

Alternate Midterm Examination Physics 100

Feb. 20, 2014

Name/Student #:

Instructions: Formulas at the back (you can rip that sheet off). Questions are on both sides. Calculator permitted. Put your name and student number at the top of the question sheet and complete all questions on the question sheet. Point values are shown with the questions. Include the correct units. Total exam is worth 50 points. The Ch. 11 question is on page 3.

1. 0.10 mol of a monatomic gas follows the process shown in Fig. 1. Once you have converted units $p_1 = p_2 = 4.05 \times 10^5$ Pa, $p_3 = 2.02 \times 10^5$ Pa, $V_1 = 8.0 \times 10^{-4}$ m³, $V_2 = V_3 = 1.6 \times 10^{-3}$ m³.

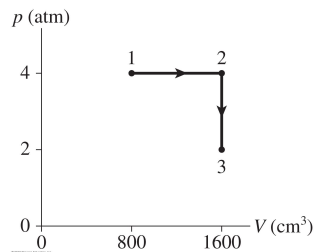


Figure 1: Figure for question 1

- (a) Calculate the temperature of the gas in Kelvin at point 1 (T_1). The gas constant is on the formula sheet. (3 points)
- (b) $T_2 = 2T_1$ for this process (temperature is doubled). With this information calculate ΔE_{th} between points 1 and 2. (3)
- (c) Calculate the work done by the gas between points 1 and 2. (3)
- (d) Calculate the heat energy transferred to the gas between points 1 and 2. (Use a dummy answer of $W_{out} = 400$ J if you like.) (2)

2. Air flows through the tube shown in Fig. 2. $\rho_{\text{air}} = 1.20 \text{ kg/m}^3$ and $\rho_{\text{Hg}} = 13600 \text{ kg/m}^3$.

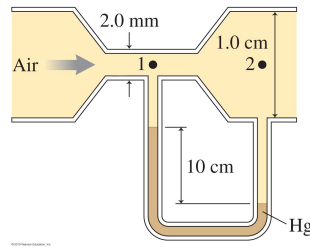


Figure 2: Figure for question 2

- (a) Give the pressure difference between region 1 and region 2 based on the mercury manometer. (3)
- (b) $v_1 = 25v_2$. Why? (2)
- (c) Use the pressure difference from part 2a to calculate v_1 . (dummy answer $p_2 - p_1 = 14000 \text{ Pa}$) using Bernoulli's equation. You may assume that $y_1 = y_2 = 0$ and you may also ignore the v_2^2 term in Bernoulli's equation if you like (reason: it is much smaller than the other terms). (3)

3. An electrical power plant uses energy from burning coal to generate steam at 450°C (723 K). The plant is cooled by 20°C water from a nearby river i.e. $T_C = 20^{\circ}\text{C} = 293\text{ K}$. If burning coal provides 100 MJ of heat what is the theoretical minimum amount of heat that must be transferred to the river during the conversion of heat to electric energy.

- A. 100 MJ B. 90 MJ
C. 60 MJ D. 40 MJ

Please show your work for full credit. (6)

4. The position of a 0.050 kg oscillating mass is given by $x(t) = (0.02\text{ m})\cos(10t)$ where t is in seconds. Determine: A. the amplitude (1 point), B. the period (2 points), C. the spring constant (3 points), D. the maximum speed (3 points)

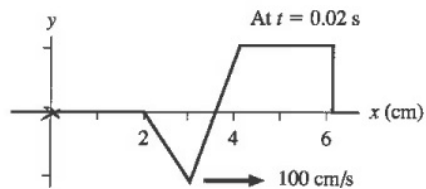


Figure 3: Figure for question 5.

5. A snapshot of a wave pulse on a string is shown in Fig. 3. Draw a history graph at $x = 0$ cm over a time range of -0.06 s to 0.02 s. Show the steps for how at least one feature is mapped from the snapshot graph to the history graph. (8 points)

6. Figure 4 shows a standing wave oscillating at 100 Hz on a string. What is the mode number? What is the wavelength? What is the wave speed? (7)

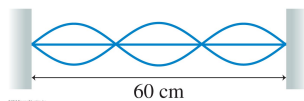


Figure 4: Figure for question 6.

$$e = \frac{\text{what you get out}}{\text{what you pay for}} = \frac{W_{\text{out}}}{Q_H} = 1 - \frac{Q_C}{Q_H}$$

definition of efficiency and formula for a heat engine, can also use powers in Watts rather than Joules

$$e_{\text{max}} = 1 - \frac{T_C}{T_H}$$

the maximum or Carnot efficiency of a heat engine $\Delta S_{\text{system}} = 0$

$$\Delta S = \pm \frac{Q}{T} = -\frac{Q_H}{T_H} + \frac{Q_C}{T_C}$$

entropy change associated with heat or a heat engine

$$k_B = 1.38 \times 10^{-23} \text{ J/K} = \frac{R}{N_A}$$

Boltzmann's constant and its relationship to the gas constant $R = 8.31 \text{ J/K}$ and Avogadro's Number $N_A = 6.02 \times 10^{23}$

$$pV = Nk_B T = nRT$$

ideal gas law, N is the number of molecules, n is the number of moles, T is in Kelvin

$$E_{th} = \frac{3}{2} Nk_B T \text{ and } \Delta E_{th} = \frac{3}{2} Nk_B \Delta T$$

for a monatomic gas

$$\Delta E_{th} = W_{\text{in}} + Q_{\text{in}} = -W_{\text{out}} + Q_{\text{in}}$$

1st Law of Thermodynamics, you need to modify the signs if you are talking about a Q that is "leaving" the system

$$\Delta S_{\text{system}} \geq 0$$

2nd Law of Thermodynamics for an isolated system, could also say state of disorder increases with time

$$v_{rms} = \sqrt{\frac{3k_B T}{m}}$$

the average velocity of an atom in a gas at temperature T . Can find m from molecular weight (in kg) divided by $N_A = 6.02 \times 10^{23}$.

$$E_{th} = NK_{avg} = N\left(\frac{1}{2}mv_{rms}^2\right) = \frac{3}{2}Nk_B T$$

for a monatomic gas the thermal energy represents that the total kinetic energy of the molecules which is proportional to v_{rms}^2 and T

$$p = \frac{F}{A}$$

definition of pressure, units are Pascals (Pa) when F is in Newtons and A is in m^2

$$W_{\text{gas, out}} = p\Delta V = \text{"area under } pV \text{ curve"}$$

an *expanding* gas does work on its environment. If the pressure is constant then you may use the simple ΔV expression, otherwise it is the area

$$V_i = V_f$$

a constant volume process $W_{\text{out}} = 0$

$$T_i = T_f$$

an isothermal process $\Delta E_{th} = 0$

$$p_i V_i^{\frac{5}{3}} = p_f V_f^{\frac{5}{3}}$$

an adiabatic process $Q = 0$ and $\Delta S = 0$

$$\frac{p_i V_i}{T_i} = \frac{p_f V_f}{T_f}$$

once you have identified the process you can use this formula, a form of the ideal gas law if N is constant

$$\rho = \frac{m}{V}$$

definition of density, use m in kg and V in m^3 . $1 \text{ m}^3 = 1000 \text{ L} = 10^6 \text{ cm}^3 = 10^6 \text{ mL}$

$$p = p_0 + \rho_f g d$$

pressure in a fluid of density ρ_f as a function of depth. p_0 is a "reference pressure" where $d = 0$. This equation also supports *Pascal's principle*: if the pressure changes at one point in the fluid it changes by the same amount at every other point.

$$p_t = p_b - \rho_f g h$$

If a parcel of fluid with a height of h is in hydrostatic equilibrium then the pressure at the top is lower than the pressure at the bottom.

$$F_B = \rho_f V_f g$$

buoyant force directed upward. V_f is the volume of fluid displaced and it equal to the volume of the object *if* the object is submerged. Object will also experience the force of gravity *weight* $w = mg$ directed downward.

$$p_{\text{atmos}} = 101.3 \text{ kPa} = 1 \text{ atm}$$

atmospheric pressure

$$v_1 A_1 = v_2 A_2$$

$$Q = vA = \frac{\Delta V}{\Delta t}$$

$$p_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2 = p_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1$$

$$\omega = 2\pi f = \frac{2\pi}{T}$$

$$(F_{\text{net}})_x = -kx$$

$$x(t) = A \cos(\omega t) = A \cos(2\pi t) = A \cos(2\pi \frac{t}{T})$$

$$v_x(t) = -A\omega \sin(\omega t)$$

$$a_x(t) = -A\omega^2 \cos(\omega t) = -\omega^2 x(t)$$

$$\omega = \sqrt{\frac{k}{m}} = \sqrt{\frac{g}{L}}$$

$$T = 2\pi \sqrt{\frac{m}{k}} = 2\pi \sqrt{\frac{L}{g}}$$

$$E = K + U = \frac{1}{2}mv_x(t)^2 + \frac{1}{2}kx(t)^2$$

$$K_{\text{max}} = U_{\text{max}} = \frac{1}{2}m(v_{\text{max}})^2 = \frac{1}{2}kA^2$$

$$y(x, t) = A \cos\left(2\pi\left(\frac{x}{\lambda} - \frac{t}{T}\right)\right)$$

$$v = f\lambda = \frac{\lambda}{T} = \frac{\Delta x}{\Delta t}$$

$$v_{\text{sound}} = \sqrt{\frac{\gamma k_B T}{m}} = \sqrt{\frac{\gamma R T}{M}}$$

$$v_{\text{string}} = \sqrt{\frac{T_s}{\mu}}$$

$$v_{\text{light}} = c = 3.00 \times 10^8 \text{ m/s}$$

$$m \frac{\lambda_m}{2} = L \quad m = 1, 2, 3, \dots$$

$$m \frac{\lambda_m}{4} = L \quad m = 1, 3, 5, \dots$$

$$f_m = \frac{v}{\lambda_m}$$

equation of continuity for an incompressible fluid

volume flow rate in m^3/s

Bernoulli's equation. Often used to find a pressure difference $p_2 - p_1$. If the fluid is low density (like air) and the change in y is small you can drop the $\rho g y$ terms.

relationship between angular frequency ω , frequency f and period T

This is for a horizontal, frictionless mass-spring system where x represents displacement from equilibrium. This pattern of a linear restoring force is the same for other examples of simple harmonic motion.

the motion of an object in simple harmonic motion. For vertical mass spring system substitute $y(t)$ for a pendulum either $\theta(t)$ or $s(t)$ (the arc length). $x_{\text{max}} = A$. If you need to calculate an actual x at some time make sure you take the cosine in radians.

velocity as a function of time. $v_{\text{max}} = A\omega$. Substitute in frequency f and period T as necessary.

acceleration as a function of time. Substitute in frequency f and period T as necessary.

angular frequency for mass-spring and pendulum systems

period for mass-spring and pendulum systems

energy relationships in a simple harmonic oscillator

max energies

sinusoidal wave moving to the right (change to positive sign for wave to the left)

basic relationship between speed, frequency, period, and wavelength. Use the "quotes" form to relate history and snapshot graphs.

speed of sound $\gamma = 3/2$ for monatomic gases, $5/2$ for diatomic

waves on a string, T_s is tension, μ is linear density

speed of electromagnetic waves in vacuum (including light, radio waves)

waves on string, closed-closed or open-open pipe (draw a picture!), m is the mode number

waves in open-closed pipe (draw a picture!) m isn't mode number; it is the number of quarter-wavelengths in the standing wave. Set $m = 1$ for the fundamental, $m = 3$ for 2nd harmonic etc.

changing resonant wavelengths to frequency, this formula works for either open-open or open-closed *with the m in the previous formulas*