

Prob. 1 A 36-kg mass is placed on a horizontal frictionless surface and then connected to walls by two springs with spring constants $k_1 = 3.0 \text{ N/m}$ and $k_2 = 4.0 \text{ N/m}$, as shown in the figure. What is the period of oscillation for the 36-kg mass if it is displaced slightly to one side?

- a) 11 s
- b) 14 s
- c) 17 s
- d) 20. s
- e) 32 s
- f) 38 s



Prob. 2 Which one of the following transverse waves has the greatest power?

- a) a wave with velocity v , amplitude A , and frequency f
- b) a wave with velocity v , amplitude $2A$, and frequency $f/2$
- c) a wave with velocity $2v$, amplitude $A/2$, and frequency f
- d) a wave with velocity $2v$, amplitude A , and frequency $f/2$
- e) a wave with velocity $2v$, amplitude $A/2$, and frequency $2f$

Prob. 3 The intensity of electromagnetic waves from the Sun at the Earth is 1400 W/m^2 . How much power does the Sun generate? The distance from the Earth to the Sun is $149.6 \cdot 10^6 \text{ km}$.

- a) $1.21 \cdot 10^{20} \text{ W}$
- b) $2.43 \cdot 10^{24} \text{ W}$
- c) $3.94 \cdot 10^{26} \text{ W}$
- d) $2.11 \cdot 10^{28} \text{ W}$
- e) $9.11 \cdot 10^{30} \text{ W}$

Prob. 4 If two loudspeakers at points A and B emit identical sine waves at the same frequency and constructive interference is observed at point C , then the

- a) distance from A to C is the same as that from B to C .
- b) points A , B , and C form an equilateral triangle.
- c) difference between the distance from A to C and the distance from B to C is an integer multiple of the wavelength of the emitted waves.
- d) difference between the distance from A to C and the distance from B to C is a half-integer multiple of the wavelength of the emitted waves.

Prob. 5 What is the focal length of a flat sheet of transparent glass?

- a) zero
- b) infinity
- c) thickness of the glass
- d) undefined

Prob. 6 A pea sits at the focal point of a converging lens, 3 cm to the left of that lens on the optical axis. A second identical lens is at a distance of 12 cm to the right from the first one. Where is the image of the pea located, and is it real or virtual?

- a) A virtual image 3 cm to the left of lens 2
- b) A real image 3 cm to the left of lens 2
- c) A virtual image 3 cm to the right of lens 2
- d) A real image 3 cm to the right of lens 2
- e) No image can be formed, because the 2 lenses are more than 2 focal lengths apart.

Prob. 7 If Huygens's Principle holds everywhere, why does a laser beam not spread out?

- a) All the light waves that spread in the perpendicular direction from the beam interfere destructively.
- b) It does spread out, but the spread is so small that we don't notice it.
- c) Huygens's Principle isn't true in general; it only applies to slits, edges, and other obstacles.
- d) Lasers employ additional special beams to keep the main beam from spreading.

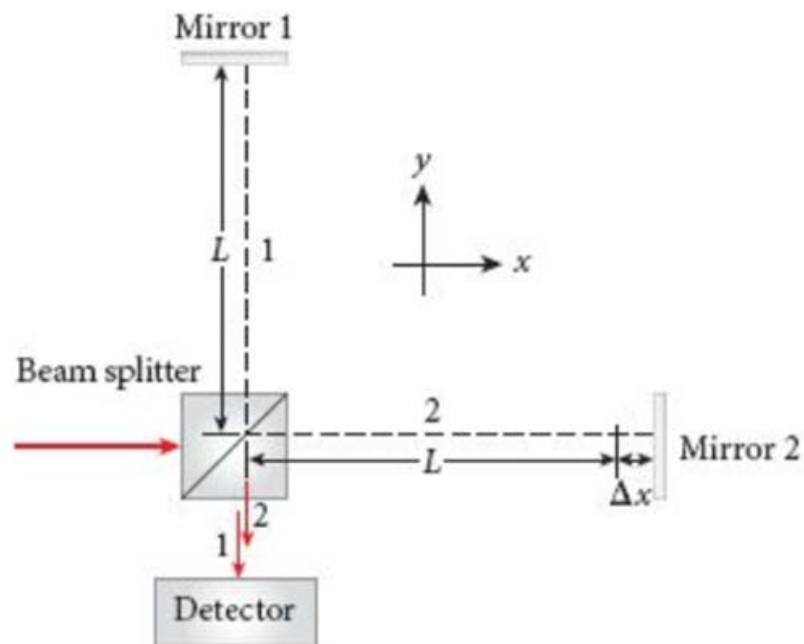
Prob. 8

Linearly polarized light is to have its axis of polarization rotated by 90° by employing some number of polarizers. In which of the following cases does the final beam have the greatest intensity?

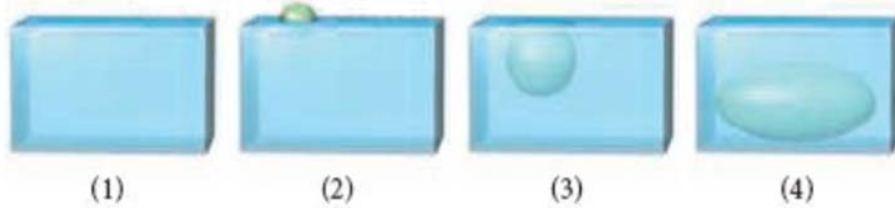
- (a) 3 polarizers, where each polarizer rotates the axis of polarization by 30° .
- (b) 2 polarizers, where each polarizer rotates the axis of polarization by 45° .
- (c) 1 polarizer, which rotates the axis of polarization by 90° .
- (d) None of above, since the axis of polarization cannot be rotated in this way.

Prob. 9 A laser beam with wavelength 633 nm is split into two beams by a beam splitter. One beam goes to mirror 1, a distance L from the beam splitter, and returns to the beam splitter, while the other beam goes to mirror 2, a distance $L + \Delta x$ from the beam splitter, and returns to the beam splitter. The beams then recombine and travel to a detector together. If $L = 1.00000$ m and $\Delta x = 1.00$ mm, which best describes the kind of interference observed at the detector? (*Hint: To double-check your answer, you may need to use a formula that was originally intended for combining two beams in a different geometry.*)

- a) purely constructive
- b) purely destructive
- c) mostly constructive
- d) mostly destructive
- e) neither constructive nor destructive



Prob. 10 The figure shows four identical open-top tanks filled to the brim with water and sitting on a scale. Balls float in tanks (2) and (3), but an object sinks to the bottom in tank (4). Which of the following correctly ranks the weights shown on the scales?



- a) $(1) < (2) < (3) < (4)$ c) $(1) < (2) = (3) = (4)$
 b) $(1) < (2) = (3) < (4)$ d) $(1) = (2) = (3) < (4)$

Prob. 11 Many altimeters determine altitude changes by measuring changes in the air pressure. An altimeter that is designed to be able to detect altitude changes of 100 m near sea level should be able to detect pressure changes of

- a) approximately 1 Pa. d) approximately 1 kPa.
 b) approximately 10 Pa. e) approximately 10 kPa.
 c) approximately 100 Pa.

Prob. 12 A beaker of water is sitting on a scale. A steel ball hanging from a string is lowered into the water until the ball is completely submerged but is not touching the beaker. The weight registered by the scale will

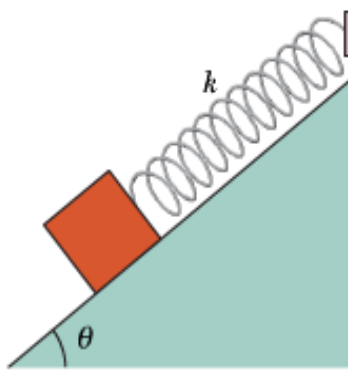
- a) increase. b) decrease. c) stay the same.

Prob. 13

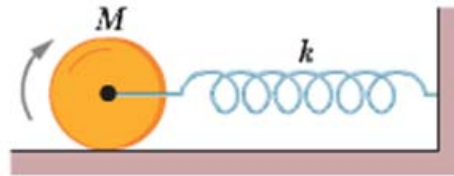
A piece of unpainted porous wood barely floats in an open container partly filled with water. The container is then sealed and pressurized above atmospheric pressure. What happens to the wood? (a) It rises in the water. (b) It sinks lower in the water. (c) It remains at the same level.

16 short problems (some of them with * are somewhat challenging, maybe) are given here for your review. The actual exam will have only about 4 short problems plus an extra credit problem.

Prob. 14 A block weighing 14.0 N, which can slide without friction on an incline at angle $\theta = 40.0^\circ$, is connected to the top of the incline by a massless spring of unstretched length 0.450 m and spring constant 120 N/m. (a) How far from the top of the incline is the block's equilibrium point? (b) If the block is pulled slightly down the incline and released, what is the period of the resulting oscillations?



Prob. 15 A solid cylinder attached to a horizontal spring ($k = 3.00$ N/m) rolls without slipping along a horizontal surface. If the system is released from rest when the spring is stretched by 0.250 m, find (a) the translational kinetic energy and (b) the rotational kinetic energy of the cylinder as it passes through the equilibrium position. (c) Show that under these conditions the cylinder's center of mass executes simple harmonic motion with period



$$T = 2\pi \sqrt{\frac{3M}{2k}},$$

(The moment of inertia of a cylinder = $MR^2/2$.)

Prob. 16 One of the harmonic frequencies of tube A with two open ends is 325 Hz. The next-highest harmonic frequency is 390 Hz. (a) What harmonic frequency is next highest after the harmonic frequency 195 Hz? (b) What is the number of this next-highest harmonic?

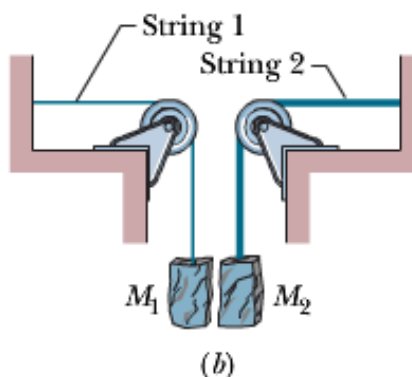
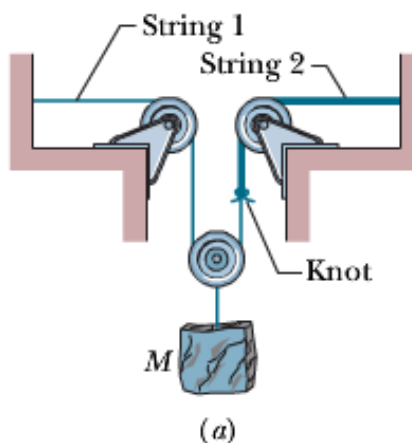
One of the harmonic frequencies of tube B with only one open end is 1080 Hz. The next-highest harmonic frequency is 1320 Hz. (c) What harmonic frequency is next highest after the harmonic frequency 600 Hz? (d) What is the number of this next-highest harmonic?

Prob. 17 A 2000 Hz siren and a civil defense official are both at rest with respect to the ground. What frequency does the official hear if the wind is blowing at 12 m/s (a) from source to official and (b) from official to source?

(Hint: this problem is practically identical to a problem in midterm 2, if one uses the Galilean relativity principle, i.e., the relativity principle of the Newtonian mechanics.)

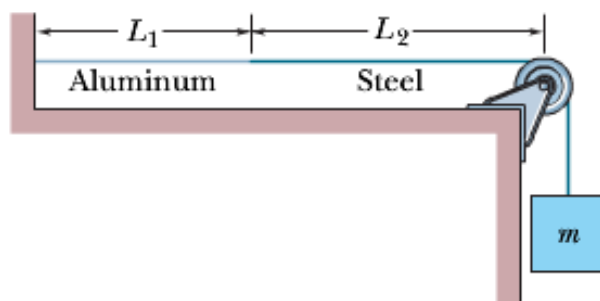
Prob. 18*

In **Figure (a)**, string 1 has a linear density of 3.00 g/m , and string 2 has a linear density of 5.00 g/m . They are under tension due to the hanging block of mass $M = 500 \text{ g}$. Calculate the wave speed on (a) string 1 and (b) string 2. (*Hint: When a string loops halfway around a pulley, it pulls on the pulley with a net force that is twice the tension in the string.*) Next the block is divided into two blocks (with $M_1 + M_2 = M$) and the apparatus is rearranged as shown in **Figure (b)**. Find (c) M_1 and (d) M_2 such that the wave speeds in the two strings are equal.



Prob. 19*

An aluminum wire, of length $L_1 = 60.0 \text{ cm}$, cross-sectional area $1.00 \times 10^{-2} \text{ cm}^2$, and density 2.60 g/cm^3 , is joined to a steel wire, of density 7.80 g/cm^3 and the same cross-sectional area. The compound wire, loaded with a block of mass $m = 10.0 \text{ kg}$, is arranged so that the distance L_2 from the joint to the supporting pulley is 86.6 cm . Transverse waves are set up on the wire by an external source of variable frequency; a node is located at the pulley. (a) Find the lowest frequency that generates a standing wave having the joint as one of the nodes. (b) How many nodes are observed at this frequency?



Prob. 20

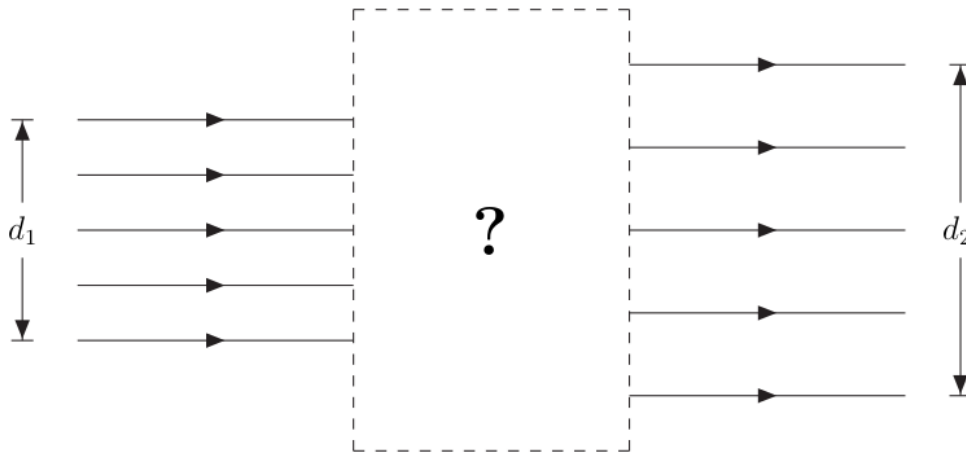
A horizontal concave mirror with radius of curvature of 0.97m holds a layer of water with an index of refraction of 1.33 as shown. At what height above the mirror must an object be placed so that its image is at the same position as the object? You can assume that the water is shallow enough that its thickness is very small compared to radius of curvature. The thin lens equations can then be applied.

Useful information: Lensmaker's equation: $1/f = (n - 1)(1/R_1 + 1/R_2)$



Prob. 21

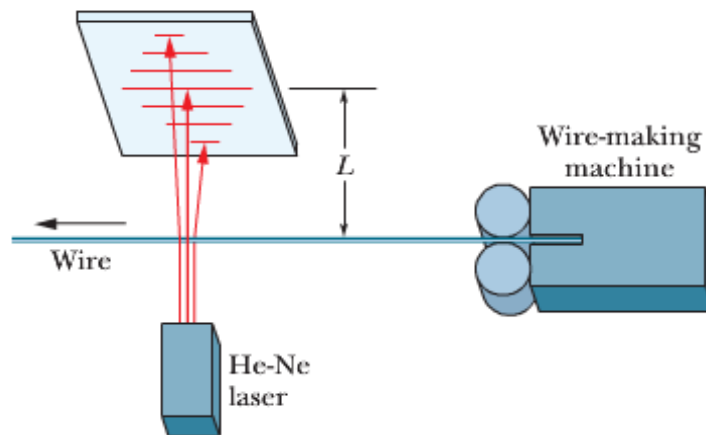
In many applications, it is necessary to expand the diameter of a beam of parallel rays of light. This change can be made by using a converging lens and a diverging lens in combination. Suppose you have a converging thin lens of focal length 21 cm and a diverging thin lens of focal length -12 cm . Let d_1 be the diameter of the incoming beam of parallel rays, as shown in the figure below. Arrange the two lenses (inside the dashed box area shown below) so that the light beam that emerges is still composed of parallel rays with a beam diameter of d_2 such that $d_2 > d_1$.



- Through which lens does the incoming beam first pass?
- What is the distance between the two lenses?
- Compute the ratio d_2/d_1 by which the diameter of the beam has been increased.

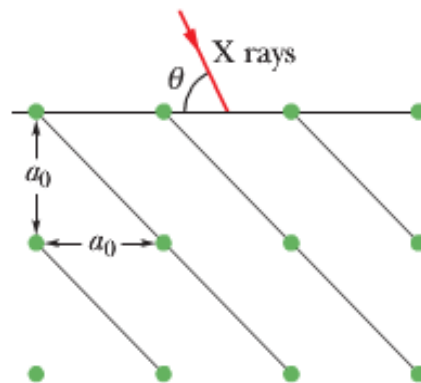
HINT: Draw a ray diagram to make sure that your answer makes sense. In particular, the ray diagram will help you answer part (c).

Prob. 22 Manufacturers of wire (and other objects of small dimension) sometimes use a laser to continually monitor the thickness of the product. The wire intercepts the laser beam, producing a diffraction pattern like that of a single slit of the same width as the wire diameter (Fig. 36-37). Suppose a helium–neon laser, of wavelength 632.8 nm , illuminates a wire, and the diffraction pattern appears on a screen at distance $L = 2.60\text{ m}$. If the desired wire diameter is 1.37 mm , what is the observed distance between the two tenth-order minima (one on each side of the central maximum)?



Prob. 23 A diffraction grating having 180 lines/mm is illuminated with a light signal containing only two wavelengths, $\lambda_1 = 400$ nm and $\lambda_2 = 500$ nm. The signal is incident perpendicularly on the grating. (a) What is the angular separation between the second-order maxima of these two wavelengths? (b) What is the smallest angle at which two of the resulting maxima are superimposed? (c) What is the highest order for which maxima for both wavelengths are present in the diffraction pattern?

Prob. 24 In this figure, first-order reflection from the reflection planes shown occurs when an x-ray beam of wavelength 0.260 nm makes an angle $\theta = 63.8^\circ$ with the top face of the crystal. What is the unit cell size a_0 ?



Prob. 25

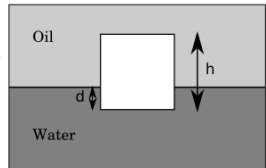
The *resolving power* of a microscope is defined by $RP = f\theta$, where f is the focal length of the objective lens and θ is the minimal angular separation of two resolvable objects according to Rayleigh's criterion.

Yellow light of wavelength 589 nm is used to view an object under a microscope. The diameter of the objective lens is 5 mm and its focal length is 9 mm.

- (a) Compute the resolving power of the microscope.
- (b) Suppose water (with an index of refraction $n = 4/3$) fills the space between the object and the objective lens. How is the resolving power of the microscope changed?

Prob. 26

In the figure shown on the right, a cube of height $h = 10\text{cm}$ and made out of an unknown material floats in equilibrium at the interface between water with a density of 1000kg/m^3 and oil of density 823kg/m^3 , at a height $d = 2\text{cm}$ below the surface of the water. Calculate the density of the the cube.



Prob. 27 A 10 kg sphere is supported on a frictionless plane inclined at angle $\theta = 45^\circ$ from the horizontal. Angle ϕ is 25° . Calculate the tension in the cable.

