INSTRUCTIONS: 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.

The use of calculators for the numerical work is strongly encouraged. 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 (25 points): True/False

Indicate whether each statement is true or false. No explanation for your choice is required. Each answer is worth 5 points.

1. The pressure of water flowing through a pipe increases as the pipe becomes narrower.

2. The acceleration of a mass on a spring undergoing simple harmonic motion is at a maximum when the spring is passing through its equilibrium position.

3. The magnification of an object viewed in a convex mirror (with no other mirrors or lenses around) is never greater than 1.

4. The closer two frequencies are to each other, the faster the resulting beat frequency will be when they are played together.

5. Parallel rays of light are incident on a diffraction grating, and the resulting interference pattern is viewed on a screen. The smaller the spacing between the slits of the grating, the further apart the principal interference maxima will be.

PART II (50 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. A container is filled with oil. Two different tubes at the top of the container are fitted with pistons, and the rest of the container is all sealed. Both pistons are attached to large horizontal platforms. The area of the left piston is 10 mm^2; that of the right piston is $10,000$ mm^2. What force must be exerted on the left piston to keep a 10,000 N car sitting on the right piston at the same height?

   (a) 10 N

   (b) 100 N

   (c) 10,000 N

   (d) 10^8 N

2. A grandfather clock has a weight at the bottom of the pendulum that can be moved up or down. If the clock is running slow, what is the quickest way to fix the clock?

   (a) Move the weight up

   (b) Move the weight down

   (c) Give it a push to make it start swinging faster

   (d) Call the repairman

3. A pendulum has a frictional force that opposes its motion. If the magnitude of the frictional force is proportional to its instantaneous angular velocity, damped oscillations will occur. Which of the following kinds of damped harmonic motion would result in the pendulum coming to rest in the least amount of time?

   (a) underdamped

   (b) critically damped

   (c) overdamped

   (d) it depends on the frequency of oscillations

4. A rope of length 2 m is attached at both ends, tightened, and then driven at a frequency of 15 Hz so that a standing wave forms. If the speed of transverse waves on the rope is 20 m/s, how many nodes are there on the standing wave?

(a) 1

(b) 2

(c) 3

(d) 4

(e) 5

5. When a sound wave passes from air into water, what property or properties of the wave will change?

(a) the frequency

(b) the wavelength

(c) the speed of the wave

(d) both the frequency and the wavelength

(e) both the wavelength and the speed

6. A bat emits a sound at a frequency of 30.0 kHz as it approaches a wall. The bat detects beats such that the frequency of the echo is 900 Hz higher than the frequency the bat is emitting. What is the speed of the bat? Assume that the speed of sound in air is 340 m/s.

(a) 20.0 m/s

(b) 15.0 m/s

(c) 10.0 m/s

(d) 30.0 m/s

(e) 5.0 m/s

7. A converging lens is placed to the right of another converging lens, and an object is placed to the left of both of the converging lenses. Assuming these are the only lenses involved, and they both have the same focal length, where can the final image for this object be formed?

(a) To the left of both lenses

(b) In between the lenses

(c) To the right of both lenses

(d) Either (b) or (c) depending on the separation between the lenses.

(e) Either (a), (b), or (c) depending on the separation between the lenses.

8. A ray of sunlight is incident on a triangular glass prism. The ray is split into a rainbow which can be seen on a wall. Which color of light on the wall is furthest from the point on the wall where the original ray would have fallen if the prism had not been placed in its path? (You may assume that the refractive index for higher frequency light is greater than for lower frequency light, which is generally the case in glass.)

(a) red

(b) green

(c) violet

(d) it depends on the angle of incidence

(e) it depends on the angles of the base of the triangular prism

9. Monochromatic light passing through a tiny circular hole forms a diffraction pattern on a screen on the other side. There is a bright spot at the center, with several dimmer rings surrounding it on the screen. Which of the following would increase the radius of the central bright spot?

(a) Moving the screen closer to the hole

(b) Increasing the radius of the hole

(c) Increasing the wavelength of light

(e) Increasing the size of the screen

10. You observe light from an unknown source with intensity I and are asked to identify its polarization. You observe the light passing through a vertical polarizer and determine that the intensity of the transmitted light is $\frac{1}{2}I$. You conclude that:

(a) the light emitted by the source is linearly polarized with an axis of 45° from the vertical.

(b) the light emitted by the source is unpolarized

(c) the light emitted by the source is circularly polarized

(d) the polarization of the light emitted by the source cannot be determined based on your observation.

PART III (100 points): Short problems

To earn full credit on the following problems, you must exhibit the steps that lead to your final result. Problems 1, 5 and 6 are worth 10 points each; problem 2 is worth 20 points each, and problem 3 and 4 are worth 25 points each.

1. A raft is made of 12 logs lashed together. Each is 45cm in diameter and has a length of 6.1 m. How many people can the raft hold before they start getting their feet wet, assuming the average person has a mass of 68 kg? Do not neglect the weight of the logs. Assume the specific gravity of wood is 0.60.

2. During ascent, and especially during descent, volume changes of trapped air in the middle ear can cause ear discomfort until the middle-ear pressure and exterior pressure are equalized.

(a) If a rapid descent at a rate of 7.0 m/s or faster commonly causes ear discomfort, what is the maximum rate of increase in atmospheric pressure (that is, dP/dt) tolerable to most people? (Note: the 7.0 m/s descent rate is for an altitude low enough that the density and pressure of the air is not significantly different from their values at the surface.)

(b) In a 350-m-tall building, what will be the fastest possible descent time for an elevator travelling from the top to ground floor, assuming the elevator is properly designed to account for human physiology?

3. The A string of a violin is 32 cm long between fixed points with a fundamental frequency of 440 Hz and a mass per unit length of 7.2×10^{-4} kg/m.

(a) What are the wave speed and tension in the string?

(b) What is the length of the tube of a simple wind instrument (say, an organ pipe) closed at one end whose fundamental is also 440 Hz if the speed of sound is 343 m/s in air?

(c) What is the frequency of the first overtone of each instrument?

4. A child's eye has a near point of 15 cm.

(a) What is the maximum magnification the child can obtain using an 8.5-cm-focal length magnifier?

(b) What magnification can a normal adult eye (with a near point of 25 cm) obtain with the same lens?

(c) Does the adult see less or more detail than the child?

5. X-rays of wavelength 0.10 nm fall on a microcrystalline powder sample. The sample is located 12 cm from the photographic film. The crystal structure of the sample has an atomic spacing of 0.22 nm. Calculate the radii of the diffraction rings corresponding to first and second-order scattering.

6. Unpolarized light passes through six successive Polaroid sheets each of whose axis makes a 45° angle with the previous one. What is the intensity of the transmitted beam?