NAME:__________________________

Physics 260 - SPRING 2011 – Sample Common Final Exam

Professors Fleming, Nandikotkur, Wellstood – Friday, 6:30-8:30 PM, May 13, 2011

Instructions

(1) Check that you have EIGHT pages, including this cover page.

(2) Write your name on each page of the exam. Write Clearly. Do this now.

(3) Read and Sign the Academic Integrity Pledge*:*

I understand that Academic dishonesty is a serious offense that may result in expulsion from the University. In addition to any other action taken, the grade "XF" denoting "failure due to academic dishonesty" will normally be recorded on the transcripts of students found responsible for acts of academic dishonesty.

The work on this exam is entirely my own and I will comply with the instructions.

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(4) This is a closed book exam. No books, crib sheets, scrap paper, computers, or cell phones are allowed. All books must be placed on the floor under your desk.

(5) Keep your exam flat on the writing desk at all times.

(6) Write your answers in this booklet on the same page as the question is written.
If you run out of space, use the back side.

(7) <u>If you want credit, write clearly and always show your work</u>.

(8) There are no "trick questions" in this exam. If you have a question about a problem, raise your hand to let your instructor know.

(9) Check your answers! Did you answer the question, does your answer have units, are the units right, is the sign right, is the quantity a vector, did you use the correct number of significant figures, is the answer reasonable?

problem #	points	maximum possible
1		20
2		20
3		20
4		20
5		20
6		20
total GRADE		120

Possibly

Useful formulae:

$K = \frac{1}{2}mv^2$	$v_{max} = \omega A$	$\omega = \sqrt{g/L}$
$x(t) = A\cos(\omega t + \phi_0)$	$\omega^2 = \frac{k}{m}$	$v_x(t) = -A\sin(\omega t + \phi_0)$
$vA =$ constant	$p + \frac{1}{2}\rho v^2 + \rho g y =$ constant	$p = \rho g h$
$\rho = \frac{M}{V}$	$F_B = \rho g V_f$	$F_B = Mg$
$f_\pm = f_0/(1 \mp v_s/v)$	$f_\pm = f_0(1 \pm v_o/v)$	$v = \sqrt{\frac{T}{\mu}}$
$\Delta\phi = 2\pi\frac{\Delta r}{\lambda} + \Delta\phi_0 = 2m\pi$	$\Delta\phi = 2\pi\frac{\Delta r}{\lambda} + \Delta\phi_0 = 2\left(n + \frac{1}{2}\right)\pi$	$\lambda_m = \frac{4L}{m}$ (open-closed)
$A = 2a\cos\left(\frac{\Delta\phi}{2}\right)$	$\sin(\alpha \pm \beta) = \sin\alpha\cos\beta \pm \cos\alpha\sin\beta$	$v = \lambda f$
$Q = \pm ML$	$Q = Mc\Delta T$	$pV = nRT$
Equilibrium: $(\epsilon_1)_{avg} = (\epsilon_2)_{avg}$,	$E_{1f} = n_1/(n_1+n_2)E_{tot}$,	$E_{2f} = n_2/(n_1+n_2)E_{tot}$
$K = Q_C/W_{in}$	$\eta = W_{out}/Q_H$	$W_{out} = Q_H - Q_C$
$Q_H = Q_C + W_{in}$	$\eta_{Carnot} = 1 - T_C/T_H$	$K_{Carnot} = T_C/(T_H - T_C)$
Monoatomic gas : $E_{th} = 3/2nRT$	Diatomic gas : $E_{th} = 5/2nRT$	$Q = nC_V\Delta T$ at constant V
Monoatomic gas : $C_V = 3/2\ R$	Diatomic gas : $C_V = 5/2\ R$	$C_P = C_V + R$
$\frac{Q}{\Delta t} = k\frac{A}{L}\Delta T$	$\frac{Q}{\Delta t} = e\sigma A\left(T^4 - T_0^4\right)$	$W_{isothermal} = -nRT\ln(V_f/V_i)$
$W = -\int_{V_i}^{V_f} pdV$	$T_K = T_C + 273$	$\gamma = \frac{C_P}{C_V}$
$F_{1\ on\ 2} = F_{2\ on\ 1} = \frac{1}{4\pi\epsilon_0}\frac{\lvert q_1\rvert\lvert q_2\rvert}{r^2}$	$\bar{F} = q\bar{E}$	$(E_{disk})_{on\ axis} = \frac{\eta}{2\epsilon_0}\left[1 - \frac{z}{\sqrt{z^2+R^2}}\right]$
$(E_{ring})_{on\ axis} = \frac{1}{4\pi\epsilon_0}\frac{zQ}{(z^2+R^2)^{3/2}}$	$\lvert(E_{plane})_z\rvert = \frac{2\pi\eta}{4\pi\epsilon_0}$	$\bar{E}_{sphere,\ point\ charge} = \frac{1}{4\pi\epsilon_0}\frac{Q}{r^2}\hat{r}$
$\Phi_e = \int \bar{E}.d\bar{A} = \frac{Q_{in}}{\epsilon_0}$	$J = \sigma E$	$I = ei = neAv_d$
$\sigma = \frac{ne^2\tau}{m}$	$V_{sphere,\ pointcharge} = \frac{1}{4\pi\epsilon_0}\frac{Q}{r}$	$U_{q+sources} = qV$
$V_{capacitor} = Es$	$\left(\bar{E}_{dipole}\right)_{on\ axis} = \frac{1}{4\pi\epsilon_0}\frac{2\bar{p}}{r^3}$	$p = qs$
$U_{q_1+q_2} = \frac{1}{4\pi\epsilon_0}\frac{q_1q_2}{r}$	$U_{dipole} = \bar{p}.\bar{E}$	$V_{ring\ on\ axis} = \frac{1}{4\pi\epsilon_0}\frac{Q}{\sqrt{R^2+z^2}}$
$V_{disk\ on\ axis} = \frac{2Q}{4\pi\epsilon_0}\frac{\left(\sqrt{R^2+z^2}-z\right)}{R^2}$	$\Delta V = V(s_f) - V(s_i) = -\int_{s_i}^{s_f} E_s ds$	$E_s = \frac{dV}{ds}$
$E_{wire} = \frac{\Delta V_{wire}}{L}$	$I = \frac{\Delta V_{wire}}{R}$	$R = \frac{\rho L}{A}$
$\Delta V_{bat} = \mathcal{E}$	$Q = C\Delta V_C$	$U_C = \frac{1}{2}C(\Delta V_C)^2 = \frac{Q^2}{2C}$
$u_E = \frac{\epsilon_0}{2}E^2$	$C_{eq}^{series} = \left(\frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} + ...\right)^{-1}$	$C_{eq}^{parallel} = C_1 + C_2 + C_3 + ...$
$R_{eq}^{series} = R_1 + R_2 + R_3 + ...$	$R_{eq}^{parallel} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + ...\right)^{-1}$	$I = \frac{\Delta V}{R}$
$P_R = I\Delta V_R = I^2R = \frac{(\Delta V_R)^2}{R}$	$Q = Q_0e^{-t/\tau}$	$I = \frac{Q_0}{\tau}e^{-t/\tau}$
$\tau = RC$	junction law : $\sum I_{in} = \sum I_{out}$	loop law : $\sum_i (\Delta V)_i = 0$
$E = \frac{\Delta V_C}{d}$	$V = \Delta V_C\left(1 - \frac{x}{d}\right)$	$Q = Q_{max}\left(1 - e^{-t/\tau}\right)$
$U = \frac{1}{2}kx^2$	$\lambda_m = \frac{2L}{m}(open - open)$	

CONSTANTS

permittivity of free space: $\varepsilon_o = 8.85\text{x}10^{-12}\ C^2/Nm^2$

$k_e = 1/(4\pi\varepsilon_o)$

Boltzmann's constant: $k_b = 1.38\text{x}10^{-23}$ J/K

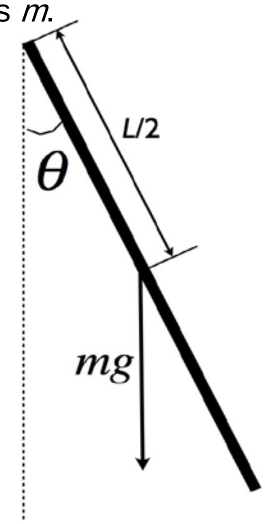
Gas constant: R = 8.3 J/K

Avogadro's number $N_o = 6.02\text{x}10^{23}$

mass of an electron: $m_e = 9.11\text{x}10^{-31}$ kg

charge of an electron: -e = $-1.6\ \text{x}10^{-19}$ C

1. The **physical pendulum** pictured at the right is a uniform rod of length L and mass m.



(a) (4 points) Write an equation for the gravitational torque exerted on the pendulum as a function of m, L, g, and θ.

(b) (4 points) Write an approximation for the torque that is valid at small angles.

(c) (4 points) Using Newton's second law for rotational motion, one can derive the following equation of motion for small angle oscillations:

$$\frac{d^2\theta}{dt^2} = \frac{-mgL}{2I}\theta.$$

Does the physical pendulum exhibit simple harmonic motion? Explain.

(d) (4 points) The moment of inertia of a rod pivoted about it's end is $I = \frac{1}{3}mL^2$. What is the frequency of the rod's oscillations?

(e) (4 points) How long would a **simple pendulum** with mass $2m$ have to be to have the same frequency (as you found in part (d) for a rod of mass m and length L)?

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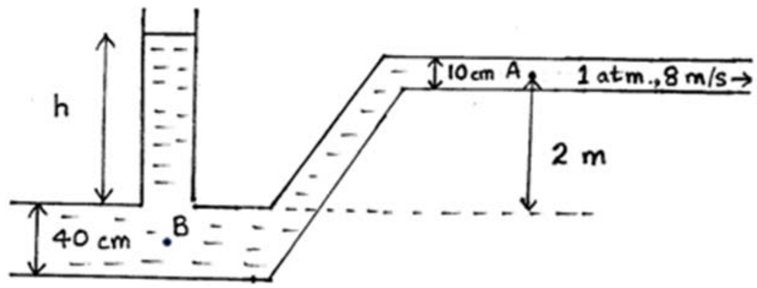
2. Water flows in the upper section of a pipe (point A) with a speed of 8.0 m/s and at 1 atmospheric pressure (1x 10^5 Pa): see the figure. The density of water is 10^3 kg/m^3 and g = 9.8 m/s^2.

(a) (4 points) What is the speed of the water at point B?

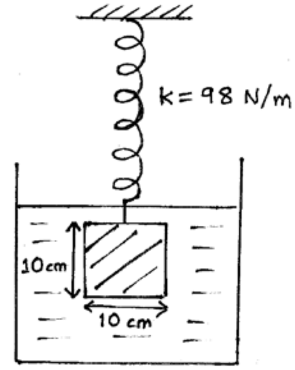


(b) (4 points) How many kilograms of water per second are flowing in the pipe?

(c) (4 points) What is the water pressure at point B?

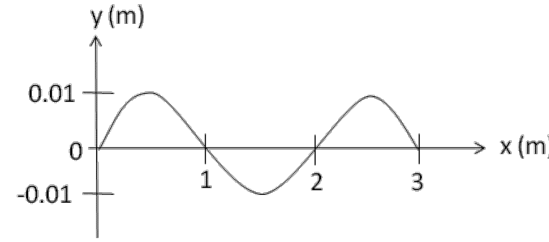
(d) (4 points) What is the height h of the standing column of water shown in the figure?

(e) (4 points) Consider a cube of length 10 cm and mass 2 kg which hangs from a spring and is fully submerged in water (see figure below). If the spring constant is 98 N/m, by how much does the spring stretch (from its equilibrium length)?



3. A 3.0 m long wire with mass of 0.1 kg has a tension of 200 N is held fixed at its ends (x=0 and x=3.0 m). A standing wave is present on the string. The plot below shows the waves displacement y as a function of the position x on the string at time t=0, when the magnitude of the string's displacement is largest at each point.

[5 points] (a) What is the frequency *f* of oscillation of the standing wave shown in the plot?



[5 points] (b) For the wave shown in the sketch, write an explicit equation for the displacement y as function of x and t. **Define any variables or parameters that appear in your equation.**

[5 points] (c) In the space below, sketch the displacement as a function of x at time

[5 points] (d) What is the maximum acceleration in the transverse direction (y-direction) of a small piece of the wire at x=1.5 m?

4. 2.0 mol of a diatomic gas which initially fills a 1000 cm^3 volume at 1 atm (101.3 kPa) undergoes the following cycle:

- Step 1: The gas undergoes isochoric (equal volume) heating to twice its original pressure.
- Step 2: The gas undergoes isobaric compression to half its original volume.
- Step 3: The gas is isothermally expanded until the pressure is restored to its initial value.

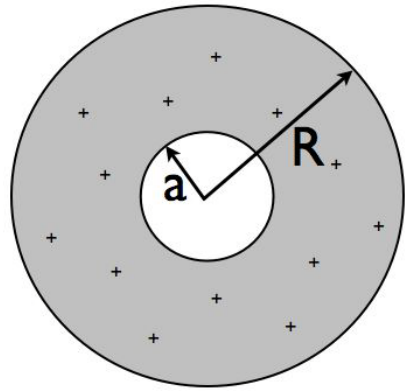
(a) (4 points) Draw a Pressure versus Volume diagram of the cycle.

(b) (4 points) The system is in contact with a cold reservoir whose temperature, T_C, is equal to that of the gas at the beginning of step 1 and a hot reservoir whose temperature, T_H, is equal to the temperature of the gas at the end of step 1. Find T_C and $T_{H.}$

(c) (6 points) Identify the step(s) in which heat is transferred into the gas and find the magnitude of the heat transfer. Is this heat extracted from the hot reservoir or heat extracted from the cold reservoir? Explain.

(d) (6 points) Is the area inside the curve the work done by the gas or work done on the gas? What is its value?

5. Consider a uniformly charged sphere with radius R (made from an insulating material) with a spherical hole of radius a at its center. The total charge that is distributed over the material is +Q.



(a) (5 points) Find an expression for the electric field in the region r < a. Be sure to include both the magnitude and direction.

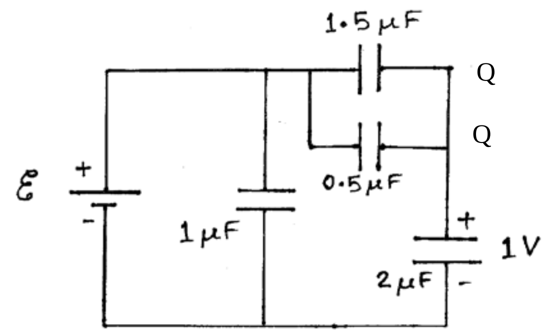
(b) (5 points) Find an expression for the electric field in the region r > a. Be sure to include both the magnitude and direction.

(c) (5 points) Find an expression for the electric field in the region a < r < R (5 points). Be sure to include both the magnitude and direction.

(d) (5 points) Find the potential difference between the inner and outer surfaces of the material if Q=250 nC.

6. For parts a-c, consider the capacitor circuit shown at right. The voltage across the 2 μF capacitor is 1 V.

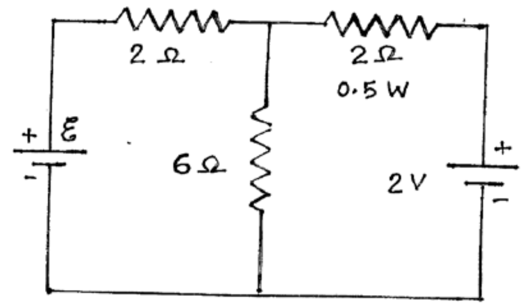
(a) (4 points) What is the charge Q on the 1.5 μF capacitor?



(b) (4 points) What is the voltage of the battery?

(c) (4 points) What is the charge on the 1 μF capacitor?

(d) (4 points) Consider the resistor circuit shown in the figure below. The power consumed by the 2 Ω resistor is 0.5 W. What is the magnitude and direction (up or down) of the current through the battery on the right-hand side?



(e) (4 points) For the resistor circuit shown in the figure above, what is the voltage of the battery on the left-hand side?