

Name: \_\_\_\_\_

Student No.: \_\_\_\_\_

Qualifying/Placement Exam  
9:00 am, August 23, 2005

Put your NAME on every sheet of this  
12 problem Exam -- NOW

You have 3 hours to complete the 12 problems on this exam. Show your work! Full credit will not be given for answers without justification. Some partial credit may be earned for the correct procedure, even if the correct answer is not achieved. Answers must be in the spaces provided. The **BACK** of the problem page may be used for lengthy calculations. Do not use the back of the previous page for this purpose!

You may need the following constants:

Speed of light in vacuum:  $c = 3.00 \times 10^8$  m/s

Boltzmann constant:  $k = 1.38 \times 10^{-23}$  J/K

Planck's constant:  $h = 6.63 \times 10^{-34}$  J s =  $4.14 \times 10^{-15}$  eV s

$$hc = 1240 \text{ eV nm}$$

Gas constant:  $R = 8.31$  J/(mol K)

Permittivity of free space  $\epsilon_0 = 8.99 \times 10^9$  C<sup>2</sup>/(N m<sup>2</sup>)

Permeability of free space  $\mu_0 = 4\pi \times 10^{-7}$  N s<sup>2</sup> / C<sup>2</sup>

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1. An object of mass  $m$  is dropped from height  $y = 0$  and falls under the influence of gravitational acceleration  $g$ . The object is falling in a viscous medium which produces a resistive force proportional to the velocity,  $-\gamma v_y$ . The initial velocity is zero.
  - a. [3 pts] Find an expression for the terminal velocity.
  - b. [7 pts] Find an expression for the velocity as a function of time.

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2. A fisherman is in a boat on a small pond. Consider each action below independently and indicate whether the level of the water in the pond **Rises, Falls, or is Unchanged**. Indicate by a short explanation why your choice is correct.

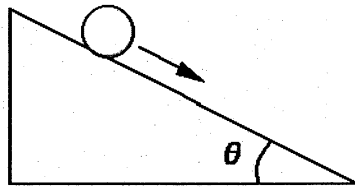
- a. [4 pts] The fisherman knocks the tackle box overboard, and it sinks to the bottom.
- b. [3 pts] The fisherman lowers the anchor and it hangs one foot above the bottom of the pond.
- c. [3 pts] The fisherman fills a glass with water from the pond and drinks it.

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3. A uniform steel ball of mass  $M$  and radius  $R$  (and hence moment of inertia  $I=2MR^2/5$ ) rolls without slipping down a ramp that makes an angle  $\theta$  with the horizontal. It starts from rest.

- a. [3 pts] Calculate the component of force on the ball due to the ramp in the direction parallel to the ramp.
- b. [4 pts] Calculate how far it has traveled as a function of time.
- c. [3 pts] If oil is poured on the ramp, and the ball starts to slide without friction, would the magnitude of its acceleration be more than, less than, or equal to that in part a.? Why?



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4. [10 pts] A parallel-plate capacitor with capacitance  $C$  has charges  $q$  and  $4q$  on its plates. What is the potential difference between the plates?

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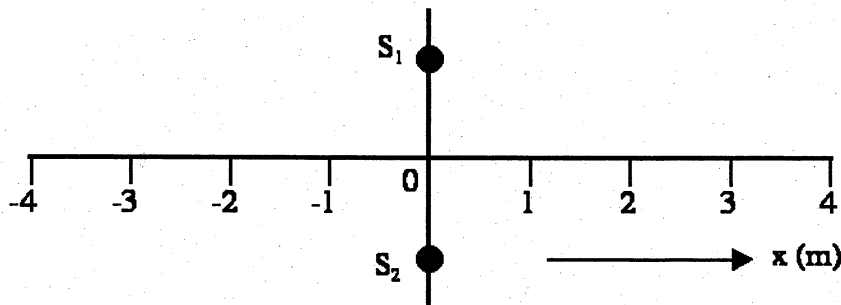
5. Assume that a 100 Watt light bulb emits linearly-polarized light equally in all directions.
- a. [4 pts] What is the time-averaged magnitude of the Poynting vector at a distance of 1m from the light bulb?
  - b. [6 pts] What are the peak and rms values of the electric and magnetic fields at this distance from the bulb?

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6. [10 pts]  $S_1$  and  $S_2$  are point sources of electromagnetic radiation. They are coherent and in phase. Placed 2.0 meters apart, as shown in the figure below, they emit equal amounts of radiation in the form of  $\lambda = 0.5$  meter radio waves.

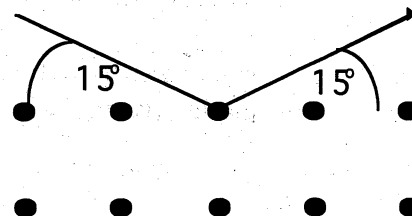
Make a sketch of the power received as a function of the distance along the x axis, paying particular attention to the positions of any maxima or minima.



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7. [10 pts] If an X-ray beam impinging on a crystal with a lattice spacing  $d = 0.3 \text{ nm}$  has *its first* diffraction maximum at a glancing angle of  $15^\circ$ , what is the energy of the X-ray beam?





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8. A particle of mass  $m$  is confined in the interval  $0 < x < L$  and is described by the wave function at  $t = 0$ :

$$\varphi(x,0) = N \left( i \sin\left(\frac{\pi x}{L}\right) + \sqrt{2} \sin\left(\frac{2\pi x}{L}\right) \right).$$

- a. [3 pts] Find the coefficient of normalization  $N$ .
- b. [4 pts] If we measure the energy of this particle what are the possible values?
- c. [4 pts] What are the relative probabilities for these values?

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9. [10 pts] If a particle's kinetic energy is  $n$  times its rest energy, what is its speed?

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10. A neutral pion with rest energy 135 MeV and total energy 300 MeV is traveling in the +z direction. It decays into two massless photons ( $\pi^0 \rightarrow \gamma + \gamma$ ) which happen to go in the +z and -z directions.

- a. [7 pts] Find the momentum of each photon (in MeV/c or kg m/s).
- b. [3 pts] Find the wavelength of each photon.

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11.

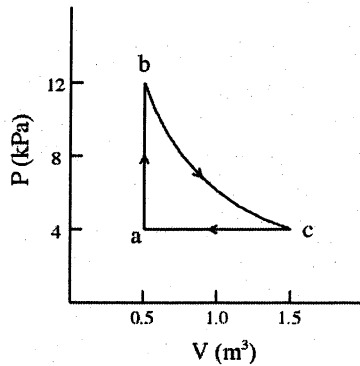
- a. [5 pts] Ten grams of ice at  $0^{\circ}\text{C}$  melt slowly to water at  $0^{\circ}\text{C}$ . Find the change in entropy of the ice.
- b. [5 pts] The water is heated slowly to  $100^{\circ}\text{C}$  at a constant pressure of 1 Atmosphere. Find the change in entropy of the water.

Useful Information: The latent heat of fusion is  $80\text{ cal/g}$ . A calorie is  $4.18\text{ Joules}$ . Assume the heat capacity  $C_P$  is constant at  $1\text{ calorie}/(\text{gram K})$ .

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12. Two moles of an ideal gas are taken through the reversible cyclic process  $abca$  as shown in the figure. Path segment  $bc$  is performed at constant temperature,  $ca$  at constant pressure, and  $ab$  at constant volume.



Data:

$$P_a = P_c = 4000 \text{ Pa,}$$

$$P_b = 12000 \text{ Pa,}$$

$$V_a = V_b = 0.5 \text{ m}^3,$$

$$V_c = 1.5 \text{ m}^3.$$

- [2 pts] What is the change in the internal energy in the complete cycle?
- [2 pts] What is the work done by the gas in path segment  $ca$  ?
- [2 pts] What is the temperature of the gas during the isothermal segment  $bc$  ?
- [2 pts] What is the work done by the gas in the isothermal segment  $bc$  ?
- [2 pts] What is the net amount of heat added in the complete cycle?