Hints on how to solve the homework assignments
(based on Young and Freeman, University Physics, 12th ed.)

- Hints for problem set 1 (on Chap. 33):

Prob. 5: The speed of light in quartz gives you the index of refraction of quartz at this wave length. Then use the fact that the frequency of light does not change as light enters any transparent material, but the speed of light changes, so the wavelength changes.

Prob. 9: To get the speed of light in the plastic, first calculate its index of refraction using the law of refraction, i.e., Snell’s law.

Prob. 19: In (a), light is traveling from inside the liquid across the liquid/air interface into air. In (b), light is traveling from air across the air/liquid interface into the liquid.

Prob. 21: Light is in the cube to begin with. You just need to know the concept of total reflection. Only one face of the cube is involved. So you don’t really need to know that the shape of the glass is a cube.

Prob. 27: You just need to know under what condition will the refracted light be completely polarized. (What would be the direction of this polarization?)

Prob. 31: Treat the exit polarized light of the first filter as the incident polarized light of the second filter. So first you need to know what happens to an unpolarized light as it goes through the first filter. Then calculate the effect of the second polarizing filter.

Prob. 41: Gradually increase $\theta_a$ from 0, and see what happens to the refracted light. Initially, the refracted light beam will hit the opposite face. At some $\theta_i$ the light beam will begin to hit the side face, at an incident angle to the side face that is so large that total reflection will occur. Increase $\theta_a$ further, and total refraction will cease to occur at some $\theta_a$. This is the angle you are looking for, beyond which, total reflection will not occur at the side face of the block, and light will come out of the side face.

Prob. 45: The emulsion on the front surface of the glass plate acts as a scatterer of light. So the point of the emulsion lit by the incident focused beam will act as a point source of light toward the inside of the glass plate. Consider all these light rays from that point source inside the glass plate, and find out which ones are totally reflected by the back surface of the glass plate, and which ones are not. Those not totally reflected will essentially exit on the back side of the glass plate, and not generate the halo. Those that are totally reflected will return to the front of the glass plate to generate the halo, but the longer the distance traveled by the light ray, the weaker it will contribute to the halo, so halo exists only for some radial distance from the point where the light beam hits the emulsion, and a little bit beyond. You can now relate the inner radius of the halo to the index of refraction of the glass plate. (You need to draw the light rays to see it.)

Prob. 47: Using all the lengths given, you can figure out the incident and refracted angles. Assuming that the water surface is flat and horizontal, you can see what the direction of the surface normal is.

Prob. 49: The index of refraction of ice (1.309, from Table 33.1 of the text) is different from that of water (1.333) and air ($\approx$ 1). Largest angle for no total reflection is the same as the smallest angle for total reflection. This is the angle you are looking for. Note that total reflection can happen at the water-ice interface or at the ice-air interface. Which one is the relevant one? Draw a ray picture of each case before analyzing it.
Hints for problem set 2 (on Chap. 34):

Prob. 5: Simple use of formulas. No hints needed.
Prob. 15: You can do this problem using Eq. (34.11) of the text, if you understand the meaning of every quantity in that equation! (A flat interface is a special case of a spherical interface with an infinite radius!) Note that the image formed is a virtual image, since it requires extrapolation of the light rays. Thus the image distance of this problem is negative. Note also that the formula can not be used if the image is not viewed at normal incidence, since the formula has assumed paraxial approximation. That is, it has assumed that all angles involved are very small. When this is not true, don’t use this formula. Instead, use the law of refraction and trigonometry to solve the problem.
Prob. 25: For thin lens the focal length is the same whether light is incident from left or right. So you can take either surface to be the first one and then the other one will be the second one. Draw a picture of the lens in order to decide on the signs of the radii. This is important if you wish get the answer right! \((R_1\) and \(R_2\) are positive if they are curving toward the incident light, otherwise they are negative.)
Prob. 39: You want the image to barely fit into the 24 mm × 36 mm film. (The camera can be held vertically or horizontally depending on the shape of the object to be filmed. Assume that the height of the mobile home is less than 6.4 m, so the camera should be held horizontally.)
Prob. 47: You wish to change the near point to 25 cm and the far point to infinity. In either case the image distance is negative here since the image to be seen by the eye is virtual, because it is on the incoming side of light.
Prob. 51: In this problem the image is again virtual for the eye to see it. You are asked to find the object distance.
Prob. 53: The image of the objective serves as the object of the eye piece, but note that the distances are measured from the center of the respective lens you are working on. So in going from the objective lens to the eye piece, you have to translate the distances.
Prob. 57: Here the final image is virtual again. Note that part (b) is worded poorly. Both phrases “formed by the objective” and “of a building 60.0 m tall, 3.00 km away” are about the image. Do not read it as “… objective of a building …”, which would not exist. So for this part you should not look at the effect of the whole telescope, just the effect of the objective alone. The object distance is clearly not infinite for this part.
Prob. 89: The image of the first lens serves as the object of the second lens. Its position must now be measured from the center of the second lens. If light rays are intercepted by the second lens before the image of the first lens is formed, that is, if the image of the first lens is to be formed farther than the location of the second lens, then the object distance of the second lens is negative. Does this situation happen in this problem?
Prob. 103: A camera has only one lens. So this problem is not hard. But it uses two equations — one on the image distance, and one on the image size.

Note: Getting the signs of the distances and focal lengths right is crucial in mirror and lens problems! If you do not wish to fail the course, you must pay attention to the signs.
Hints for problem set 3 (on Chap. 35):

Prob. 1: “Consider points along the line”, not outside of it. So distances to A and B are easy to figure out in this problem. Remember that the number of wavelengths that can fit into any distance multiplied by $2\pi$ is the increase of phase of a wave reaching one end of that distance from the other end of it.

![Diagram of points A and B along a line]

Prob. 15. Use the first part of the problem to figure out the distance between the two slits. Then do the second part as a standard double-slit interference problem.

Prob. 23: Part (a) is a standard use of a formula. Part (b) talks about the shortest distance where the intensity can drop by a factor of 2. That is within the central bright peak. You have to use two formulas: Eq. (35.10) and Eq. (35.13) in the text. Since, in this problem, $\lambda$ is very small in comparison with $d$, the angle $\theta$ must be very small even though $\phi$ is not small. Thus in this problem you can use the small angle approximation to replace $\sin \theta$ and $\tan \theta$ by $\theta$ in radians — An approximation valid for $\theta$ less than about 5 degrees. Don’t use this approximation in problems where the angles involved are not small!

Prob. 35: You must take into account: (i) The plastic substrate changes the light wavelength. (ii) In a reflected light path, the path is traveled twice — once forward, and once backward! So when you calculate distance, you get an extra factor of two.

Prob. 37: Each fringe moving across a line in the field of view means an extra wavelength in the difference of the two path lengths of light involved in this problem. So in this problem, you must first see that light starting at a single source point takes two different paths to reach the same point in the field of view, thus causing interference.

Prob. 41: The wavelength of light got changed by the index of refraction of the liquid.

Prob. 43: In this problem, there are two wave lengths. Find out the locations of bright fringes for each wave length, and then compare them for the two wave lengths. You should draw a figure to help you solve this problem.

Prob. 51: Here reflected paths are involved, so light travels twice the distance involved — once forward and once backward. Use the lower temperature data to figure out the original thickness of the film. Then use the higher temperature date to figure out the new thickness of the film, assuming that the index of refraction of the film does not change when its thickness changes with temperature. Finally, use the definition of the coefficient of linear expansion to calculate this quantity.

Prob. 55: This problem has its own hints. But note that one sentence in this problem is not needed, and should be deleted. This is the sentence “The distance $x$ is small compared to $h$ so that the reflection is at close to normal incidence.” This sentence serves only to confuse you. Disregard its existence. Note also that the longest wavelength corresponds to the smallest $m$ allowed. You should be able to see it from the equation derived. The only formula you need to solve this problem is Eq. (35.11). It is so simple and fundamental that you should remember it.

Prob. 59: The wavelength of light in the glass is smaller. So the same distance occupied by the glass can now fit in more wavelengths (than if the region is occupied by air). The total number of wavelengths that can fit in a path, multiplied by $(2\pi)$, is the phase change of light traveling through that path, which is changed by the insertion of the glass plate.
Hints for problem set 4 (on Chap. 36):

Prob. 11: To observe the diffraction pattern in the focal plane of the lens, light rays from the different points of the slit to reach one point in the pattern must be parallel to each other before entering the lens. Thus without the lens these rays can only reach one point on a screen if the screen is at infinity. The difference in path lengths between light rays from different points in the slit can then be figured out exactly as discussed in the text for the case when the screen is very far away. The lens can only move the diffraction pattern from infinity to its focal plane, without changing the shape of the pattern, but it will change the size of the pattern. Note also that you can not use the small angle approximation in this problem.

Prob. 13: Simply calculate the first two minima on one side of the central maximum, and the first minimum on the other side. Use them to answer the questions in this problem.

Prob. 17: In a single-slit diffraction experiment, the relation between the angular position of a point in the pattern and the total phase difference between wavelets from the top and bottom edges of the slit is given by Eq. (36.6). The relation between the intensity at a point in the pattern and the above-said phase difference is given by Eq. (36.5).

Prob. 25: In this problem, we have \( N = 4 \). Don’t look for a formula to do this pattern. Use your understanding of the concepts about \( N \) slits diffraction. You are asked to draw phasor diagrams. (If you really understand the relevant concepts, you should be able to handle \( N = 5, 6 \), and beyond as well.)

Prob. 31: Once you can answer the first question right, you’ll know what to do for the second question. The first order maxima for two different wavelengths are located at two different positions on the screen. Write down the equation governing each of these two positions. Make the approximation allowed by the answer to the first question. Then take the difference of the two equations. (Note that the approximation is important. Otherwise the problem becomes much harder.)

Prob. 33: Since the laser light is at normal incidence, it must be in phase when hitting two neighboring tracks of the CD. When the reflected light rays are at an angle from normal, and they are essentially parallel to each other if they are to reach a point on a far-away screen, then the path length difference can be figured out in the same way as in a usual diffraction grating with the viewing screen very far away.

Prob. 47: This is a standard resolving power problem.

Prob. 55: This is a standard single-slit diffraction problem, only the angles are not small, so don’t use the small-angle approximation. The index of refraction changes the wavelength of light. You have to apply the formula twice, once for the wavelength in air, and once for the wavelength in the unknown liquid. Do not hope to directly put in the difference in the angular location of the first dark bands for the two wavelengths into the formula. It won’t let you get directly the difference in light wavelength. The formula does not allow you to use it this way when the angles involved are not small.

Prob. 65: The longest wavelength corresponds to the largest angle (which must be less than 90°). Do not use small angle approximation here. Nor should you use any formula that has used the small angle approximation.

Prob. 71: This is a standard resolving power problem.
• **Hints for problem set 5 (on Chap. 13)**

Prob. 3: Remember the difference between a simple harmonic motion (SHM) and a wave. A SHM varies only in time. A wave varies in both space and time. A SHM is basically the motion of a single point (say, the tip of a tuning fork). A wave, on the other hand, is the cooperative motion of many, many points in space. Thus the concept of wavelength applies to a wave only. It does not exist in a SHM. But both motions are characterized by a frequency \( f \) (if the wave is monochromatic, meaning that it is characterized by a single frequency), and a period \( T \), which is just \( 1/f \). A general oscillatory motion can be a superposition of many SHMs of different amplitudes and frequencies (or periods). Then the point is doing several SHMs at the same time. Similarly, a general wave can be a superposition of many monochromatic waves of different wavelengths, frequencies (or periods), and amplitudes.

Prob. 19: This problem requires you to be able to read off the meaning of the expression given for \( x(t) \). For part (a) you need to know that a cosine function repeats itself when its argument increases by \( 2\pi \). This is what should happen when \( t \) increases by a whole period \( T \). For part (b), you need the formula relating \( T \) to the force constant \( k \) and the mass \( m \). For part (c), find first the velocity function \( v(t) \). Then read off from it the maximum speed. For part (d), find first the acceleration function \( a(t) \), read off its maximum, and then use the Newton’s law \( F = ma \) to find \( F \). Everything for part (e) can be read off from \( x(t) \), \( v(t) \), and \( a(t) \). Newton’s second law is used to get force.

Prob. 27: This problem requires you to find \( A \) and \( \omega \) in \( x(t) = A \cos (\omega t + \phi) \), by using the information given at a certain unknown time \( t = t_0 \), namely, \( x(t_0) \), \( v(t_0) \), and \( a(t_0) \). (Note that “to the right” is positive, and “to the left” is negative. You need to first derive \( v(t) \) and \( a(t) \) from \( x(t) \) before considering the special time \( t = t_0 \). You won’t be able to obtain \( \phi \) because you don’t know \( t_0 \), but the problem can be answered without knowing \( \phi \).) Finally, you can use the equation \( x(t) = A \cos (\omega t + \phi) \) to answer the question.

Prob. 35: This problem involves an angular SHM. So mass \( m \) becomes the moment of inertia \( I \) (of the wheel), and the force constant \( k \) becomes the torque constant \( K \). You have to know how to find \( I \) for the given wheel. (Review the material about moment of inertia in an earlier chapter.)

Prob. 45: When the apple is hung on the spring, the spring stretches to a new equilibrium length. The oscillation is about this new equilibrium length and is described by the equations for a SHM. The swinging motion is a simple pendulum. Each motion has a formula to describe its frequency. The given relation between the two frequencies let you set up an equation. Solving it let you find the new equilibrium length of the spring. But the weight of the apple and the force constant let you find out the change of length of the spring, which is the difference between the new equilibrium length of the spring and the un-stretched length of the spring (when the apple is not hung on it).

Prob. 49: The knife edge is the upward tip of the little black triangle in the figure. This problem requires just one formula about a physical pendulum.

Prob. 53: The pendulum \( b \) is a physical pendulum. First, you need to find its total moment of inertia, which is the sum of those for the ball and the bar. (Review the material about moment of inertia in an earlier chapter.) Then, you need to know the location of the center of mass of this ball-bar combination. This is a torque problem. So review the chapter about torques.
Prob. 63: The piston of the engine only moves up and down (or back and forth). The shaft connected to the piston does a circular motion. (See figure.) One revolution of the latter is one cycle of the former. For part (d), the average power is the total increase of kinetic energy divided by the total time elapsed. Part (e) asks you to find the effects of doubling the frequency.

Prob. 77: You need 218 stuff for this problem as well. Note that for totally inelastic collisions, such as the collision of the steak with the pan, only total momentum is conserved. The total kinetic energy is not conserved, yet the kinetic energy of the steak just before hitting the pan comes from dropping the steak by the height given. This kinetic energy determines the velocity of the steak before hitting the pan. For part (b), energy is again conserved. For part (c), all you need is the total mass that is in the SHM motion (the steak and the pan moves together), and the force constant of the spring.

Prob. 89: The downward swinging of the upper ball conserves total energy (i.e., the kinetic energy of this ball and the gravitational potential energy of this ball). It lets you find out the velocity of the upper ball when it hits the lower ball. The collision is completely inelastic, and only momentum conservation is useful to you. (Energy is conserved if you count also the heat generated in this collision, but how much heat is generated is not given, so energy conservation does not help you.) It lets you find out the velocity that the two balls begin to swing upward with after they got stuck together. Then when the two balls swing together total energy is conserved again.
**Hints for problem set 6 (on Chap. 15)**

Prob. 5: The math involved in this problem is easy, but you should remember the answers. It is important information about nature and the human limitations. Note that the energies in the electric and magnetic fields of a light wave play the roles of the kinetic and potential energies of a mechanical wave. In each case, only the sum of the two kinds of energies is a constant of time. In a mechanical wave, the energy changes back and forth between the kinetic and potential types. In a light wave, the energy changes back and forth between the electric and magnetic types.

Prob. 9: First, understand what is meant by “the wave equation”. It refers to Eq. (15.12) which is the equation satisfied by all waves of the same velocity \( v \) moving along \( \pm x \), therefore all waves that can be carried by the same string under the same tension. (It can be generalized to an equation for all waves moving along all directions in a plane or in the three dimensional space.) Part (d) can be answered by “partial differentiation” with respect to time only, holding \( x \) constant, as you are looking at the transverse motion of a particle at a fixed position \( x \) on, say, a string (or whatever that carries this mechanical wave along \( x \)).

Prob. 15: The weight of the hanging mass determines the tension of the rope. Part (c) lets you see the effect of doubling the tension.

Prob. 23: The intensity of a wave is its power (energy per unit time) falling on a unit cross-sectional area perpendicular to the direction of propagation of the wave. For a spherical wave, the total power of the point source is spread over the total area of a spherical surface, which is larger for a larger radius. Hence the intensity of the wave diminishes, as the sphere gets larger. (The SI unit of power is W, or Watt, which means J/s, or “joules per second”’. The SI unit of intensity is therefore W/m\(^2\), or “Watt per square meter”.)

Prob. 31: This is a problem on the superposition principle. If you understand this principle, this problem is easy. (See an example problem on this topic.)

Prob. 33: To answer this problem, all you need is to analyze the \( x \)-dependent factor, and see when it vanishes, and when it has the largest magnitude. (Sign is not important here, since the time-dependent factor will change its sign periodically.)

Prob. 47: This is a simple standing wave problem. For part (a), first find the wavelength. Since the frequency is given, you can then determine the speed of the wave. For part (b), note that the speed changes if the tension is changed, but the wavelength of the fundamental mode does not change. For part (c), note that the frequency of the sound in air generated by the string is the same as that of the string. But the wavelength of the sound wave in air is not the same as the wavelength of the mechanical wave on the string, because the speeds of the waves are different.

Prob. 53: To solve this problem, you need to know the relation between the tension and the speed of the wave, and the relation between the top speed of the ant and the amplitude and frequency of the wave. Do not get confused between the speed of the wave, (which does not change in time,) and the speed of the vibration at a fixed point of the rope (which changes sinusoidally in time). The latter determines the speed of the ant (which also changes sinusoidally in time).

Prob. 59: This is a \( y \)-directional wave and a \( z \)-directional wave happening simultaneously on the same string. (\( x \), \( y \), and \( z \) are three mutually perpendicular directions.) For part (a)
you consider a fixed point on the string of position $x$, and see how its $y$ and $z$ are related to each other. By changing $t$ a small fraction of the period at a time, you can get many pairs of $y$ and $z$, allowing you to plot $y$ versus $z$, obtaining a smooth curve in the $y$-$z$ plane. On this curve, you can indicate the $t$ value at which each pair of $y$ and $z$ is obtained. (How small a fraction of the period is small enough? Use $1/16$ is good enough to let you guess what will happen if you use a fraction smaller by another factor of two.) The next question in the problem asks you to look at some special values of $t$. Note that $\pi/2\omega$ is just $T/4$, so it and its multiples have already been considered when you use a step of $(1/16)T$. For part (b), find first $v_y = \partial y / \partial t$ and $v_z = \partial z / \partial t$ with $x$ held fixed. Together they give the velocity vector in the $y$-$z$ plane. The speed of the particle is the magnitude of this velocity vector. For part (c) you have to do partial differentiation with respect to $t$ one more time. The last question gives an extra minus sign to $z$. This is like flipping every curve vertically about the horizontal line represented by $z = 0$.

Prob. 65: You need only Eq. (15.25) and the formula for the speed of a transverse wave on a string to do this problem. But understand why Eq. (15.25) appears that way. That is, understand why $\mu, f, \omega$, and $A$ all appear in the numerator, and yet some appear in a square root, and some appear squared.
• **Hints for problem set 7 (on Chap. 16)**

Prob. 1: You need to know the relation between the displacement wave amplitude and the pressure wave amplitude. The pressure unit Pa (pascal) is just N/m². Don’t just work on the numbers. Work on the units as well. Some data given in example 16.1 is still needed. It is important for you to realize that if the pain threshold is exceeded, the sound wave can **permanently** damage the hearing function of your ears. So you should avoid very loud music or other sound.

Prob. 11: This is a simple problem. The two waves travel at different speeds, Of course they arrive at different time moments.

Prob. 15: For this problem, you need the formula for the intensity of a sound wave in terms of the sound amplitude, and the formulas for the speed of sound in water (a liquid) and in air (an essentially ideal gas).

Prob. 27: This is a simple problem on the standing-wave normal modes in a stopped pipe.

Prob. 33: This is an interference problem. You need to know how to determine the phase of each sound wave when arriving at the listener, as a function of the distance between the listener and the source of the sound. The phase difference between the two sound waves when arriving at the listener needs to be \( \pi \), or \( 3\pi \), or \( 3\pi \), etc., to get destructive interference, and 0, or \( 2\pi \), or \( 4\pi \), or \( 6\pi \), etc., to get constructive interference. In each case, pick the phase difference to get the lowest frequency.

Prob. 39: This problem is about “beats”. That is, the combined sound heard will have an oscillating amplitude at a “beat frequency”. The amplitude will change back and forth between a maximum and a minimum (which is zero, if the two sounds played are equally strong when arriving at the listener site), which you can find from a formula describing the beat phenomenon.

Prob. 43: In this problem, the sound source A is not moving and the sound source B is moving to the right. The listener is also moving to the right but with a lower speed. The relative position of the source and listener is also important, since what matters is whether they are moving toward each other (which makes the apparent sound frequency heard by the listener higher than the true frequency), or away from each other (which makes the apparent sound frequency heard by the listener lower than the true frequency). The wavelength is also changed, since we always have \( f\lambda = v \). In doing such problems, never use the relative velocity. The source velocity and the listener velocity produce different effects. They show up in the formula differently.

Prob. 49: Treat reflection of the radar wave as re-emission after absorption, so the thunderstorm cloud becomes the source of the reflected wave, and the receiver of this wave is at the radar station. So the frequency of the radar wave is corrected twice, once in going from the radar station to the thunder cloud, and once in going from the thunder cloud back to the radar station.

Prob. 65: The movable piston can change the length of this stopped pipe. Knowing the pressure and temperature of air in the pipe means you also know the density of the air, via the ideal gas law, \( pV = NkT \), where \( k = R/N_A \) is the Boltzmann constant. (You should first get the number density \( N/V \), which must yet be converted to mass density by multiplying it with the molecular mass, \( m = M/N_A \).) You can then find the speed of sound in this pipe. Part (c) tells you that the anti-node is slightly outside the pipe. So the effective length of the pipe is actually slightly longer than the actual length of the pipe. If that extra length is
δ, then the lengths you should use are actually (18.0 cm + δ), (55.5 cm + δ), and (93.0 cm + δ), and for the right δ, their ratio should be exactly 1:3:5. What δ can it be? After that, the problem is easy. The problem can also be solved by looking at the change of length and relate it to the wavelength.

Prob. 67: This problem involved the concepts of resonance and standing-wave normal modes. It is a straightforward problem.
• **Hints for problem set 8 (on Chap. 17)**

Prob. 15: Varying linearly means that if you plot the data in a \( t-P \) plane, you will get a straight line, but this straight line may not go through the origin in general. Thus it does not mean that \( t \) is proportional to \( P \). For an ideal gas, \( P \) is proportional to the absolute temperature \( T \), which differs from the Celcius temperature \( t \) by a constant. For an non-ideal gas, even that is not true either.

Prob. 25: This is a thermal expansion problem. You need to realize that both mercury and glass expand. It is because mercury expands more than glass that mercury overflows. Also, when the glass expands, its hollow volume also expands, and at the same rate. Treat the expansion of the hollow volume inside the glass as if it is the expansion of solid glass of the same initial volume.

Prob. 29: This is a simple linear thermal expansion problem. For the coefficient of linear (thermal) expansion of iron use that for steel in table 17.1. (Their difference can be neglected here.) If both the iron lid and the glass jar were held in warm water together you would have to calculate the difference in their expanded diameters, but here the glass temperature is held fixed.

Prob. 37: This problem simply requires you to know what is meant by specific heat. If you don’t know, read the relevant part of the text or lecture notes again.

Prob. 45: “In boiling water for several minutes” means that the metal chunk has already reached thermal equilibrium with the boiling water. Styrofoam is a good thermal insulator and has also negligible heat capacity. The problem can be solved by either of the two approaches covered in the lecture notes, but never mix up the two approaches! That is, you must not do half of this and half of that.

Prob. 69: This problem is in English units! (This is necessary because U.S. is one of the few countries in the world which still uses the English unit system.) Otherwise it is a standard thermal conduction problem. You need to know what is meant by an \( R \)-value.

Prob. 83: For this problem, you need to realize that both the olive oil and the glass expand, but not at the same rate. The oil expands more quickly. Also, when the glass expands, its hollow volume also expands, and at the same rate. Treat the expansion of the hollow volume inside the glass as if it is the expansion of solid glass of the same initial volume.

Prob. 97: This problem has given you the hint. You have to integrate \( dQ \) to get the total \( Q \). (The book used the notation \( d\bar{Q} \), which is somewhat misleading.) You need to know that \( dQ = C \, dT \), so you need to use the right hand side of the given equation for \( C \) before you can do integration with respect to \( T \).

Prob. 103: The copper also absorbs heat, not just the ice. You need to look up the specific heat of copper. But the copper does not change phase at the temperature range between 0°C and 100°C, so no latent heat is involved with copper. Do this problem in the way of the two examples in the lecture notes. If you can do this problem, you can do a lot of other such problems.

Prob. 109: This is a thermal conduction problem. When the glass window is inserted, some heat leaks out through the glass and some heat leaks out through the wood door, which now has a smaller area than the original door, after the window is inserted. The total heat loss to the outside is the sum of the two contributions. For each part, add the effective glass or wood thickness of the respective air films to the thickness of the glass
or wood door, so the glass and wood door are effectively thicker. You need the two thicknesses in the formula to calculate the heat flow through them.
Hints for problem set 9 (on Chap. 18)

Prob. 7: Watch out! “Gauge pressure” is not real pressure at all! It is the excess pressure over and above the atmospheric pressure, $1 \text{ atm} = 1.01 \times 10^5 \text{ Pa}$. Once you know this, this problem just needs the ideal gas law.

Prob. 29: For part (a), you need to know the density of liquid water, $\sim 1 \text{ g/cm}^3$, or equivalently, $1000 \text{ kg/m}^3$, or $1.00 \times 10^3 \text{ kg/m}^3$. [You better know that $1 \text{ m}^3$ is not equal to 100 cm$^3$, or 1000 cm$^3$, but is equal to $(100 \text{ cm})^3$, or $10^6 \text{ cm}^3$.] You also need to know that the molar mass $M$ of water (H$_2$O) is $2 \times 1 + 16 = 18 \text{ (g/mole)}$. It means that 1 mole of H$_2$O has 18 g of mass in it. Combining the two you can get the volume of 1 mol of liquid water. (You should have learned this in your chemistry class.) Part (b) is simple, if you know that one mole of a substance always has $6.022 \times 10^{23}$ molecules, which is the Avogadro number, $N_A$. Note that the diameter of a water molecule is just a few Ånströms, and one Ånström (Å) is equal to $10^{-10} \text{ m}$.

Prob. 35: Note that the $m$ in the formula for the rms speed is the mass of a single particle, and here a particle means a deuteron nucleus containing one proton and one neutron. A lot of people get this $m$ confused with $M$, the atomic or molecular mass, which would be essentially equal to 2 g/mol for deuteron nucleus. (The missing electron has negligible mass in comparison with the total mass of a proton and a neutron.) But it is actually far off. The molecular mass $m$ is actually a far smaller mass. It is per molecule, not per mole.

Prob. 43: First get molar heat capacity using the principle of equipartition of energy, and then convert it to the specific heat capacity. Note that molar heat capacity is the heat needed to raise one mole of the substance by one $\text{C}^\circ$, whereas the specific heat capacity is the heat needed to raise one gram of the substance by one $\text{C}^\circ$. So for the conversion you need the molar mass $M$ of nitrogen (N$_2$) and water (H$_2$O). If you realize that the unit of $M$ is g/mol, you would know how to do the conversion. Simply work with numbers and units at the same time. For part (b), you need to know that 1 L (liter, or litre) is equal to $(1/1000) \text{ m}^3$, and $1000 \text{ cm}^3$. In another word, it is 1 dm$^3$ (decimeter cube). (One decimeter is one tenth of a meter, whereas one centimeter is one hundredth of a meter.) For the whole part (b) of the problem, treat air as 100% N$_2$, so you can use the specific heat value you have already found for N$_2$ in part (a).

Prob. 49: Note that $k_B / m$ is the same as $R / M$, where $k_B$ is the Boltzmann constant, $R$ is the ideal gas constant, $m$ is the molecular mass (of the kind of molecules involved), and $M$ is the molar mass (of the same kind of molecules).

Prob. 55: When the pressure drops at constant temperature and volume, its number of moles $n$ must drop (according to the ideal gas law). The change in $n$ is the part used up. Convert it to grams by using the molar mass of propane. Watch out for the difference between “gauge pressure” and “true pressure”.

Prob. 59: You better know the consequence of this problem. Otherwise your car tires might explode after you have driven on the highway for some time, and you could get into a bad accident. The gauge pressure given in the problem is that of the air inside the tire. To get its true pressure you have to add to it the outside atmospheric pressure, which is also given in the problem. After computing the new true pressure of the air inside the tire after the car has been driven 30 minutes, convert it to gauge pressure again by subtracting from it the outside atmospheric pressure.

Prob. 61: Compare the $n$ for one cylinder and the $n$ in the balloon. Again, watch out for
the difference between “gauge pressure” and “true pressure”. The buoyancy of the balloon is an upward force with a magnitude equal to the weight of the air displaced by the balloon. This is the only upward force. For equilibrium it must be equal to the total downward force, which is just the total weight of all hydrogen molecules inside the balloon, plus the total weight supported by the balloon, including the weight of the balloon itself, and the weight of the load. This problem tells you that hydrogen balloon is much better than helium balloon in carrying heavy load. Unfortunately, hydrogen can burn easily, causing an explosion of the balloon. I suppose you have heard the story of the Hindenburg disaster, which occurred on May 6, 1937.

Prob. 65: This problem just needs the concept of Avogadro’s number, $N_A$. Estimate the number of water molecules first.

Prob. 75: The mass $m$ in $v_{\text{rms}}$ is the mass of one molecule! Not the molar mass! But you can use the fact that $k_B / m$ is the same as $R / M$. 
Hints for problem set 10 (on Chap. 19)

Prob. 5: You need the formula for the (here negative) work done in an isothermal compression. Note that for an ideal gas under constant temperature, the pressure is inversely proportional to volume. For part (b), the sketch should be reasonably to scale, using the calculated values of $P$ and $V$ for the initial and final state, and the fact that this is an isothermal process.

Prob. 9: This is an isobaric process. To answer part (c), see whether you have used the ideal gas law here. If yes, the gas has to be ideal. If not, then the gas needs not be ideal.

Prob. 13: This problem needs no formulas of this chapter, just the basic concepts about energy, and the formula for the kinetic energy that you learned in Phys. 218.

Prob. 23: This problem has given some redundant data that is inconsistent with the rest of the data in the problem, but those redundant data are not really needed to solve this problem. To make this problem consistent, either the pressure should be changed to $3.00 \times 10^7$ Pa, or the volume should be changed to 400.0 cm$^3$. But, as I have said, these data are not needed to solved this problem, so they might as well be not given. To do this problem, all you need to know are the molar specific-heats at constant volume and pressure for a molecular nitrogen gas. Note that Table 19.1 in the textbook is really for low pressure gases only, but you are asked to use it in this problem for a high pressure gas anyway. Don’t worry about this aspect of the problem.

Prob. 35: This problem involved an adiabatic process. Remember that the change of internal energy of an ideal gas depends only on the initial and final temperatures, and is independent of the process involved. Thus you need to first find the initial and final temperatures of this ideal gas, using the fact that you have an ideal gas, and that the process is adiabatic.

Prob. 41: Note that this straight line process is neither isothermal, nor isochoric, nor isobaric, nor adiabatic. Nevertheless, it is easy to compute $W$ and $\Delta U$ for this process. Then you also have $Q$. This is because $W$ is an integral that can be easily done, and $\Delta U$ for an ideal gas depends only on the initial and final temperatures, and is independent of the process involved. Then you have the first law of thermodynamics to give you $Q$.

Note that the figure has a misleading aspect: The extension of the straight line really does not go through the origin. The data given in part (b) reveals that. (If the straight line were to go through the origin, than the ratio $p_b / p_a$ would have to be equal to the ratio $V_b / V_a$. But the given data do not satisfy this relation.)

Prob. 47: The cycle is actually $a \rightarrow b \rightarrow c \rightarrow a$, but the problem did not say what is the process $c \rightarrow a$, so you can not draw this leg accurately. Just draw a dashed straight line connecting $c$ and $a$ to reflect this missing information. But you can draw the processes $a \rightarrow b$ and $b \rightarrow c$ correctly. That $T_b > T_a$ tells you the direction of the process $a \rightarrow b$.

The temperature $T_c$ is not given, so at first sight it seems that you can not tell where is exactly the state $c$ in the $pV$ diagram. But since you do know the total heat $Q$, including its sign, you should be able to deduce the total work of this cycle by the first law, including its sign. (Note that the $Q$ of a cycle is equal to the sum of the $Q$’s of all of its processes, and the $W$ of a cycle is equal to the sum of the $W$’s of all of its processes.) From the sign of the total work you know the direction of this cycle (i.e., a right-handed loop or a left-handed loop), from which you can tell the direction of the process $b \rightarrow c$.

The picture you draw should reflect this point. For part (b), the work for the process $ca$ follows easily from the work of the cycle and the work for the other two processes, ab
and be. You must get all the signs right in order to get the right answer.

Prob. 53: Note that a liquid does not obey the ideal gas law! It obeys its own simple law of thermal expansion. The law for heat flow $Q$ is also simple. (There is now negligible difference between $c_V$ and $c_p$.) The work done is also simple since the force is a constant here. The increase of internal energy is related to $c_V$ and the temperature change.

prob. 59: This is an ideal gas problem. The situation is a bit like the situation when you pump air into a tire of your car. Note that the compression is adiabatic. The air will begin to flow into the tank when the air pressure becomes equal to the pressure in the tank. (A pump always has a valve to prevent air from flowing in the opposite direction.) For adiabatic compression, the temperature changes too.

Prob. 67: In part (a), note that rapid compression is adiabatic, since heat has no time to flow. In part (b), the pressure is kept constant, so it is an isobaric process. This process can not be rapid.
- **Hints for problem set 11 (on Chaps. 19, 20)**

**On Chap. 19:**

Prob. 55: The concept involved in this problem is the following: The heat of reaction is the heat released (per kg of the substance) through the chemical reaction involved, and this heat is used up to raise the temperature of the substance from 20°C to 100°C. In spite of the high problem number and long wording, this problem is actually an easy one.

Prob. 57: The answer to part (a) of this problem hinges on the behavior of an ideal gas. “Fast moving” is the key. Find out the difference in the textbook or in the lecture notes about a thermodynamic process that happens rapidly versus one that happens slowly.

For part (b), first work out the temperature of the air in the Chinook wind when it arrives at Denver, using the fact that the pressure of this air has changed substantially during its trip grown from the Grays peak. Assuming that this air replaces the air originally in Denver, which was at 2.0°C, you can find the change of temperature in Denver due to this wind. Remember to work with the absolute temperature.

**On Chap. 20:**

Prob. 3: Part (a) is easy. Just use the definition of thermal efficiency. For part (b), use energy conservation in the form of the first law of thermodynamics for a cycle. Part (c) is easy. Part (d) just needs the definition of “power”. This is the power associated with the work done by the engine (hence called “power output”).

Prob. 7: This is a straightforward application of a formula (for Otto cycle).

Prob. 11: (a) Power consumption is the work input into the air conditioner per second. (Watt is J/s.) For part (b), use the definition of “energy efficiency rating” of an air conditioner.

Prob. 15: This problem is about a Carnot cycle. (This is a hypothetical ideal machine with the best possible efficiency of all heat engines. No real machine can operates in a Carnot cycle!) For part (a), all you need is the general definition of engine efficiency, which is valid for any cycle. For part (b), you need the formula specific for the efficiency of a Carnot cycle.

Prob. 19: This is a problem on a Engine running backward to serve as an freezer, which has the same principle as an air conditioner. (Running backward means reversing the direction of all heat flows and the work involved.) Thus $|W|$ is now going into the engine; $|Q_{c}|$ is now heat flowing into the engine from the cold reservoir; and $|Q_{h}|$ is now heat flowing out of the engine into the hot reservoir. The coefficient of performance of a freezer (or air conditioner) is defined to be $\frac{|Q_{c}|}{|W|}$, since we all would like to spend the least amount of $|W|$, to pump out the largest amount of $|Q_{c}|$ from the cold reservoir (the inside of the freezer). The warmer room serves as the hot reservoir. To get maximum performance coefficient, assume that the freezer is a Carnot engine running backward, so that $\frac{|Q_{h}|}{|Q_{c}|} = \frac{T_{h}}{T_{c}}$ is true.

Prob. 27: For part (a), ask yourself whether the reverse process can happen in nature (without trying something extra). For part (b), by “the system” it should mean the ice and the room. That is, you should look at the total change of entropy of the ice and the room. This is what is meant by the net entropy change, since one of the two parts is negative.

That is: \[
\Delta S_{\text{total}} = \Delta S_{\text{melting}} + \Delta S_{\text{water \to 20^\circ C water}} + \Delta S_{\text{air}}
\]
Hints for problem set 12 (on Chap. 20)

Prob. 31: Only simple computations are involved in this problem. But to answer the last two questions in this problem requires you to understand the concept about entropy. You are then no longer merely doing math, but are now also doing physics.

Prob. 35: What does the velocity distribution depend on? If you know that, part (a) is easy. Your results for parts (b) and (c) should agree. This shows that they are both correct formulas for calculating the change of entropy. But Eq. (20.18) is macroscopic and phenomenological, and Eq. (20.23) is microscopic and based on the microscopic meaning of entropy. Also, Eq. (20.23) is based on Eq. (20.22), which can, in principle at least, let you calculate the total entropy of any given state, whereas Eq. (20.18) can only let you calculate the change of entropy when the system changes its (thermodynamic) state.

Prob. 41: You can’t do part (a) really rigorously. All you can do is to show that (i) points a and b are at the same temperature, and (ii) the whole curve a → b appears to be more-or-less at a single temperature. Your answers to the two questions in part (b) should be based on true knowledge about the three processes involved. Do not make random guesses! Note that one of the two questions has multiple answers. Part (c) through (e) are typical questions in this subject.

Prob. 43: Before doing this problem, first determine where is the maximum temperature reached. The figure given is somewhat misleading. The process b → c is isothermal, but it looks more like it is adiabatic. That $p_b = 3 p_a$ is also not correctly indicated in the figure. To answer part (a), you need to first know which process requires heat input, and which process releases heat to the environment. To do part (b), you need to know that the work done by the cycle is the algebraic sum of the works done by all three processes. (Algebraic sum means taking into account in the sum that some contribution is negative.) For part (c), note that the hot reservoir should have the hottest temperature of the cycle, and the cold reservoir should have the coldest temperature of the cycle. Then the maximum possible efficiency is given by the efficiency of a Carnot cycle running between these two reservoirs.

Prob. 49: The process c → a in this cycle is not isothermal, nor adiabatic, not isobaric, nor isochoric. So you can’t use formulas or results about these processes. Nevertheless, this problem is not hard to do. For the process c → a, you should simply realize that work done is an integral, which is just equal to the area under the curve. It is considered positive if the process is in the direction of increasing $V$, and negative if the process is in the direction of decreasing $V$. 