436 Hz and Y = 433 Hz
   B. X = 436 Hz and Y = 447 Hz
   C. X = 444 Hz and Y = 433 Hz
   D. X = 444 Hz and Y = 447 Hz
   E. X = 447 Hz and Y = 444 Hz

10. One may readily deduce how sound intensity varies with distance from a uniformly radiating sound source by making use of:

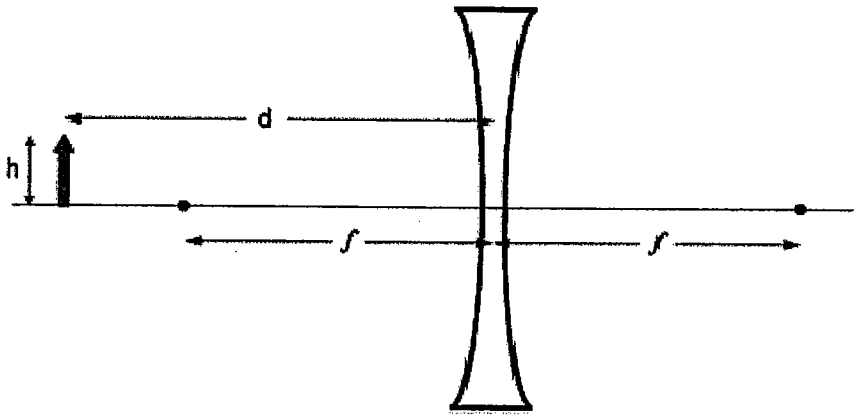
    A. The relation $v = f\lambda$.
    B. Newton's laws of motion.
    C. The law of conservation of energy.
    D. The law of conservation of momentum.
    E. The fact that sound is a longitudinal wave.

11. A ray of light hits a series of three interfaces as shown below. At what value of θ_1 will it undergo total internal reflection at the third (last) interface?



A. 21.06°
B. 44.22°
C. 70.63°
D. 86.43°
E. Since the incoming ray is always bending towards the normal, it can never undergo total internal reflection at the third interface.

12. An object with height $h = 8$ cm lies a distance $d = 32$ cm before a diverging lens with focal length $f = -25$ cm.



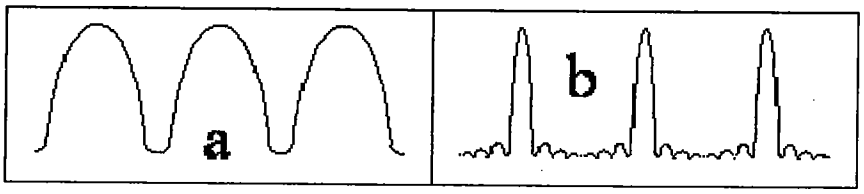
What is the size of the image produced?

A. 2.22 cm
B. 3.51 cm
C. 8.46 cm
D. 14.2 cm
E. 25.5 cm

13. A single diverging lens can only produce a virtual, reduced and upright image of a real object.

    A. True
    B. False

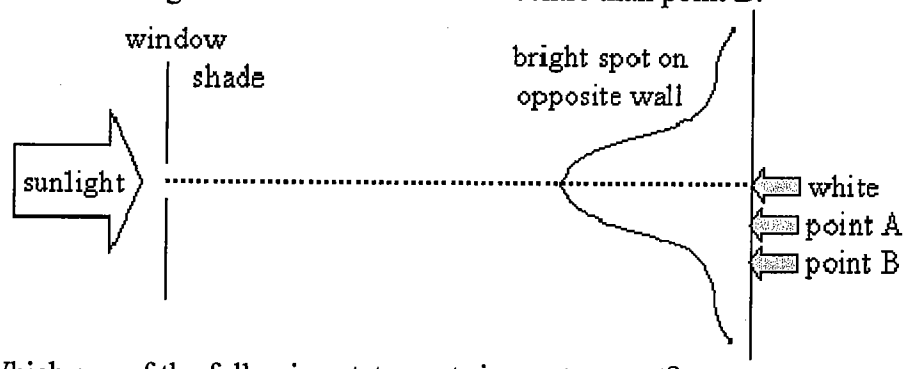
14. The following graphs indicate the intensity of the diffraction pattern created by two different multiple-slit devices illuminated by light from the same laser.



    Which device has the larger number of slits?

    A. device a
    B. device b

15. Sunlight shines through a pinhole in an otherwise opaque window shade, creating a bright spot on a wall on the opposite side of the room. Because of diffraction effects, the ***color*** of the bright spot (as well as its intensity) varies with distance from the center of the spot. Assume that the range of wavelengths in sunlight extends from 400 nm (blue) to 700 nm (red). Note that the first minima for both red and blue light occurs farther from the centre than point B.



    Which one of the following statements is most correct?.

    Relative to the center of the bright spot, which is white,

    A. point A contains equal intensities of all colors of light while point B consists only of red light.
    B. point A contains only blue light while point B contains only red light.
    C. points A and B both appear green.
    D. point A appears more red than point B.
    E. point A appears more blue than point B.

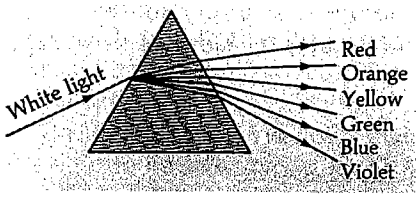
16. A string, 0.14m long, vibrating in the n = 6 harmonic, excites a nearby open pipe, 0.85m long, into second overtone (= 3rd harmonic) resonance. The speed of sound in air is 345m/s. The distance between a node and an adjacent antinode, on the string is closest to:

A. 12 mm
B. 5.8 mm
C. 18 mm
D. 23 mm
E. 140 mm

17. A metal rod of length L = 86.0 cm and mass M = 1.75 kg is free to pivot about a point a distance d = 7.80 cm from the centre of mass. A simple pendulum is to be constructed having the same frequency of oscillation. What should the length of the string be? The moment of inertia for a rod of length, L, and mass, M, pivoted at a point d from the centre of mass is $I = M\left[\frac{L^2}{12} + d^2\right]$, and use g = 9.81 m/s^2, and m = 0.500 kg for the mass for the simple pendulum, if needed.

A. 7.80 cm
B. 15.6 cm
C. 78.2 cm
D. 86.8 cm
E. 93.8 cm

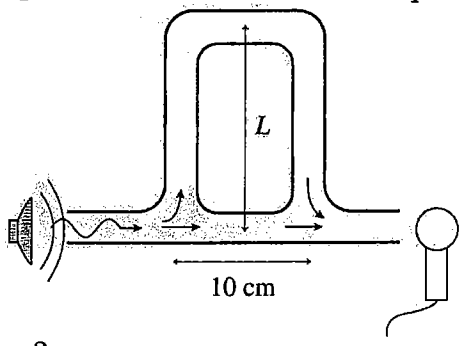
18. A beam of white light incident on a glass prism is dispersed into its component colours, as shown below.



By observation of the spectrum, one can conclude that:

A. the index of refraction decreases as wavelength decreases.
B. the index of refraction decreases as frequency decreases.
C. the index of refraction, *n*, is a constant for a particular material and not a function of wavelength or frequency.

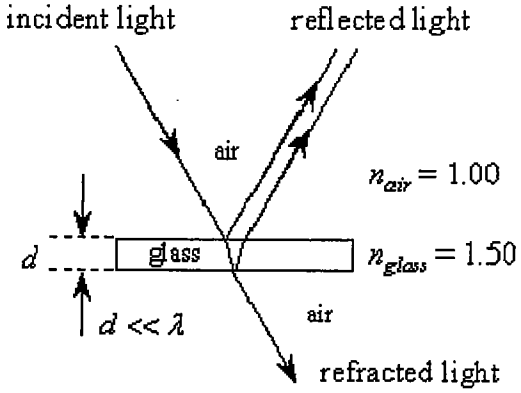
19. Sound of frequency f is broadcast into the enclosed tube, shown below, which is filled with room-temperature air. The upper section, of height L, can be extended like a trombone slide. Due to interference, a microphone at the far end of the tube detects maxima of the sound intensity when L is 24 cm, 32 cm, and 40 cm, and no positions in between. The speed of sound in air at this temperature is 344 m/s.



What is the sound frequency?

A. 1433 Hz
B. 2150 Hz
C. 3440 Hz
D. 4300 Hz
E. 8600 Hz

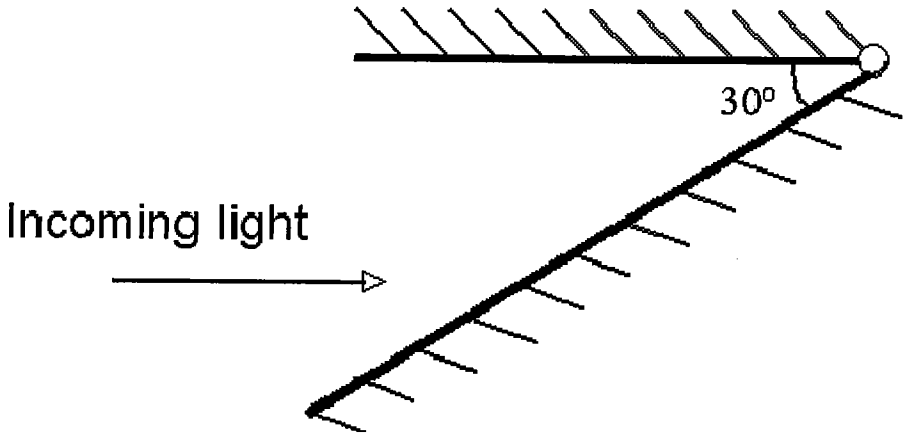
20. As shown in the figure, light of wavelength λ reflects off the front and back faces of a *very* thin sheet of glass of thickness d. The glass is so thin that compared to the wavelength of the incident light the distance the light travels inside the glass is insignificant.



Choose the most correct statement concerning the two reflected rays:

A. The interference between the two rays of reflected light is constructive.
B. The interference between the two rays of reflected light is destructive.
C. There will be no interference since the glass is so thin it has a negligible effect.

21. A ray of light is traveling toward two flat mirrors arranged at a 30° angle, as shown in the figure. The incident light is traveling parallel to the upper mirror.



How many reflections will the ray make before escaping?

A. 3
B. 5
C. The ray will never escape from the corner.

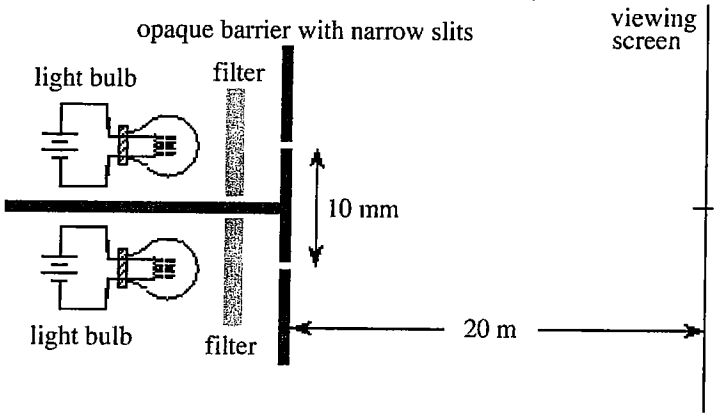
22. Two radio antennas are 10km apart on a north-south axis on a seacoast. The antennas broadcast identical AM radio signals, in phase, at a frequency of 1.20MHz. A steamship, 200km offshore, travels due north at a speed of 15km/hr and passes east of the antennas. A radio on board the ship is tuned to the broadcast frequency. The reception of the radio signal on the ship is a maximum at a certain instant. At this time the ship is an equal distance from each antenna. The speed of radio waves is the same as that for light, 3×10^8 m/s. Distances are such that small angle approximations apply. The time interval until the next occurrence of maximum reception is closest to:

A. 16 min
B. 20 min
C. 27 min
D. 33 min
E. 38 min

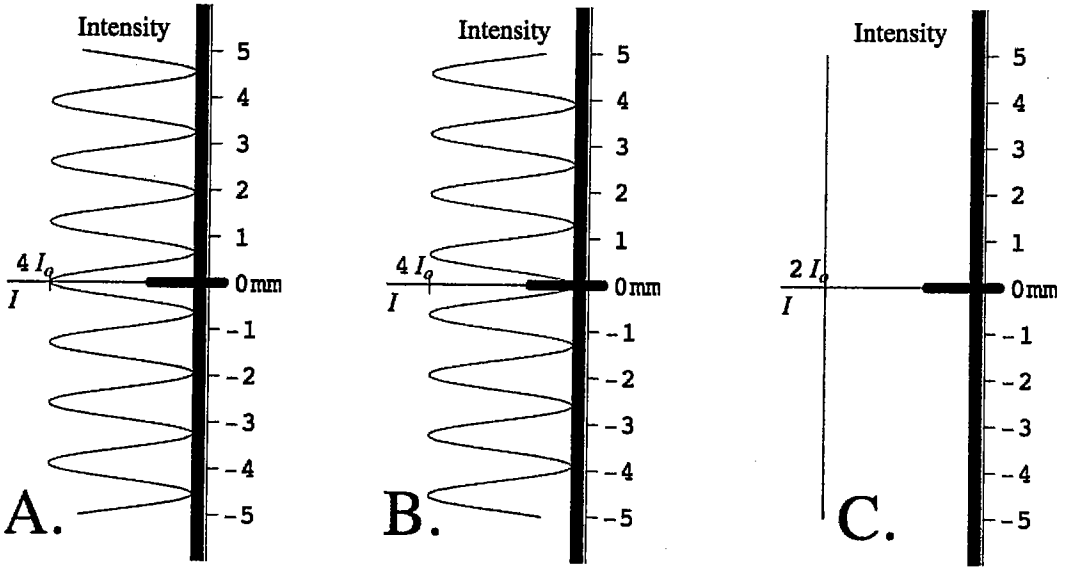
23. If an object is placed between the first focal point and the vertex of a converging lens the image formed by the lens is:

A. Real, inverted and magnified
B. Virtual, upright and magnified
C. Virtual, inverted and reduced

24. Two narrow slits spaced by 10 mm in an opaque barrier are illuminated by a pair of very bright light bulbs, as shown in the figure. Filters isolate red light with a wavelength of 650 nm for each source. A viewing screen is located 20 m to the right of the barrier. There are no other sources of light that can illuminate the screen. The width of the slits is negligible for this question.



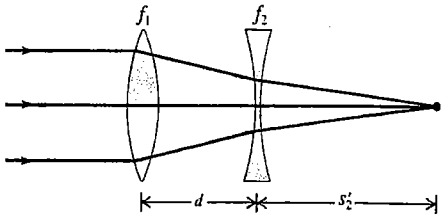
Which one of the following intensity patterns best illustrates the illumination pattern that appears on the screen? Note the tick mark that indicates the centre of the screen.



25. When a beam of monochromatic light travels from a medium with index of refraction n_1 to a medium with index of refraction n_2 ($n_1 > n_2$), the frequency of light remains the same.

A. True
B. False

26. A converging and a diverging lens are arranged as shown in the picture. The focal lengths of the lenses are $f_1 = 17.0$ cm and $f_2 = -12.00$ cm. The image of a distant object is formed at $s_2' = 20$ cm to the right of the diverging lens. What is the distance d between the lenses?



A. 12.2 cm
B. 9.50 cm
C. 5.00 cm
D. 3.00 cm
E. 1.67 cm

27. A soap bubble can show thin-film interference effects. When viewed at normal incidence, a particular bubble shows constructive interference for light of wavelength 420 nm (in air). The next longest wavelength for which destructive interference is observed is 490 nm. What is the thickness of the film? The index of refraction of the soap film is n = 1.33.

A. 1.66 μm
B. 0.842 μm
C. 0.553 μm
D. 0.421 μm
E. 0.210 μm

28. A 5.0kg block is attached to a spring whose force constant is 125N/m. The block is pulled from its equilibrium position at x=0m to a position at x=+0.687m and is released from rest. The block then executes damped oscillation along the x-axis. The damping force is proportional to the velocity. When the block first returns to x=0m, its x-component of velocity is -2.0m/s and its x-component of acceleration is $+5.6 m/s^2$. The damping coefficient, b, is closest to:

A. 14kg/s
B. 16kg/s
C. 18kg/s
D. 20kg/s
E. 22kg/s

29. Two simple pendulums have the same length, but different masses. They will therefore undergo small amplitude oscillations with the same angular frequency.

A. True
B. False

30. You've been asked to design a thin converging lens with a focal length of 18.0 cm. The glass available has an index of refraction n = 2.20. The lens must be symmetric (same curvature on each side). What radius of curvature (magnitude) is required?

A. 8.18 cm
B. 18.0 cm
C. 36.0 cm
D. 39.6 cm
E. 43.2 cm

31. A beam of light is incident on the interface between medium A (n_A) and medium B (n_B). The light gets partially reflected and partially refracted. The refracted (NOT the reflected) part:

A. does not undergo a phase shift regardless of the values of n_A and n_B.
B. undergoes a phase shift of π if $n_A > n_B$.
C. undergoes a phase shift of π if $n_A < n_B$.

The next two questions refer to the following situation:

A simple, harmonic oscillator located at the point x = 0 generates a transverse travelling wave on a long rope (Neglect reflections from the far ends). The oscillator operates at a frequency of 60 Hz and with an amplitude of 5.00 cm. The rope has a linear mass density of 1.00 g/m and is stretched with a tension of 50.0 N.

32. Find the wavelength.

A. 224 m
B. 3.73 m
C. 0.268 m

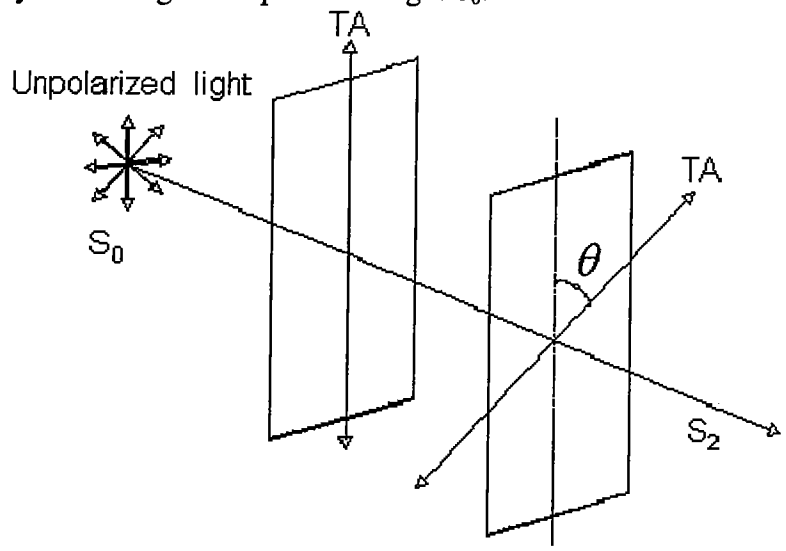
33. Find the maximum transverse acceleration of points on the rope.

A. 18.8 m/s^2
B. 711 m/s^2
C. 7110 m/s^2

34. A certain object is undergoing torsional SHM oscillations. The moment of inertia for the object is directly proportional to its mass. In order to double the period of oscillations:

A. the mass should be increased by a factor of $\sqrt{2}$.
B. the mass should be decreased by a factor of $\sqrt{2}$.

35. Unpolarized light passes through two polarizers oriented as shown in the figure. The intensity of light coming out from the second polarizer S_2 is 33% of the intensity of the original unpolarized light S_0.



What is the angle between the transmission axes of the polarizers?

A. 7.0°
B. 24.9°
C. 35.7°
D. 43.5°
E. 79.0°

36. A dolphin swimming at a speed of 9.000 m/s emits ultrasound of frequency 110.0 kHz towards a fleeing fish moving away from the dolphin at 3.000 m/s. The sound reflects off the fish and is heard by the dolphin as a different frequency. Take the speed of sound in water to be 1.300×10^3 m/s. The reflected frequency heard by the dolphin is:

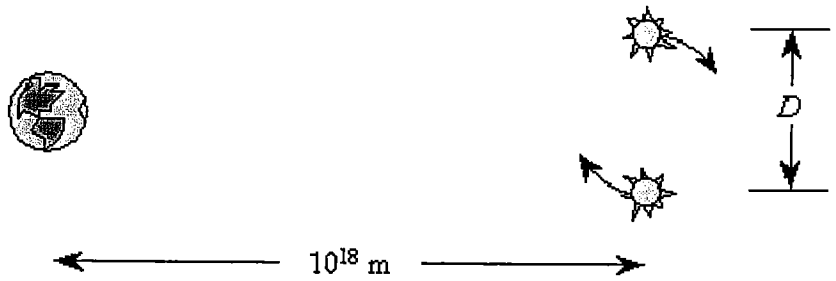
A. 106.7 kHz
B. 107.5 kHz
C. 110.5 kHz
D. 111.0 kHz
E. 112.1 kHz

37. When is the potential energy of an object undergoing simple harmonic motion momentarily equal to zero?

A. When the displacement is momentarily equal to zero.
B. When the displacement momentarily reaches its maximum value.

The next two questions refer to the following situation:

A binary star system is 10^{18} meters (approximately 100 lightyears) from Earth. The two stars in the system move in circular orbits and remain a distance *D* apart. An earth-based telescope whose aperture is 2m observes light (wavelength 500 nm) coming from the stars.



38. What is the minimum distance *D* between the stars that will allow the telescope to resolve the binary system as comprising two well-separated stars?

    A. 2.50×10^{-7} m
    B. 3.00×10^{8} m
    C. 3.05×10^{11} m
    D. 5.00×10^{11} m
    E. 5.00×10^{20} m

39. If better resolution were desired, which of the following would most directly improve the resolution?

    A. Making observations at a longer wavelength.
    B. Making observations at a shorter wavelength.
    C. Making observations using white light (a range of wavelengths) so that more of the incident light could be used.

40. Transverse waves of amplitude A propagate along a string with linear mass density μ and tension F. What must happen to the frequency of the waves if the amplitude is increased, while the average power of the waves as well as μ and F remain the same?

    A. The frequency must increase.
    B. The frequency must decrease.

Did you enter your Name, Student ID and Section (J = ?) correctly on the answer sheet?
(Failure to do so could result in a mark of zero)

Check that you have filled in all your answers. Blanks receive zero.