Phys 274 Final Exam

Time limit: 120 minutes

Each question worths 10 points.

Constants: $e = 1.6 \times 10^{-19}C$, $h = 6.63 \times 10^{-34}Js$, $c = 3 \times 10^8 m/s$, $\epsilon_0 = 8.85 \times 10^{-12}C^2N^{-1}m^{-2}$, $\mu_0 = 4\pi \times 10^{-7}Tm/A$, Boltzmann constant $k_B = 1.38 \times 10^{-23}J/K$, $R = 8.31Jmol^{-1}K^{-1}$, Avogadro number $N_A = 6 \times 10^{23}$, $1atm = 10^5 Pa$, $1cal = 4.186J$, gravitational constant $G = 6.67 \times 10^{-11}m^3kg^{-1}s^{-2}$, the speed of sound in air $v_{sound} = 344m/s$, decibel scale reference level intensity $I_0 = 10^{-12}W/m^2$.

Specific heat of water: $c_{solid} = 2.1kJkg^{-1}K^{-1}$, $c_{liquid} = 4.186kJkg^{-1}K^{-1}$, $c_{gas} = 2.0kJkg^{-1}K^{-1}$.

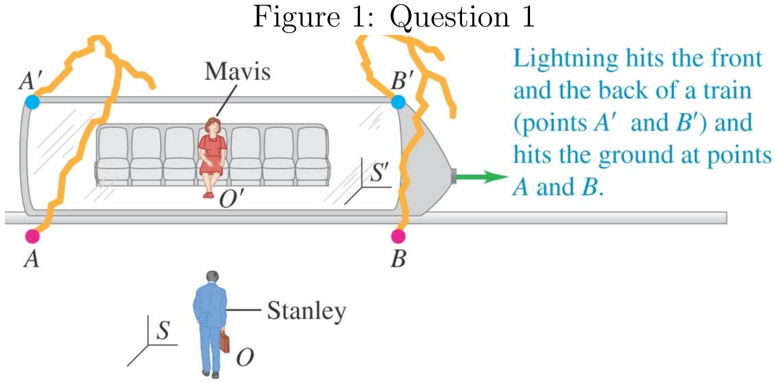
Specific heat of other materials: $c_{glass} = 0.84kJkg^{-1}K^{-1}$, $c_{gold} = 0.13kJkg^{-1}K^{-1}$, $c_{lead} = 0.13kJkg^{-1}K^{-1}$, $c_{mercury} = 0.14kJkg^{-1}K^{-1}$, $c_{aluminum} = 0.9kJkg^{-1}K^{-1}$, $c_{copper} = 0.387kJkg^{-1}K^{-1}$.

Latent Heat of water: $L_f = 333.7kJ/kg$, $L_v = 2259kJ/kg$.
Latent Heat of mercury: $L_f = 11.8kJ/kg$, $L_v = 296kJ/kg$.

Useful Information: Mass of proton $m_p = 1.67 \times 10^{-27}kg$, mass of neutron $m_n = 1.67 \times 10^{-27}kg$, mass of electron $m_e = 9.11 \times 10^{-31}kg$.

1. (a) Lightening strikes the the front and the back of a moving train at the same time from the perspective of Stanley (Figure 1). From Mavis's perspective, which side of the train was struck first (Front, back or at the same time)? (b) State the two postulates of special relativity. (c) Figure 2 shows a lightclock on Mavis' train traveling at speed v relative to Stanley. According to her, the time it takes for the photon to complete one round trip is Δt_0, but according to Stanley the trip takes time Δt. Use the figure to derive the relationship between Δt_0 and Δt.

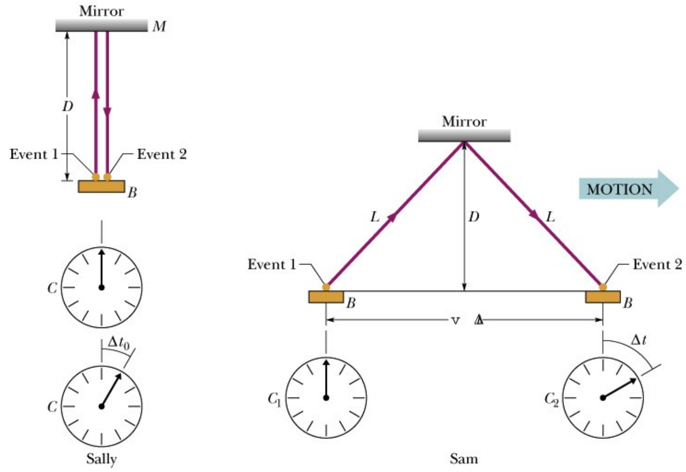
Figure 1: Question 1



2. (a) Light with a wavelength of $190nm$ is incident on a metal surface. The most energetic electrons emitted from the surface are measured to have $4.0eV$ of kinetic energy. What is the work function of this metal in eV? (b) Light with some unknown wavelength is incident on a piece of copper ($\Phi = 4.5eV$). The most energetic electrons emitted from the copper have $2.7eV$ of kinetic energy. If the copper is replaced with a piece of sodium ($\Phi = 2.3eV$), what will be the maximum possible kinetic energy KE of the electrons emitted from this new surface? Give the answer in eV.

3. An electron microscope is using a $1keV$ electron beam. An atom has a diameter of about $10^{-10}m$ meters. (a) Calculate the rest energy of an electron in eV. From your answer, explain if the electrons in the microscope are relativistic or not. (b) What is the wavelength of electrons in this microscope? (c) Can an individual atom theoretically be resolved using this electron microscope?

Figure 2: Question 1(c)

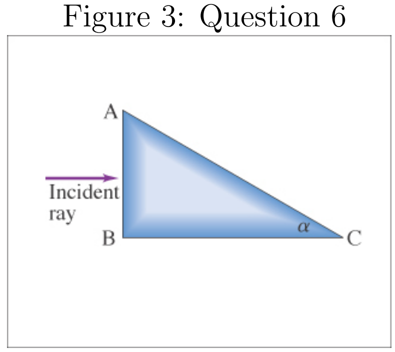


4. Two lasers, one red (with wavelength $633nm$) and the other green (with wavelength $532nm$), are mounted behind a $0.15mm$ single slit. On the other side of the slit is a white screen. When the red laser is turned on, it creates a diffraction pattern on the screen. (a) The distance d from the center of the pattern to the location of the third diffraction minimum of the red laser is $4.05cm$. How far is the screen from the slit? (b) The red laser is turned off, and the green laser is turned on. Does the central maximum become wider or narrower?

5. (a) An object is located $28.5cm$ from a certain lens. The lens forms a real image that is twice as high as the object. What is the focal length of this lens (no need to draw the ray diagram for this part)? (b) An object $5cm$ tall is $12cm$ in front of a diverging lens with focal length of $4cm$. Draw the ray diagram to find the image and measure the image distance from your diagram. Describe the image (real/virtual, upright/inverted, magnified/minimized).

6. Figure 3 shows light is incident along the normal to face AB of a glass prism of refractive index 1.55. (a) Find α_{max}, the largest value of the angle α such that no light is refracted out of the prism at face AC if the prism is immersed in air. (b) Find α_{max}, the largest value the angle α can have without any light being refracted out of the prism at face AC if the prism is immersed in water (with index of refraction 1.33).

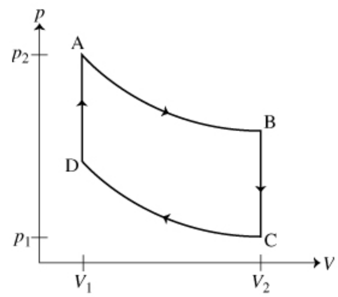
Figure 3: Question 6



7. Figure 4 shows a thermal engine filled with N molecules of a monatomic ideal gas. The gas undergoes a cyclic transformation, as shown. Processes AB and CD are isothermal (constant temperature), and processes BC and DA are isochoric (constant volume). The quantities p_1, p_2,

V_1, and V_2 are defined in the figure, all your answers must be expressed in these variables. (a) Find the work done by the gas during process $A \to B$. (b) Find the work done by the gas during process $B \to C$. (c) Find the work done by the gas during process $C \to D$. (d) Find the work done by the gas during process $D \to A$. (e) What is the total change in the gas's internal energy after it has completed a cycle?

Figure 4: Question 7



8. (a) If an otherwise empty pressure cooker is filled with air of room temperature and then placed on a hot stove, what would be the magnitude of the net force on the lid when the air inside the cooker had been heated to T_{in}? Assume that the temperature of the air outside the pressure cooker is T_a (room temperature) and that the area of the pressure cooker lid is A. Take atmospheric pressure to be P_a. Give your answer in terms of the variables given. (b) A wave on a stretched string is described in SI units by $y = 0.004 \sin(300t - 15x)$. (i) What is the maximum velocity of a particle on the string? (ii) What is the velocity of the wave? (iii) What is the wavelength and the frequency.

9. (a) A train is traveling at $30.0m/s$ relative to the ground in still air. The frequency of the note emitted by the train whistle is $f_t = 262Hz$. The speed of sound in air should be taken as $344m/s$. What frequency f_p is heard by a passenger on a train moving at a speed of $18.0m/s$ relative to the ground in a direction opposite to the first train and approaching it? (b) In an insulated container, $0.50kg$ of water at $80°C$ is mixed with $0.050kg$ of ice at $-5.0°C$. After a while, all the ice melts, leaving only the water. Find the final temperature T_f of the water.