Name of School____________________________ **Team Number**____________________________

Team Member____________________________ **Team Member** ____________________________

Crave the Wave!

Your score will be based on your work (which you will show below) and not just the final answer.

1. (a) (10) Given the wavelength of the light from the laser pointer, the measured spacing between dots along the wall, and the distance from the CD or DVD to the wall, calculate the spacing between the grooves on the CD or DVD, in microns (to within about 10%).

(b) (4) Estimate the angular resolution of the human eye (when it sees by visible light), using the Rayleigh criterion for the minimum angular separation that can be resolved. Assume that the resolution is limited only by diffraction. You may give your answer in radians or degrees for full credit (even though arcseconds is best).

2. (20) A long tube contains air at a pressure 0.98 atm and a temperature of 295 K. The tube is open at one end, and closed at the other by a movable piston. A tuning fork near the open end vibrates with a fixed frequency. Resonance is produced when the piston is at distances of 18.0, 55.5 and 93.0 cm from the open end. These data show that a displacement antinode is slightly outside of the open end of the tube. How far outside is it?

3. Using a flashlight, you shine a beam of white unpolarized light on the surface of a perfectly planar sheet of clear ice that has formed atop a lake. The indices of refraction are 1.000 for air and 1.309 for this ice.

(a) (4) Let θ be the angle between your flashlight beam and the surface of the ice. What should θ be if you want the reflected light to be completely polarized?

(b) (4) As you hold your flashlight so that the incident beam maintains this angle, there is also a refracted beam in the ice. What is the angle between this refracted beam and the surface of the ice?

(c) (4) Now a friend comes up and holds a polarizing sheet of plastic in the path of the reflected beam, with this polarizer rotated so that it permits light to pass only when the direction of the electric field is 30° above the horizontal. If the intensity of the original beam incident on the ice is $1.0\ \mathrm{W/cm^2}$, what is the intensity of the beam after being reflected and passing through the polarizer?

(d) (4) What happened to the lost intensity? Be as specific as possible, based on how a plastic polarizer works.

4. This is about water waves. **Discuss; do not give mere yes or no answers.**

(a) (2) You are sitting beside a filled bathtub. You slap the water at one end, and a wave goes to the other end. Do the water molecules that you hit with your hand travel across the bathtub?

(b) (2) You are in the ocean by the seashore. When a water wave goes by you, it crashes against the shore. Do the water molecules in this wave crash to the shore?

(c) (2) If your answers to (a) and (b) differ, explain why.

(d) (2) When you drop a pebble into the water in a pond, does the wave it produces retain its waveform as it propagates?

(e) (2) When you speak to someone across the room, does the sound wave you produce retain its waveform when it gets to the other side of the room?

(f) (2) Why is it that sound waves in water or air are a good medium for signaling, but water waves are not?

5. This is about stringed instruments. **Discuss; don't give mere yes or no answers.**

(a) (2) When you pluck a violin or guitar string, in which direction(s) does the string vibrate?

(b) (2) Does the material where the string was plucked travel with the wave produced by the plucking?

(c) (2) Qualitatively, how does the frequency of the wave depend on the tension T of the string? Give the units of tension.

(d) (2) Qualitatively, how does the frequency of the wave depend on the linear mass density μ of the string? Give the units of linear mass density.

(e) (2) Use dimensional analysis to find how the velocity of the wave depends on T and μ.

(f) (2) How does the fundamental frequency of the string depend on the length L of the string? Give the units of L.

6. Suppose that we adopt the simplistic criterion that a photon might cause harm to our bodies if it has an energy greater than that required for a chemical reaction: roughly $1 \text{ eV} = 1.60 \times 10^{-19}$ joule. For each kind of radiation below, make a rough estimate of the photon energy, and determine to what extent it might be harmful according to this criterion. (If you need them, the speed of light is 3.00×10^{8} m/s and Planck's constant is 6.63×10^{-34} J s.)

(a) (2) infrared

(b) (2) X-ray

(c) (2) ultraviolet

(d) (2) radio

(e) (2) visible

(f) (2) microwave

(g) (2) gamma ray

7. (a) (4) A star is observed by an astronomer and found to have a redshift of 0.08. How fast is it moving away from us? (The speed of light is 3.00×10^{8} m/s .)

(b) (4) One can do astronomy from the Earth's surface using visible light and radio waves, but observations with infrared radiation are done from satellites outside the Earth's atmosphere. What is responsible for the absorption of infrared radiation in the atmosphere? (Be as specific as possible.)

(c) (4) What is the most important greenhouse-effect gas in the atmosphere, and what are some additional greenhouse gases?

(d) (4) Why is there a greenhouse effect in the earth's atmosphere?

8. (20) A jet plane flies at constant altitude h above ground level. An observer on the ground hears a sonic boom at time t after the plane passes directly overhead. Show that if the speed of sound v is the same at all altitudes, the speed of the plane is given by

$$v_p = \frac{hv}{\sqrt{h^2 \pm v^2 t^2}}$$

where you will determine the appropriate sign in doing this problem. Please show each step clearly. **You are strongly encouraged to make a clearly labeled drawing, and to use it in your work.**