<u>INSTRUCTIONS</u>: This is a closed book exam. You may consult four (two-sided) 8 1/2" × 11" sheets of paper of personal notes. However, you may not collaborate and/or plagiarize anyone else's work. Failure to comply with these rules will result in a zero on this exam.

You have three hours to complete this exam (unless special prior arrangements have been made). The point count of each problem is specified below; the total points for this exam is 175. Use this information to manage your time wisely.

PART I (15 points): True/False

Indicate whether each statement is true or false. No explanation for your choice is required. Each answer is worth 3 points.

1. If an external pressure is applied to a confined fluid, the pressure at every point within the fluid increases by that amount.

TRUE or FALSE?

2. Increasing the damping constant beyond that required for critical damping makes the system approach equilibrium more quickly.

TRUE or FALSE?

3. If two waves pass through the same region of space, they continue to move independently of one another.

TRUE or FALSE?

4. A magnifying glass (if used properly) always produces a virtual image.

TRUE or FALSE?

5. A wave that travels from a medium of higher index of refraction to a medium of lower index of refraction undergoes a 180° phase change relative to the incident wave.

TRUE or FALSE?

PART II (40 points): Multiple choice questions

Only one of the choices given is the correct answer. No explanation for your choice is required. Each multiple choice problem is worth 5 points.

1. Salt water has greater density than fresh water. A boat floats in both fresh water and in salt water. Where is the buoyant force greater on the boat?

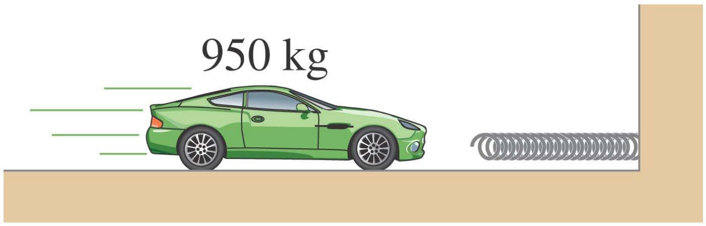
(a) salt water

(b) fresh water

(c) the buoyant force is the same in both cases

(d) cannot be determined from the information given

2. A 950-kg car strikes a huge spring at a speed of 25 m/s (see figure below), compressing the spring by 5 m.



The spring constant of the spring is given by:

(a) 38 N/m

(b) 2.1×10^3 N/m

(c) 4.8×10^3 N/m

(d) 2.4×10^4N/m

3. You blow into an pipe that is open on both ends and produce a tone. What happens to the frequency of the tone if you close one of the ends of the pipe and blow into it again?

(a) It depends on the speed of sound in the pipe.

(b) You hear the same frequency.

(c) You hear a higher frequency.

(d) You hear a lower frequency.

4. If the magnification of a mirror is negative, which of the following is correct?

(a) The image is upright and the mirror is convex.

(b) The image is inverted and the mirror is convex.

(c) The image is inverted and the mirror is concave.

(d) All of the previous answers can be correct depending on the location of the object.

(e) None of the previous answers is correct.

5. An object is placed 40 cm in front of a converging lens of focal length 40 cm. A second lens is placed 17 cm beyond the first. An image forms 48 cm past the second lens. The lateral magnification of this system is

(a) -2.8

(b) -1.2

(c) 1.2

(d) 2.8

(e) impossible to determine with the information given.

6. Two light sources individually provide an output intensity of I_0. Consider the superposition of the two sources such that they are coherent but out of phase by 30^0. The intensity of the superposition of the two sources is given by:

(a) $3.7\, I_0$

(b) $2.0\, I_0$

(c) $3.0\, I_0$

(d) $2.8\, I_0$

(e) I_0

7. Spy planes fly at extremely high altitude (25 km) to avoid interception. Their cameras are reportedly able to discern features as small as 5 cm. Assuming that the wavelength of light is $\lambda = 550$ nm, the minimum aperture of the camera lens required to afford this resolution is roughly

(a) 3.0 mm

(b) 3.1 cm

(c) 28 cm

(d) 34 cm

8. Unpolarized light falls on two polarizer sheets whose axes are at right angle. A third polarizer is placed between the first two so that its axis makes a 60° degree angle with the axis of the first polarizer. The fraction of the incident light that is transmitted through all three polarizers is

(a) 37.5 %

(b) 12.5 %

(c) 9.38 %

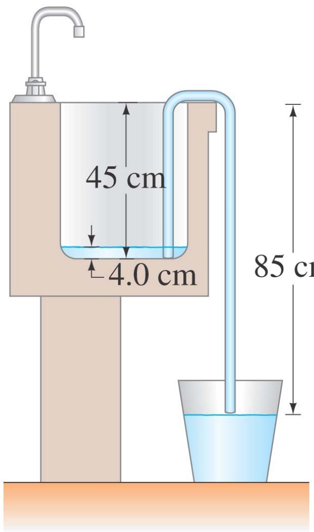
(d) 6.25 %

(e) 0 %

PART III (120 points): Short problems

To earn full credit on the following problems, you must exhibit the steps that lead to your final result (and will depend on the clarity of your method of solution as well as on your final answer). Each problem is worth 20 points.

1. You need to siphon water from a clogged sink. The sink has an area of 0.38 m^2 and is initially filled to a height of 4 cm. Your siphon tube rises 45 cm above the bottom of the sink and then descends 85 cm to the pail as shown in the figure below. The siphon tube has a diameter of 2 cm.



(a) Assuming that the water level in the sink has almost zero velocity, compute the water velocity when it enters the pail. Ignore any effects of viscosity.

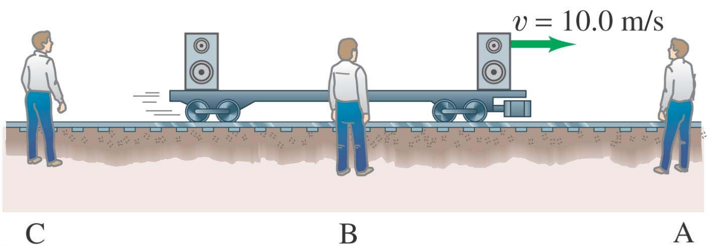
(b) Determine how long it will take to empty the sink.

2. Two loudspeakers are at opposite ends of a railroad car as it moves at 10 m/s past a stationary observer, as shown in the figure below. Assume that the speed of sound is 340 m/s. If the speakers emit identical sound frequencies of 200 Hz, what is the beat frequency heard by the observer when

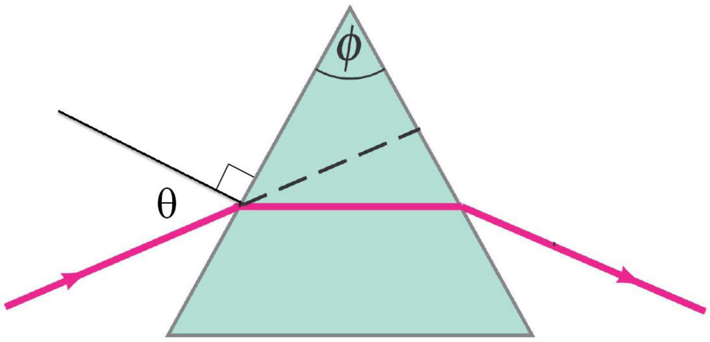
(a) the observer listens from position A, in front of the car;

(b) when the observer is between the speakers, at B;

(c) when the observer hears the speakers after they have passed him, at C?



3. If the apex angle of a prism is $\phi = 72°$ (see figure below), what is the minimum incident angle θ for the ray if it is to emerge from the opposite side (i.e., not be totally internally reflected)? Take the index of refraction of the prism to be $n = 1.56$.



NOTE: The dashed line in this figure can be ignored as it is not relevant for this problem.

4. A lucite planoconvex lens (shown in the figure below) has one flat surface and one one hemispherical surface with $R = 18.4$ cm. It is used to view an object, located 66 cm away from the lens, which emits light that is a mixture of red and yellow. The index of refraction of the lucite is 1.5106 for red light and 1.5226 for yellow light. Determine the locations of the red and yellow images formed by the lens. How far apart are the two images?

Planoconvex

Lens

NOTE: You may assume that the thin lens approximation is valid.

5. Consider light with a wavelength of 600 nm incident normally upon a glass pane. The index of refraction of the glass is $n_{\text{glass}} = 1.5$. Although most light is transmitted through the glass, some of the light is reflected. To reduce the reflection to zero, the glassmaker applies a thin film of a transparent substance of index of refraction n. The glassmaker discovers that she must apply a *minimum* film thickness of 150 nm in order to reduce the reflection of the treated glass pane to (nearly) zero when light of 600 nm is incident normally upon it.

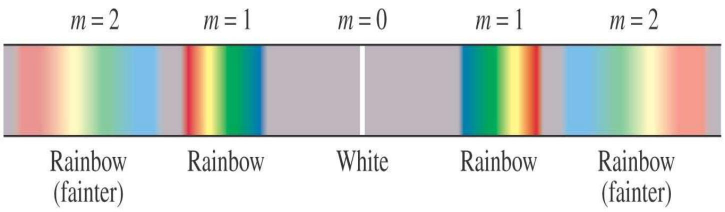
(a) Assuming that $n > n_{\text{glass}}$, determine n.

(b) Show that $1 < n < n_{\text{glass}}$ would not be consistent with the observation above.

6. White light shines on a transmission diffraction grating, and the resulting spectra are observed on a screen behind the grating.

(a) Show that the second-order and third-order spectra always overlap.

(b) Compute the corresponding ranges of the overlapping wavelengths of the second-order and third-order spectra.



NOTE: The above figure shows a typical spectrum resulting when white light passes through the diffraction grating. Note that only the first and second order spectra are shown above. The third order spectrum, which has been omitted from the above figure, would partly overlap the second order spectrum [as you shall prove in part (a) above].