Exam 2 solutions

**Problem 1:**
A body attached to a hanging spring is oscillating in simple harmonic motion.

The maximum amplitude depends on the total energy (KE + PE). The PE is obviously the same for both cases since the displacement from equilibrium is the same. The KE is also the same since it is proportional to $v^2$ and the velocities only differ by a sign. Therefore the maximum amplitude is the same for both cases.

**Problem 2:**
Two strings of identical material and radius are stretched with the same tension with their ends fixed, but one string is 8.0 mm longer than the other...

The beat frequency is the $f_1 - f_2$ where $f_1, f_2$ are the fundamental frequencies of the two strings. We are given $f_2$ (fundamental of the longer string) so we need to find $f_1$. We can do this as follows:
First, find the wavelength ($\lambda_2 = \frac{v_{\text{sound}}}{f_2}$). This allows us to find the length of the string $L_2$, since fundamental wavelength is 2x the length of the string. Then $L_2 - 0.008m = L_1$, and half of that is $\lambda_1$.
Finally $f_1 = \frac{v_{\text{sound}}}{\lambda_1}$.
Now you can find $f_{\text{beat}} = f_1 - f_2 = 11$ Hz.

**Problem 3:**
Consider a mass-spring system oscillating in simple harmonic motion. If we double the amplitude of the oscillation, by what factor does the maximum acceleration change?

acceleration = $A\omega^2$ → acceleration doubles when amplitude doubles.

**Problem 4**
A torsional pendulum executes simple harmonic motion by rotating about its axis.

$T = 2\pi \sqrt{\kappa/I}$ where $I$ is the moment of inertia. Since the torsional spring constant does not change, we just need to find out how $I$ changes.

$I = \frac{1}{2}MR^2$. If we double the size of the disk, and double the height, then the volume changes by a factor of 8. Since the density remains the same, $M_{\text{new}} = 8^*M_{\text{old}}$. So $I_{\text{new}} = 32*I_{\text{old}}$

$T_{\text{new}} = \sqrt{32} T_{\text{old}} = 4\sqrt{2} T_{\text{old}}.$

**Problem 5**
A sound wave resonates in a pipe with one closed end and one open end. The note heard is the lowest possible resonant frequency for this length of pipe. If the pipe is length $L$, what is the wavelength of the note?

$4L$ (see textbook)

**Problem 6:**
A bicycle wheel is supported by two strings parallel to the y-axis and spins on its axis....

Angular momentum $L$ points in the $-x$ direction. Torque = $r \times F$ points in the $+z$ direction. The wheel precesses out of the page, in the $+z$ direction.
Problem 7
Water flows through a pipe of circular cross section and radius of 1 meter. The circular pipe is joined to another pipe of square cross section, with each side measuring 1 meter. As the water flows through the square pipe its velocity is approximately

\[ \text{Area} \times \text{velocity has to stay the same. Area is reduced by a factor of } \pi. \]
Therefore the velocity has to increase by the same factor (approximately 3).

Problem 8
As you stand by the side of the road, a car approaches you at a constant speed, sounding its horn, and you hear a frequency of 80 Hz. After the car goes by, you hear a frequency of 60 Hz. What is the speed of the car? The speed of sound in the air is 344 m/s?

You are not given the frequency of the horn, but you do not need it. You can set up 2 equations, one for when the car is coming towards you, and another for when the car is moving away from you.

\[ 80 \text{ Hz} = \left[ \frac{v_{\text{sound}}}{v_{\text{sound}} - v_{\text{car}}} \right] \times f_{\text{horn}} \]
\[ 60 \text{ Hz} = \left[ \frac{v_{\text{sound}}}{v_{\text{sound}} + v_{\text{car}}} \right] \times f_{\text{horn}} \]

You can divide these two equations and eliminate \( f_{\text{horn}} \)

\[ \frac{4}{3} = \left( \frac{v_{\text{sound}} + v_{\text{car}}}{v_{\text{sound}} - v_{\text{car}}} \right) \]

Solve this for \( v_{\text{car}} \).

\[ v_{\text{car}} = \frac{v_{\text{sound}}}{7} \]

Problem 9
Two identical loudspeakers that are 5.00 m apart and face toward each other are driven in phase by the same oscillator at a frequency of 875 Hz....

The path length difference must equal \( \frac{1}{2} \lambda \) for there to be destructive interference.
IF you walk a distance \( d \) towards one speaker the path length difference is 2d

\[ 2d = \frac{1}{2} \lambda \]
\[ 4d = \lambda \]

We know \( \lambda = \frac{344 \text{ m/s}}{875 \text{ Hz}} = 0.393 \text{ m} \). So \( d = 0.0983 \text{ m} \)

Problem 10
You are driving a convertible (a car with a fabric roof) with the roof up, on the New Jersey Turnpike at 65 miles per hour. You notice that the fabric of the roof

Bows outward since pressure is lower for moving fluid (outside) than fluid at rest (inside).

Problem 11
What is the radius of a sphere that has a density of 5000 kg/m3 and a mass of 6.00 kg? Pick the closest answer.

Volume of sphere = \( \left( \frac{4}{3} \right) \pi R^3 \).
Mass = density * Volume.
6.00 kg = 5000 kg/m^3 * (4/3) \pi R^3.

Solve. R = 0.0659 m or 6.59 cm

**Problem 12**
A standing wave is produced by the interference of two sinusoidal waves traveling in opposite
directions, each of frequency 100 Hz. The distance from the second node to the fifth node is 60 cm.
The wavelength of the sinusoidal waves is

40 cm (draw out the wave).

**Problem 13**
A piano wire, clamped at both ends, has a length of 81 cm (0.81 m) and a mass of 2.0 grams...

Fundamental wave
wavelength is 2x length of the wire.
So f = sqrt(T/(m/L)) / 2L

**Problem 14:**
One violin can play a note at 70 dB...

70 db = 10^{-5} W/m^2 (done in the text of the problem). So three violins have total intensity 3*10^{-5} W/m^2. Convert to db. Total = 75 db.

**Problem 15:**
In recitation you measured the weight of a steel cube using a spring-scale as it was immersed into a beaker of water. Your scale measures the weight of the cube to be 1.5 N when the cube is in air, and 1.0 N when the steel cube in fully immersed in water. What will the scale measure if the beaker was filled with alcohol? The density of alcohol is 800 kg/m3. The density of water is 1000 kg/m3.

Buoyancy = weight of displaced liquid. The scale will measure 1.5 N – Buoyancy force.

We are not given the volume of the cube, but we know the weight of an equal volume of water is 1.5N – 1.0N = 0.5N.

So weight of an equal volume of alcohol is 0.5N *(800/1000) = 0.4 N.

So 1.5N – 0.4 N = 1.1N is what the scale will measure.