*<u>INSTRUCTIONS</u>: This is a closed book exam. You may consult two (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.*

*The use of calculators for the numerical work is strongly encouraged. You have one hour and ten minutes to complete this exam (unless special prior arrangements have been made). The point count of each problem is specified below; use this information to manage your time wisely.*

## PART I: 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. A guitar string is supposed to have a fundamental frequency 256 Hz. It currently has a fundamental frequency 248 Hz. What percentage increase in tension is required to bring the guitar string into tune?

(a) 3.13%

(b) 6.56%

(c) 1.60%

(d) 6.15%

(e) 3.23%

2. If the intensity level of one trombone is 70 dB, what is the intensity level of 76 trombones?

(a) 146 dB

(b) 89 dB

(c) 70 dB

(d) 76 dB

(e) 82 dB

3. A pipe of length L closed at one end and open at the other is resonating at its fundamental frequency. Which statement is correct?

(a) The wavelength is 4L and there is a displacement node at the pipe's open end.

(b) The wavelength is 4L and there is a displacement antinode at the pipe's open end.

(c) The wavelength is 4L and there is a pressure antinode at the pipe's open end.

(d) The wavelength is 2L and there is a pressure node at the pipe's open end.

(e) The wavelength is 2L and there is a pressure antinode at the pipe's open end.

4. Is it possible to see a virtual image?

(a) No, since the rays that seem to emanate from a virtual image do not in fact emanate from the image.

(b) No, since virtual images do not really exist.

(c) Yes, the rays that appear to emanate from a virtual image can be focused on the retina just like those from an illuminated object.

(d) Yes, since almost everything we see is virtual because most things do not themselves give off light, but only reflect light coming from some other source.

(e) Yes, but only indirectly in the sense that if the virtual image is formed on a sheet of photographic film, one could later look at the picture formed.

5. Concave spherical mirrors produce images which

(a) are always smaller than the actual object.

(b) are always larger than the actual object.

(c) are always the same size as the actual object.

(d) could be smaller than, larger than, or the same size as the actual object, depending on the placement of the object.

6. An object is placed 100 cm in front of a lens of focal length 20 cm. A second lens, whose focal length is 8.0 cm, is placed 35 cm beyond the first lens (further from the original object). The final image

(a) is virtual and upright

(b) is real and upright.

(c) is virtual and inverted.

(d) is real and inverted.

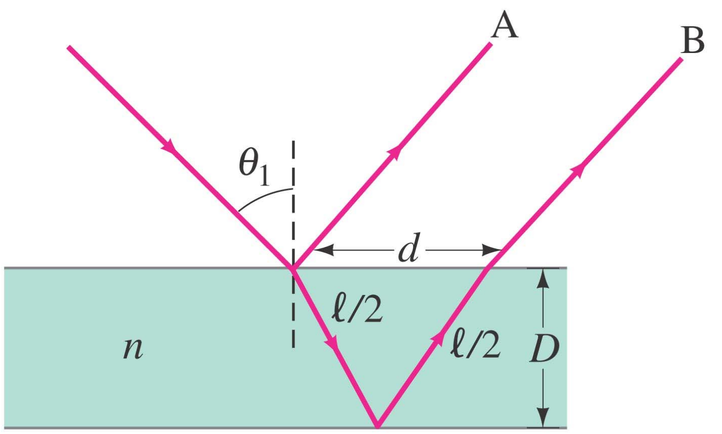
(e) cannot be determined with the information given.

**PART II: 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). Problem 7 and 8 are worth 20 points each, and problem 9 is worth 30 points.*

7. A policeman in a stationary car measures the speed of approaching cars by means of an ultrasonic device that emits a sound with a frequency of 41.2 kHz. A car is approaching him at a speed of 33.0 m/s. The wave is reflected by the car and interferes with the emitted sound producing beats. What is the frequency of the beats? Take the speed of sound in air to be 343 m/s.

8. A slab of thickness $D$, whose two faces are parallel, has index of refraction $n$. A ray of light incident from air onto one face of the slab at incident angle $\theta_1$ splits into two rays $A$ and $B$, as shown in the figure below.

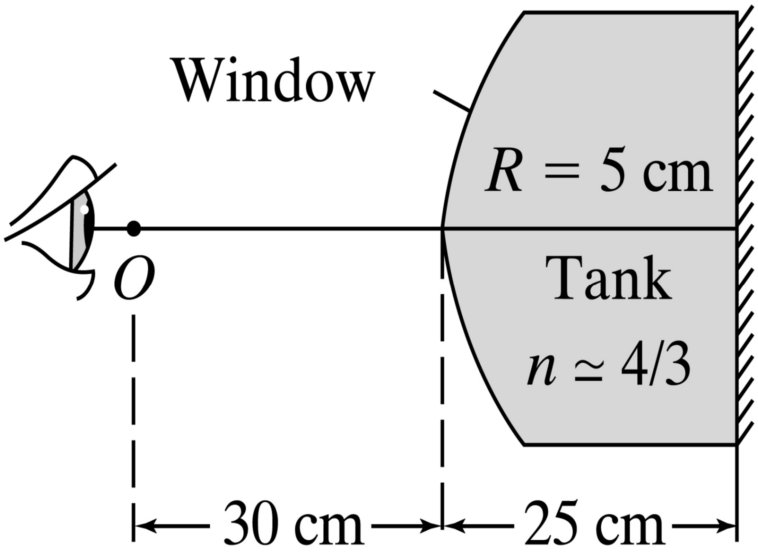



Ray $A$ reflects directly back into the air, while ray $B$ travels a total distance $\ell$ within the slab before re-emerging from the slab's face a distance $d$ from its point of entry.

(a) Derive expressions for $\ell$ and $d$ in terms of $D$, $n$ and $\theta_1$.

(b) For normal incidence (i.e., $\theta_1 = 0°$) show that your expressions yield the expected values for $\ell$ and $d$.

9. A small object $O$ faces a convex spherical glass window of a small water tank. The radius of curvature of the window is 5 cm. The inner back side of the tank is a plane mirror, 25 cm from the window, as shown in the figure below.




If the object is 30 cm outside the window, determine the nature of its final image. In particular,

(a) Is the final image virtual or real?

(b) Is the final image inverted or right side up?

(c) Determine the location of the final image and its magnification.

*HINT: Light rays from the object are refracted by the water tank, reflected off the plane mirror and then refracted one final time upon exiting the tank. You should neglect any reflection or refraction of the light rays by the thin spherical glass window itself (its only purpose in this problem is to contain the water in the tank). Take the index of refraction of the water to be* $n = 4/3$.