Name:_____ ID: _____

Physics 202

Final Exam

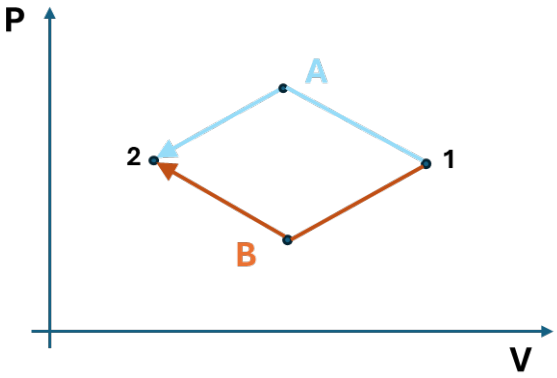
3/17/2026

Collaboration is not allowed. Allowed on your desk are: ten 8.5 x 11 inch doubled-sided sheets of notes that are bound together, graphing scientific calculator (no other computerized devices are allowed), a page of scratch paper, writing utensils, and the exam. You will have 110 minutes to complete this exam.

For questions 1 through 7 **fill in the square** next to all correct answers. A given problem may have more than one correct answer. Each correctly bubbled answer will receive two points. There are **8** correct answers in this section and only the first **8** filled in answers will be graded. There is no partial credit.

For questions **1 - 4**, consider a gas that can go through two paths, **A** or **B**, as shown in the PV diagram. Both start at the same point 1 and end at the same point 2. They have different intermediate points.

1. How does the change in temperature compare between path **A** and **B**?
   - □ (a) $\Delta T_A > \Delta T_B$
   - □ (b) $\Delta T_A < \Delta T_B$
   - ☑ (c) $\Delta T_A = \Delta T_B$
   - □ (d) not enough information



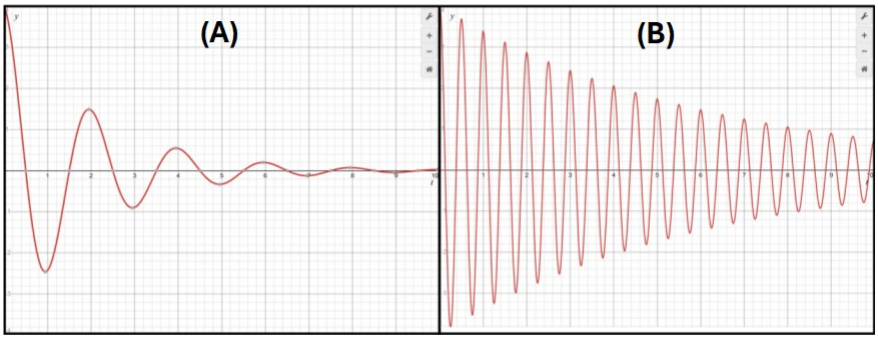
2. What is the sign of the work on the gas in path **A**?
   - ☑ (a) positive
   - □ (b) negative
   - □ (c) zero
   - □ (d) not enough information

3. Which path indicates a larger magnitude of work?
   - ☑ (a) **A**
   - □ (b) **B**
   - □ (c) **A** and **B** do equal work
   - □ (d) not enough information

4. Which path indicates a greater magnitude of net heat?
   - ☑ (a) $Q_A > Q_B$
   - □ (b) $Q_A < Q_B$
   - □ (c) $Q_A = Q_B$
   - □ (d) not enough information

5. Imagine in front of you, two containers. One is labeled "**5 mol of Argon**" and the other is labeled "**1 mol of Xenon**." Assume the gases are at the same temperature. You look up that Argon has an average mass per particle, $\mathbf{6.64 \times 10^{-26}}$ **kg**, and Xenon has an average mass per particle, $\mathbf{2.18 \times 10^{-22}}$ **kg**. Which gas has the higher average speed per particle (v_{rms})?
   - ☑ (a) Argon
   - □ (b) Xenon
   - □ (c) they have the same average speed
   - □ (d) not enough information

6. Pictured here are graphs representing the displacement of two different masses, each attached to an identical spring. The initial displacement of each oscillator is **+6 cm** and they are each plotted from **t = 0 s** to **t = 10 s**. Which of the following statements are true?



☑ (a) $\mathbf{m_A > m_B}$
□ (b) $\mathbf{m_A < m_B}$
□ (c) The time constant, tau (τ), for (A) is **larger** than it is in (B)
☑ (d) The time constant, tau (τ), for (A) is **smaller** than it is in (B)
□ (e) The time constants (τ) are **identical** for both (A) and (B)
□ (f) The gravitational acceleration, **g**, in (B) must be larger than in (A)

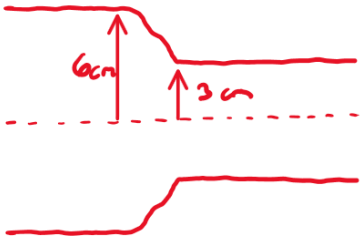
7. Consider **3 kg** cubes of each material in the table, which are heated from room temperature. Each material gets the same amount of thermal energy. Which material will increase in temperature the most?

Material	**Density**	**Melting Point**	**Specific Heat (c)**	**Conductivity** (k)
Copper	8.96 g/cc	1085 °C	385 J/kg°C	401 W/m°C
Magnesium	1.74 g/cc	650 °C	1020 J/kg°C	156 W/m°C
Aluminum	2.70 g/cc	660 °C	897 J/kg°C	237 W/m°C
Titanium	4.50 g/cc	1650 °C	520 J/kg°C	17 W/m°C
PLA	1.17 g/cc	130 °C	1800 J/kg°C	0.13 W/m°C

☑ (a) Copper
□ (b) Magnesium
□ (c) Aluminum
□ (d) Titanium
□ (e) PLA

8. (8 points) A fire breaks out on the fourth floor of Weniger Hall. Each floor is **4 meters** tall. The Corvallis Fire Department quickly arrives. The fire truck hose has a diameter of **6 cm** and can reach, via the fire truck ladder, to the exact height of the fire. A pump in the truck can push water into the hose with a velocity of **13 m/s** and an initial pressure of **1.39x10^6 N/m^2**. The hose narrows near the top, decreasing the diameter in half.

(a) What is the velocity of the water in the narrowed region of the hose?
(b) What is the pressure in the narrowed region of the hose, at the top of the fourth floor?



(a) $A_1 v_1 = A_2 v_2$

$\pi r_1^2 v_1 = \pi r_2^2 v_2$] ↑ ×4

$(\downarrow \times \frac{1}{2})^2$

$\Rightarrow v_{3cm} = 52\ m/s$

(b) $P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1^{\nearrow 0} = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$

$(4v_1)^2$ $\quad$ 16m

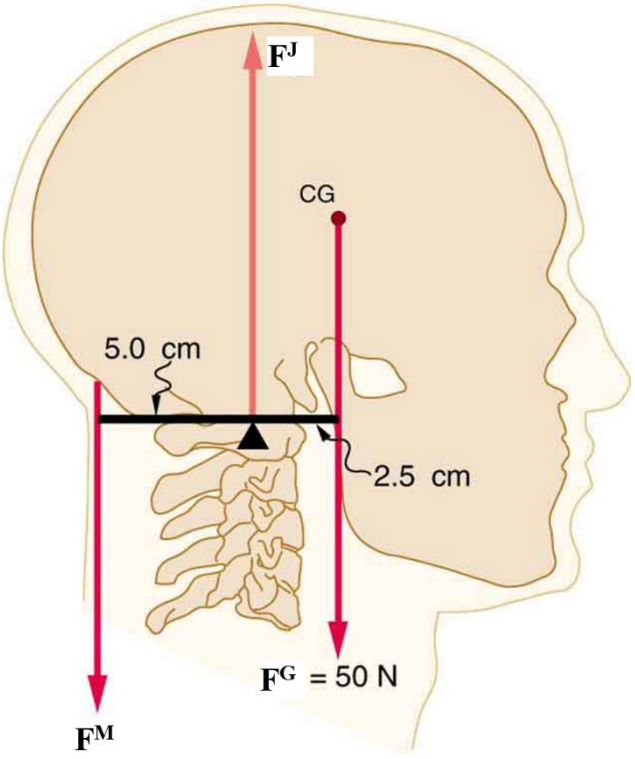
$P_2 = P_1 + \frac{1}{2}\rho v_1^2 - \frac{1}{2}\rho v_2^2 - \rho g y_2$

$= 1.53\times10^6\ Pa + \frac{1}{2}\left(1000\frac{kg}{m^3}\right)\left[(13\ m/s)^2 - (52\ m/s)^2\right]$

$- \left(1000\frac{kg}{m^3}\right)(9.8\ m/s^2)(16m)$

$= 105{,}700\ Pa$

9. (8 points) When you are at rest muscles in your head and neck must prevent your head from falling forward, like it does when you fall asleep in class. This is because the force of gravity ($\mathbf{F}^G$) doesn't align vertically with the main support on your spine, $\mathbf{F}^J$, called the atlanto-occipital joint. The muscles at the back of the neck, $\mathbf{F}^M$, must exert a force to keep the head erect.



(a) Calculate the force, $\mathbf{F}^M$.
(b) Determine the force $\mathbf{F}^J$ provided by the atlanto-occipital joint?

(a) $\Sigma T = I\alpha^{0}$

$+|T^M| + |T^J|^{0} - |T^G| = 0$

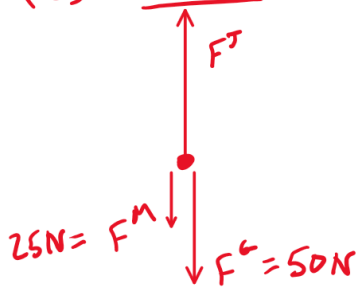
$F^M(r_m \sin\theta_m) - F^J(r_J \sin\theta_J) = 0$

$0.05m \qquad 0.025m$

$F^M = 50N \frac{0.025m}{0.05m}$

$\boxed{F^M = 25\,N}$

(b) FBD



$\Sigma F = ma^{0}$

$F_y^J + F_y^M + F_y^G = 0$

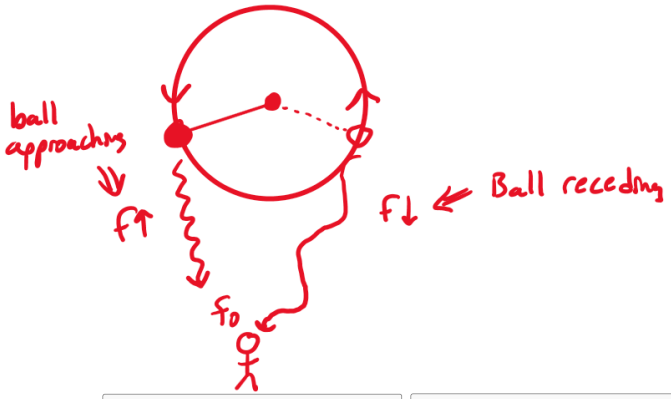
$\boxed{F^J = 75\,N}$

10. (6 points) Your faithful physics professor has created a somewhat annoying demonstration for class. He has tied a ball which emits a constant **440 Hz** tone to a string. He holds onto the string a distance**, L = 183 cm**, from the ball. As you sit in the auditorium and watch, he spins the ball in a circle above his head. He spins the ball faster and faster with a constant angular acceleration until the highest frequency heard by you, in the audience, is **473 Hz**. After it reaches this speed, the ball maintains uniform circular motion. If the constant acceleration phase lasted for **8.4 seconds** as the ball spun from rest up to this speed, what was the magnitude of the angular acceleration?

ball approaching ⇒ f↑

⇒ denominator smaller

⇒ $v - v_s$



$$F_o = f_s\left(\frac{v + v_o}{v - v_s}\right)$$

$$473 = 440\left(\frac{343\ m/s}{343\ m/s - v_s}\right)$$

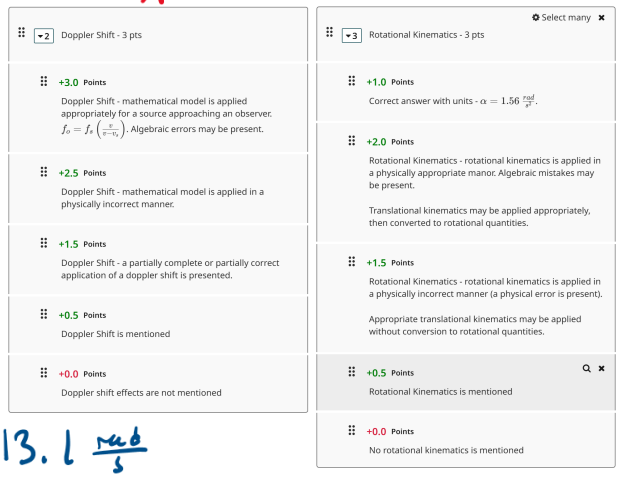
$$v_s = 23.9\ m/s$$

now to rotational land

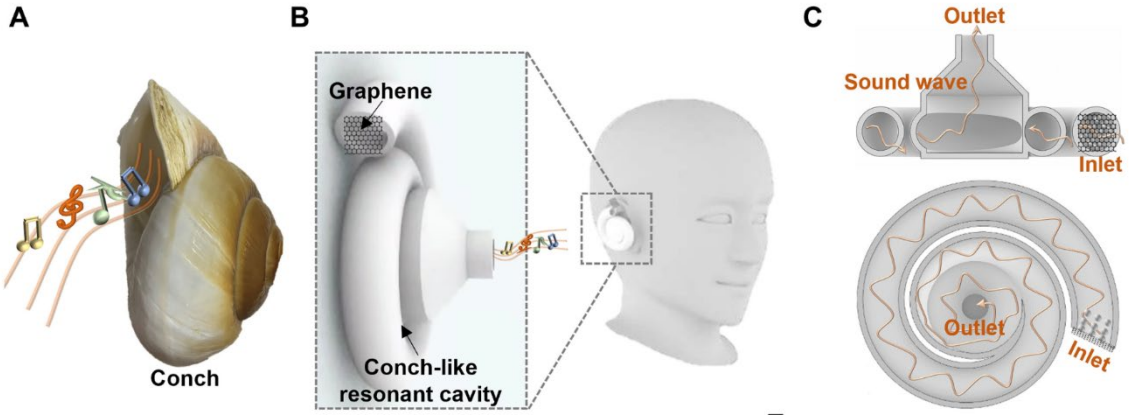
$$\omega = \frac{v}{r} = \frac{23.9\ m/s}{1.83\ m} = 13.1\ \frac{rad}{s}$$

$$\omega_f = \omega_i + \alpha\,\Delta t$$

$$\alpha = \frac{\omega_f - \omega_i}{\Delta t} = 1.56\ \frac{rad}{s^2}$$



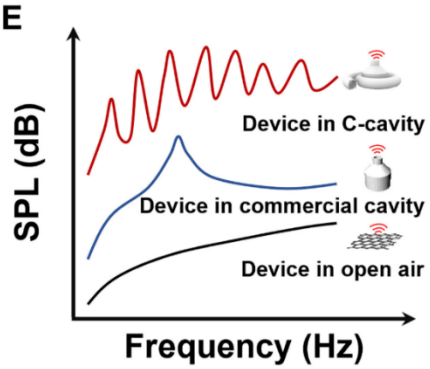
11. (8 points) In a 2025 edition of the journal Science Advances an article with the title "*Frequency-tunable sound amplification in a conch-like cavity with graphene thermoacoustic resonance*". The paper introduces a novel amplification chamber [Figure C] based off the natural conch shell [Figure A] to aid human hearing [Figure B].



(a) What is the purpose of the spiral C-cavity? It looks like it impedes the ear. Why could it be better for hearing than just an unimpeded ear?

(b) If the average radius of the spiral tube chamber is **16 mm** and it makes three full rotations [Figure C], what is the lowest frequency you would expect to amplify well? Assume the tube is open on both ends.

(c) The research team recorded sound in open air, in a normal commercial cavity, and in their spiral C-cavity. The recorded sound in dB vs frequency is shown in figure E for all three. Overall, it's clear from the figure that the C-cavity picks up more sound. Why does the spiral C-cavity oscillate in its sensitivity of sound vs frequency?



(a) The C-cavity is a **resonant chamber**. Similar to a speaker box, it provides space for the sound waves to bounce around and add constructively, increasing the amplitude of the waves.

(b) Symmetric System: $\lambda_1 = 2L$, $f_1 = \frac{v}{\lambda_1}$

$L = 3C$, where $C = 2\pi r$

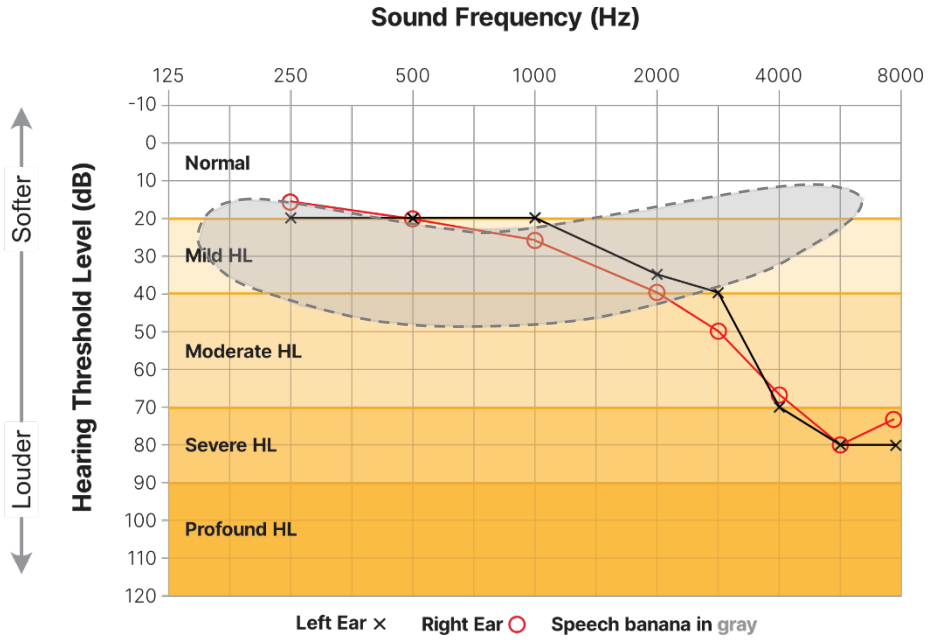
So, $f_1 = \frac{v}{2(3)(2\pi r)} = 569\ Hz$

(c) The C-cavity is specifically a **standing wave resonator**, like the straight sound in a tube systems we studied. Standing wave resonance systems **only have certain frequencies that match the boundary conditions of the system and produce a resonating standing wave**. These frequences have an increase in amplitude.

Rubric:

(a) 2 points total	(b) 4 points total 1 pt - symmetric standing wave equation (either wavelength or frequency) 1 pt - finding L 1.5 pt - application 0.5 pt - correct answer	(c) 2 points total

12. (9 points) An audiogram measures what sound intensity level is required to hear a single frequency tone for someone who has hearing loss. The figure shows the sensitivity measured in dB vs frequency and shows various levels of hearing loss (HL). Consider the left ear only.



(a) What minimum intensity, in **W/m²**, does the person require to hear at **3000 Hz**?
(b) What is the power coming from the source in part (a)? Assume the ear is **1 cm** away from the sound source - you usually use headphones during the test.
(c) How much more sensitive is the hearing at **250 Hz** compared to **8000 Hz**? Show this by finding the ratio of the threshold intensities, $\mathbf{I_{250}/I_{8000}}$.
(d) Extra credit: what is a speech banana, outlined with a dashed line, in the figure? Seriously, we don't know. Funny answers encouraged.

(a) dB @ 3000Hz = 40 dB

$\beta = 10\,dB \log_{10}\left(\frac{I}{I_0}\right) \Rightarrow \frac{40\,dB}{10\,dB} = \log_{10}\left(\frac{I}{I_0}\right)$

$10^4 = \frac{I}{I_0} \Rightarrow I_{3000} = I_0\,10^4 = 10^{-8}\,\frac{W}{m^2}$

(b) $I = \frac{P}{A}$, $A = 4\pi r^2$, so $P_{3000} = I_{3000}\,4\pi r^2 = 1.26 \times 10^{-11}\,J/s$

(c) $\Delta\beta = \beta_{250} - \beta_{8000} = 10\,dB \log_{10}\left(\frac{I_{250}}{I_0}\right) - 10\,dB \log_{10}\left(\frac{I_{8000}}{I_0}\right)$

$20dB - 80dB = 10dB \log_{10}\left(\frac{I_{250}}{I_{8000}}\right)$

$\frac{I_{250}}{I_{8000}} = 10^{-6}$

(d) Actual: region of normal speech loudness & frequencies
fun: the range of sounds a bannana screams while you eat it.

Rubric:
Part (a) - 3 points total
1 pt - decibel equation
1.5 pts - application
0.5 pts - correct answer

Part (b) - 3 points total
1 pt - intensity equation
1.5 pts - application
0.5 pt - correct answer

Part (c) - 3 points total
1 pt - delta_dB equation
1.5 pt - application
0.5 pt - correct answer

Part (d) - 0.5 point total