Name: Final Exam Solutions

ID:

Physics 202

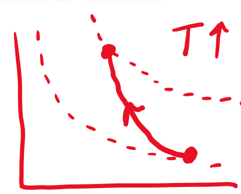
Final Exam

3/19/2024

Collaboration is not allowed. Allowed on your desk are: ten 8.5 x 11 inch doubled sided sheets of notes that are bound together, non-communicating graphing scientific calculator, a page of scratch paper, writing utensils, and the exam. You will have 110 minutes to complete this exam.

For questions 1 through 6, **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 **10** correct answers in this section and only the first **10** filled in answers will be graded. There is no partial credit.

1. A gas, confined to an insulated cylinder, is compressed adiabatically to half its volume. Which of the following statements are true regarding this situation? $\to Q=0$

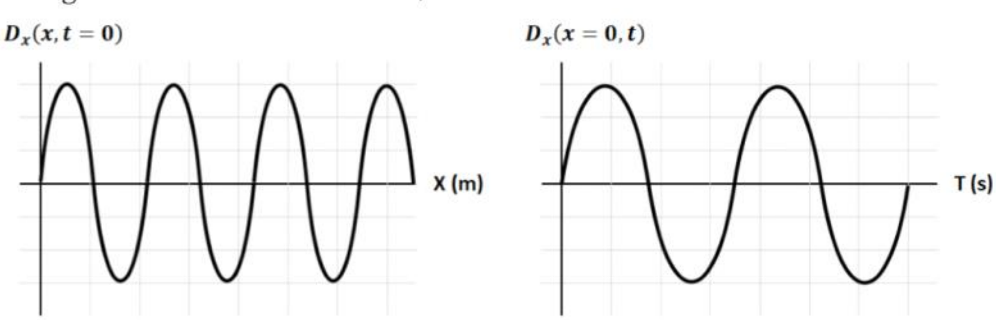


- □ (a) The entropy of the gas increases.
- □ (b) The entropy of the gas decreases.
- □ (c) The entropy of the gas remains constant.
- □ (d) The average kinetic energy of the molecules in the gas increases.
- □ (e) The average kinetic energy of the molecules in the gas decreases.
- □ (f) The average kinetic energy of the molecules in the gas remains constant.

2. The buoyancy force is equal to ______________.

- □ (a) the mass of the displaced fluid.
- □ (b) the weight of the displaced fluid.
- □ (c) the volume of the displaced fluid.
- □ (d) the pressure of the displaced fluid.
- □ (e) the mass times the acceleration

3. The snapshot and history graph of a travelling wave are pictured in the graphs. Which of the following statements about the wave is/are true?



- □ (a) The wavelength is 3.50 seconds
- □ (b) The period is 3.50 seconds
- □ (c) The period is 0.464 seconds
- □ (d) The period is 2.15 meters
- □ (e) The wavenumber is 2.15 meters
- □ (f) The wavenumber is 2.92 meters^{-1}
- □ (g) The wavenumber is 0.286 meters^{-1}
- □ (h) The wave speed is 0.615 m/s
- □ (i) The wave speed is 1.63 m/s

$\lambda = \frac{7m}{3.25 \text{ cycles}} = 2.15m$

$T = \frac{7s}{2 \text{ cycles}} = 3.5s$

$k = \frac{2\pi}{\lambda} = 2.92 \frac{1}{m}$

$v = f\lambda = \frac{1}{T}\lambda = 0.615 \, m/s$

4. A piece of rope is made from 3 braided strings. If you unravel the braids, and tie the resulting 3 strings together to create a string 3 times as long as the previous rope, by what factor would you have to multiply the rope's wave speed to get the long string's wave speed. Assume you have the same tension and total amount of material.

- ☐ (a) 0.333
- ☐ (b) 0.577
- ☑ (c) 1
- ☑ (d) 1.73
- ☐ (e) 3
- ☐ (f) 6
- ☐ (g) 9

m = same

L = 3 times bigger

$$\underbrace{v}_{\uparrow \times \sqrt{3}} = \sqrt{\frac{F^T}{\mu}} = \sqrt{\frac{F^T}{m/L \uparrow \times 3}}$$

5. Complete the following statement: The absolute temperature of an ideal gas is directly proportional to

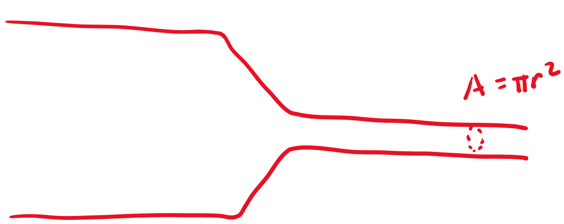
- ☐ (a) the number of molecules in the sample.
- ☐ (b) the average momentum of a molecule of the gas.
- ☑ (c) the average translational kinetic energy of the gas molecules.
- ☐ (d) the amount of heat required to raise the temperature of the gas by 1 C°.
- ☐ (e) the total potential energy stored in the gas.

$PV = nRT$

$\overline{KE} = \frac{3}{2} k_B T$

6. Water is flowing through a horizontal pipe of diameter ***d*** when is enters a region where the diameter is reduced to a third of the original diameter. Which of the following statements are true regarding this situation.

- ☐ (a) The velocity of the water will increase by a factor of 3.
- ☐ (b) The velocity of the water will increase by a factor of 6.
- ☑ (c) The velocity of the water will increase by a factor of 9.
- ☐ (d) The velocity of the water will decrease by a factor of 3.
- ☐ (e) The velocity of the water will stay the same because the pipe is horizontal.
- ☑ (f) The pressure in the water will decrease.
- ☐ (g) The pressure in the water will increase.
- ☐ (h) The pressure in the water will stay the same because the pipe is horizontal.



$$A_1 v_1 = \underbrace{A_2}_{\downarrow \times \frac{1}{9}} \underbrace{v_2}_{\uparrow \times 9}$$

$$P_1 + \rho g y_1 + \frac{1}{2}\rho v_1^2 = \underbrace{P_2}_{\downarrow} + \underbrace{\rho g y_2}_{\text{same}} + \underbrace{\frac{1}{2}\rho v_2^2}_{\uparrow}$$

7. (6 points) Sitting at the end of an ocean dock, you see a wave pass by every **12.0 s**. It then takes the wave **9.00 s** to reach the shore after passing you. If the dock is **55.0 m** long, what is the wavelength of the ocean waves?

$T = 12\,s$

$\Delta x = 55\,m$
$\Delta t = 9\,s$ $\Rightarrow v = \frac{55\,m}{9\,s} = 6.11\,m/s$

$v = \frac{1}{T}\lambda \Rightarrow \lambda = vT = \boxed{73.3\,m}$

8. (4 points) Explain the physics behind how a guitar makes sound. Use the following three phrases in your explanation: **tension, standing wave resonance, length of string**.

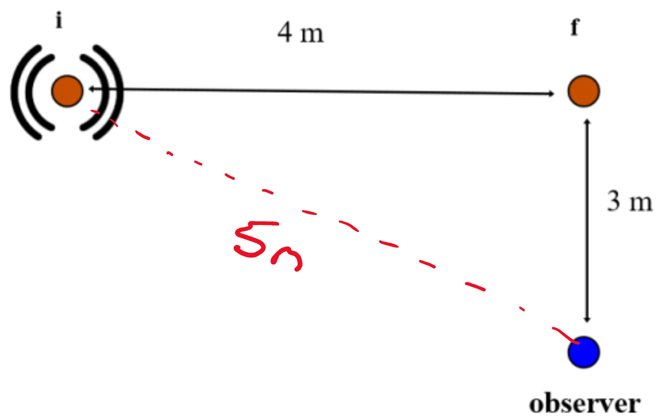
guitar strings are fixed on either end. When plucked, the strings oscillate with standing wave resonance. Two travelling waves in opposite directions create a standing wave. The frequency of the wave is determined by the length, tension, and mass of the string. Usually, the string will oscillate in its fundamental, m=1, mode.

$$F = \frac{v}{\lambda} = \frac{\sqrt{F^T/\mu}}{\frac{2L}{m}} = \frac{\text{mode}}{2L}\sqrt{\frac{F^T}{\frac{\text{mass}}{L}}} = \frac{\text{mode}}{2}\sqrt{\frac{F^T}{\text{mass} \times L}}$$

9. (8 points) An unidentified flying object (UFO) is producing a very loud single frequency tone at constant power. Its initial position relative to the stationary observer is **<-4, 3> m**. At this location, the decibel level at the observer is **116 dB**. The object then moves at a constant speed to a final location **<0, 3> m** where the UFO stops moving again.

(a) During this motion, did the frequency the observer hear increase, decrease, or stay the same? Explain.

(b) When the unidentified object is at the final location, what is the decibel level heard at the observer's location?



a) increase,

source is getting closer to observer

$$f_o = f_s \underbrace{\left(\frac{v + v_o}{v}\right)}_{>1}$$

(b) $I_i = \frac{P}{A_i}$, $I_f = \frac{P}{A_f}$

$$\frac{I_f}{I_i} = \frac{P/A_f}{P/A_i} = \frac{A_i}{A_f} = \frac{\cancel{4\pi} r_i^2}{\cancel{4\pi} r_f^2} = \frac{(5m)^2}{(3m)^2} = \frac{25}{9}$$

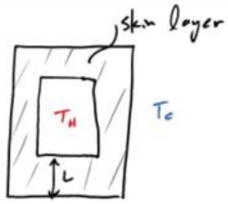
$$\Delta\beta = \beta_f - \beta_i = 10\,dB\left[\log_{10}\left(\frac{I_f}{I_i}\right)\right]$$

$$\beta_f - 116\,dB = 10\,dB\left[\log_{10}\left(\frac{25}{9}\right)\right]$$

$$\beta_f = 116\,dB + 10\,dB\,(0.444)$$

$$\beta_f = 120.4\,dB$$ (that's LOUD!)

10. (8 points) How many donuts do you need to eat each day to maintain a constant temperature? Model the body with a **4.0 cm** thick layer of skin and fat tissue that has a total thermal conductivity of **0.2 W/m·K**. Assume a surface area of **1.5 m²** and a temperature difference of **4 ºC** is maintained between the outside and inside of your skin. Finally, assume that a jelly donut contains **540,000 Calories (4.19 J/Cal)** and your body is **25% efficient** at converting that energy into thermal energy. Disregard radiation effects or insulative clothing.



Conduction $\quad \dfrac{Q}{\Delta t} = \dfrac{kA\Delta T}{L}$

w/ min Jelly donuts all Energy is converted to Heat + no work is done. The potential Energy gained by the donut is converted into heat.

Energy from donut $\quad E_{Heat} = e\,X\,E_{donut} = Q$, where e = effeciency + X = # of donuts

Conversion to S.I. $\quad E_{donut} = 540{,}000\ \text{cal} \left| \dfrac{4.19\ \text{J}}{1\ \text{cal}} \right. = 2.262 \times 10^{6}\ \text{J}$

So, $\quad \dfrac{e X E_{donut}}{\Delta t} = \dfrac{kA\Delta T}{L} \Rightarrow X = \dfrac{kA\overset{\text{temp}}{\Delta T}\,\overset{\text{time}}{\Delta t}}{e E_{donut} L} = \boxed{4.58\ \text{donuts}}$

11. (14 points) A **2.0 kg** block on a horizontal, frictionless surface is attached to a spring whose force constant is **590 N/m**. The block is pulled from its equilibrium position at **x = 0 m** to a displacement position, **x = -0.120 m**, then released from rest at **t = 0 s**. As a result, the block oscillates with simple harmonic motion along a horizontal x-axis.

(a) What is the frequency of the resulting motion?
(b) Write an equation for the position of the block as a function of time (only).
(c) Write an equation for the velocity of the block as a function of time (only).
(d) What is the maximum acceleration the block experiences during its motion and at what position(s) does this occur?
(e) You move the same oscillator to a surface with friction. With the same initial conditions, it takes **22 oscillations** for the amplitude to decay to **1/2** of the original value. What is the time constant, τ, for this oscillation?

(a) $\omega = \sqrt{k/m} = \sqrt{\frac{590\,N/m}{2\,kg}} = 17.18\ rad/sec$

$\boxed{f = \frac{\omega}{2\pi} = 2.73\ Hz}$

(b) Starts at $-X_{max}$ @ $t=0$

$x(t) = -X_{max}\cos(\omega t)$

$x(t) = (-0.12m)\cos(17.2\,\frac{rad}{s}\,t)$

(c) $v(t) = +\omega X_{max}\sin(\omega t)$

$v(t) = +2.06\,\frac{m}{s}\sin(17.2\,\frac{rad}{s}\,t)$

(d) $a_{max} = \omega^2 X_{max} = 35.5\ m/s^2$

Maximum $\vec{a}$ occurs when ΣF is maximum, which for a mass-spring

$\vec{F} = -k\vec{x} \Rightarrow |F_{max}|$ occurs at X_{max} and $-X_{max}$

(e) $T = \frac{1}{f} = 0.366\ s$

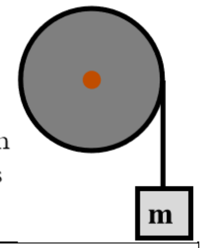
$Amp(t) = X_{max}e^{-t/\tau}$

$\Rightarrow \frac{\frac{1}{2}X_{max}}{X_{max}} = e^{-\frac{(22)(0.366)}{\tau}}$

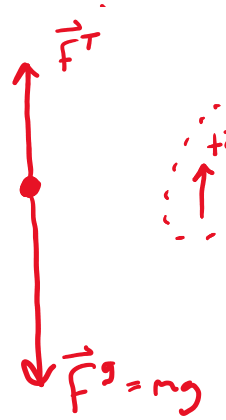
$\Rightarrow \ln(\frac{1}{2}) = -\frac{8.06}{\tau}$

$\Rightarrow \boxed{\tau = 11.6\ s}$

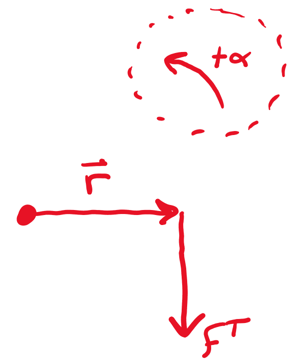
12. (12 points) A mass of **5.1 kg** is hung from a massless string which is wrapped around a disc which pivots about its center. The moment of inertia of the disc is **0.78 kg m²** and the radius of the disc is **0.26 m**. The gravitational acceleration at this location is **g = 9.78 m/s²**. The system is released from rest and the mass begins to fall.



(a) Draw a Free Body Diagram (FBD) for the mass.



(b) Draw an extended Free Body Diagram (eFBD) for the disc.



(c) Through how many radians does the disc travel in the first **8.4 seconds**?

force analysis

FBD ⇒ $\Sigma F_y = ma_y$

$+|F^T| - |F^g| = ma_y$

$F^T - mg = ma$

$F^T = mg + ma$

$a = \alpha r$

$F^T = mg + mr\alpha$

torque analysis

eFBD ⇒ $\Sigma \tau = I\alpha$

$-r F^T \sin(90) = I\alpha$

$-r F^T = I\alpha$

finding α

$-r(mg + mr\alpha) = I\alpha$

$-rmg - r^2 m\alpha = I\alpha$

$-rmg = I\alpha + r^2 m\alpha$

$-rmg = \alpha(I + r^2 m)$

$\alpha = \dfrac{-rmg}{I + r^2 m}$

$\alpha = -11.5 \frac{rad}{s^2}$

Kinematics

$\Delta\theta = \cancel{\omega_i}^{0}\Delta t + \frac{1}{2}\alpha\Delta t^2$

$\Delta\theta = \frac{1}{2}(11.5 \frac{rad}{s^2})(8.4 s)^2$

$\boxed{\Delta\theta = 407 \text{ rad}}$