Solution Videos to Physics Problems
Waves - Optics - Thermodynamics

For video solutions to these problems go to www.foothill.edu/~cascarano/videos.html

MECHANICAL WAVES

WAVES_01 Waves on a String

You are taking clothes off a clothesline after they have dried. The clothesline is basically a light rope tied between two trees. Being enrolled in physics, you decide to untie one end and, moving it up and down, send wave pulses down the line. As you vibrate your hand faster and faster you can see standing waves set up in the line at several frequencies.

You take some measurements and record your observations:

1) You measure the length of the line to be 3 m
2) You send a wave pulse down the line and determine it takes 4 seconds for it to reach the other end (you are holding your end fairly loose, so there is not much tension in the line)
3) It was a nice day, the sun was shining, and the temperature was 20°C.

What are the three lowest frequencies that give standing waves? Make sure your numbers make sense, the signs are correct, and assume all the numbers here are good to three significant figures, so you can give your answers to 3 sig figs.

WAVES_02 Waves on a String

You are taking clothes off a clothesline after they have dried. The clothesline is basically a light rope tied between two trees. Being enrolled in physics, you decide to untie one end and, moving it up and down, send wave pulses down the line. After playing around with this setup, you get bored and want to make a challenge for yourself. So, you tie a knot near the other end of the line, 0.5 m from the tree. The challenge you give yourself is to vibrate your end of the line such that the knot does not move.

You take some measurements and record your observations:

1) You measure the length of the line to be 3 m
2) You send a wave pulse down the line and determine it takes 4 seconds for it to reach the other end (you are holding your end fairly loose, so there is not much tension in the line)
3) It was a nice day, the sun was shining, and the temperature was 20°C.

What are the three lowest frequencies such that the knot does not move?

WAVES_03 Waves on a String

A transverse sine wave has the following characteristics as it travels from left to right along a string:

Amplitude = 3 mm
Wavelength = 2 m
Speed = 40 m/s

Take the origin to be the left end of the string. At t = 0 the left end of the string has its maximum upward displacement.

a) What is the function y(x, t) that describes the wave?
b) What are the frequency, angular frequency, and wave number for the wave?
c) What is the magnitude of the maximum transverse velocity of any particle on the string?

WAVES_04 Waves on a String

Two different strings are joined together at their ends and stretched between two supports with a tension of 190 N. The longer string is 3.75 m in length and has a mass density of 0.06 kg/m. The shorter string is 1.25 m in length and has a mass density of 0.015 kg/m. Find the lowest frequency such that the point where the strings are joined together does not move.

SOUND WAVES

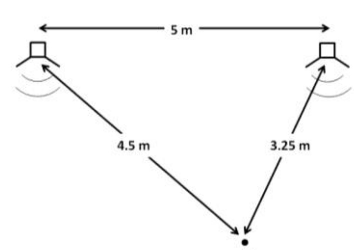
WAVES_10 Standing Sound Waves

Find the fundamental frequency and the frequencies of the first two overtones of a pipe 0.5 m long (use 344 m/s for the speed of sound in air):

a) If the pipe is open at both ends
b) If the pipe is closed at one end

WAVES_11 Sound Interference

Two speakers 5 m apart are driven at 688 Hz by the same amplifier. Does a microphone at point P pick up constructive or destructive interference? (Use 344 m/s for the speed of sound in air)



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WAVES_15 Sound, Doppler Shift, Beats
Two police cars have identical sirens that emit a frequency of 1000 Hz. You are driving between the two police cars. The car behind you is stationary and the car in front of you is going 30 m/s in the same direction as you. Your speed is 20 m/s. What beat frequency do you hear? (Use 344 m/s for the speed of sound in air)

THERMODYNAMICS

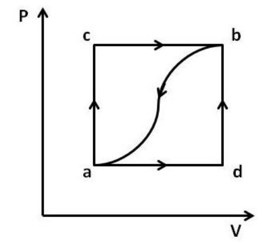
THERMO_35 Heat Transfer
Knowing you are taking physics, your neighbor asks you to help his kid with a science fair project. The kid wants to figure out how much heat is leaving her room through the walls on a cold winter night. You suggest making a small scale mock-up of the wall to test. You decide on a 4” x 4” cross section for the experiment. To simulate the wall you use 3” of fiberglass insulation next to 1” of wood siding. The wood siding is exposed to a 0^{o}C ice / water bath to simulate the outside temperature on a cold winter night. The fiberglass is exposed to a heater that maintains a constant 20^{o}C to simulate the warm interior of the bedroom.

a) How much heat per second flows through the mock-up of the wall?
b) What is the temperature of the wood / fiberglass interface?

THERMO_37 Radiation
A wood burning stove has an emissivity of 0.9 and a surface area of 3.5 m^2. (a) Determine the net radiant power when it is unheated and in thermal equilibrium with the 18°C room. (b) Determine the net radiant power when a fire is burning in it. Its surface temperature is a constant 198°C and the room warms to a constant 29°C.

THERMO_41 Calorimetry
A 5 kg block of iron at 750°C is placed on a 5 kg block of ice at -10°C in an insulated container. What is the final makeup and temperate after equilibrium is reached?

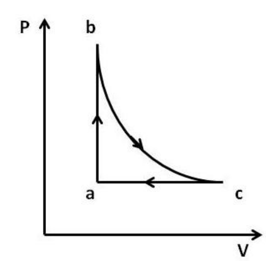
THERMO_50 (from Young and Freedman 12^{th} edition, 19-43)
When a system is taken from state a to state b along the path acb, 90 J of heat flows into the system and 60J of work is done by the system.



a) How much work heat flows into the system along path adb if the work done by the system is 15 J?
b) When the system is returned from b to a along the curved path, the absolute value of the work done by the system is 35 J. Does the system absorb or liberate (give off) heat? How much heat?
c) If U_a = 0 and U_d = 8 J, find the heat absorbed in the processes ad and db.

THERMO_52 (from Young and Freedman 12^{th} edition, 20-43) (the solution video has three parts) A heat engine operates using the cycle shown. The working substance is 2 mol of helium gas, which reaches a maximum temperature of 327°C. Assume the helium can be treated as an ideal gas. Process bc is isothermal. The pressure in state a and c is 1 x 10^5 Pa, and the pressure in state b is 3 x 10^5 Pa.

a) Tell me everything you can about the system in each of the states shown (a, b, and c) and about each path in the cycle.
b) What is the efficiency of this engine? Compare this engine’s efficiency with the maximum possible efficiency attainable with the hot and cold reservoirs used by this cycle.



THERMO_53 PV Diagram (the solution video has two parts)
0.25 mol of O_2 (which you can treat as an ideal gas) starts in state 1 (P_1 = 2.4 x 10^5 Pa, T_1 = 355 K) and is taken through the following cycle:
1) an isobaric expansion to state 2 ($V_2 = 4V_1$)
2) an andiabatic compression to state 3 ($V_3 = 2V_1$)
3) an isothermal compression to state 4 ($V_4 = V_1$)
4) cooled isochorically back to state 1

Tell me everything you can about the system in each of the states described above and about each path in the cycle.

THERMO_62 Refrigerator

The refrigerator in your kitchen has a freezer compartment that is held at -10°C and its coefficient of performance is 4. Room temperature is 20°C. The freezer can convert 2 kg of 20°C water to 2 kg of -10°C ice each hour.

a) How much electrical energy is consumed by the freezer each hour?
b) How much wasted heat is delivered to the room each hour?
c) What is the power rating of the freezer (in Watts)?

THERMO_68 Entropy

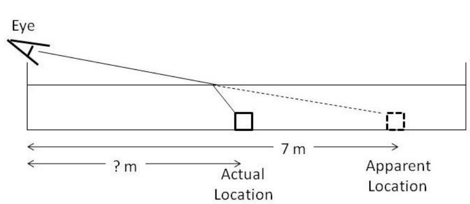
You make a cup of coffee with 0.4 kg of 202°F water. In order to drink it right away, you drop a 0.05 kg ice cube at 0°C into the coffee. While the ice is melting you walk away and forget about the coffee. You find it later, after it has cooled to room temperature (20°C).

a) Calculate the change in entropy of the coffee
b) Calculate the change in entropy of the room
c) Calculate the change in entropy of the ice

LIGHT

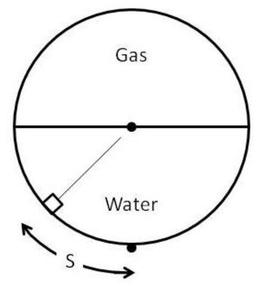
LIGHT_70 Refraction

You are looking across a shallow pool of water, trying to spot a speaker submerged in the pool. The pool is 0.5 m deep with water and your eye is 0.3 meters above the surface of the water. When you spot the speaker its apparent location is a horizontal distance of 7 m from your eye. How far is the speaker actually located from your eye (horizontal distance)?



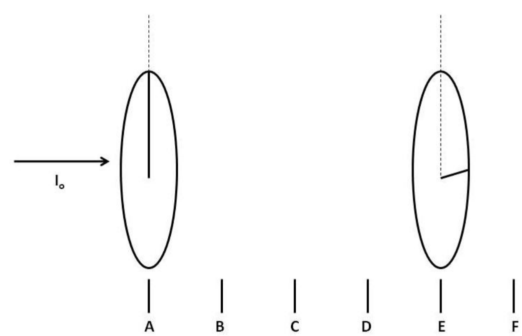
LIGHT_71 (from Young and Freedman 12th edition, 33-53)

A horizontal cylindrical tank 2.2 m in diameter is half full of water. The space above the water is filled with a pressurized gas of unknown refractive index. A small laser can move along the curved bottom of the water and aims a light beam toward the center of the water surface. You observe that when the laser has moved a distance S = 1.09 m or more (measured along the curved surface) from the lowest point in the water, no light enters the gas. (a) What is the index of refraction of the gas? (b) How long does it take the light beam to travel from the laser to the rim of the tank when (i) S < 1.09 m and (ii) when S > 1.09 m?



LIGHT_76 Polarization

A beam of unpolarized light of intensity I_o passes through two ideal polarizing filters, as shown. The first polarizer has its axis oriented vertically and the second is oriented horizontally.



(a) What is the intensity between the filters?
(b) What is the intensity at point F?

Now, a third polarizing filter is added at point C. Its axis is oriented 30^o with respect to vertical.

c) What is the intensity at point D?
d) What is the intensity at point F?

LIGHT_80 Optics (the solution video has two parts)

An object, 10 cm in height, is located in front of a concave spherical mirror (radius of curvature is 30 cm). If the object is located:

a) 5 cm in front of the mirror
b) 25 cm in front of the mirror

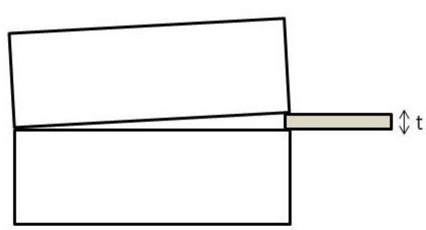
Draw the situation and include ray tracing to show the image. Calculate the position, size, orientation, and nature (real or virtual) of the image. Make sure it agrees with the ray trace.

LIGHT_83 Optics (the solution video has two parts)
An object (height = 10 cm) is located 12 cm to the left of a converging lens (f = 9 cm). 18 cm to the right of the lens is a second converging lens (f = 6 cm). Find the position, size, orientation, and nature (real or virtual) of the final image.

LIGHT_84 Optics (the solution video has two parts)
A concave mirror (radius of curvature = 10 cm) is located at x = 0. An object (height = 9 cm) is located at x = 10 cm and a diverging lens (f = -5 cm) is located at x = 20 cm. If your eye is located at a position greater than x = 20 cm and you are looking back into the lens you see two images, one from light coming directly to your eye from the object and one from the light that reflected off the mirror first. Find the positions, sizes, orientations, and natures (real or virtual) of the two images.

LIGHT_92 (from Young and Freedman 12th edition, 35-15)
Coherent light with wavelength 600 nm passes through two very narrow slits and the interference pattern is observed on a screen 3 m from the slits. The first order bright fringe is at 4.84 mm from the center of the central bright fringe. For what wavelength of light will the first order dark fringe be observed at this same point on the screen?

LIGHT_93 Interference
Two glass plates are separated on one edge by a spacer of thickness t, forming an air wedge between the plates. When illuminated from above with 600 nm light 30 dark fringes are seen. (a) What is the thickness of the spacer, t? (b) The space between the plates is now filled with a liquid instead of air and a different spacer is used. The liquid has an index of refraction of 1.65. If you again observe 30 dark fringes, what is t?



LIGHT_96 Diffraction Grating
A diffraction grating is illuminated with 500 nm light. The third order maximum is observed at 32°.

a) What is the number of lines per cm for the grating?
b) Determine the total number of primary maxima that can be observed in this situation.