Name: ______________________________

Pre-Exam II,
Physics 117-Spring 2003, Wed. 4/14/2003
Instructor: Dr. S. Liberati

General Instructions

- There are a total of four problems in this exam.
- All problems carry equal weights.
- Do all the problems by writing on the exam book (continue to work on the back of each page if you run out of room).
- Write your name (in capital letters) on every page of the exam.
- Purely numerical answers will not be accepted. Explain with symbols or words your line of reasoning. Corrected formulae count more than corrected numbers.

What you can do

- You may look at your text book in taking the exam
- Use a calculator

What you can't do

- Speak with nearby colleagues
- Use any wireless device during the exam

Hints to do well

- Read carefully the problem before to compute. Before to start you must have clear in your mind what you need to arrive to the answer.
- Do problems with symbols first (introduce them if you have to).
  Only put in numbers at the end.
- Check your answers for dimensional correctness.
- If you are not absolutely sure about a problem, please write down what you understand so that partial credit can be given.

Honor Pledge: Please sign at the end of the statement below confirming that you will abide by the University of Maryland Honor Pledge

"I pledge on my honor that I have not given or received any unauthorized assistance on this assignment/examination."

Signature:______________________________

Name: ______________________________

Exercise 1

The pressure in each of your car tires is 2 10^5 Pa. The mass of your car is 1600 kg.

Q-1.1: Assuming that each of your tires bears one-quarter of the weight of the car, what is the contact area of each tire with the road?
(Assume g=10 m/s^2)

> The pressure on the tire is equal to its share of the weight of the car divided by the contact area with the road.
>
> $P = F_{tire} / A_{contact}$
>
> This pressure must be equal to the pressure inside the tyre.
>
> So, let's start by finding the share of the car weight supported by each tire
>
> $$F_{tire} = \frac{Weight}{4} = 400 \;\; Kg \cdot 10 \;\; \frac{m}{s^2} = 4000 \;\; N$$
>
> The contact area must then be such that
>
> $$P_{tire} = \frac{F_{tire}}{A_{contact}} \Rightarrow A_{contact} = \frac{F_{tire}}{P_{tire}} = \frac{4000 \;\; N}{2 \cdot 10^5 \;\; N/m^2} = 2 \cdot 10^{-2} \;\; m^2 = 200 \;\; cm^2$$

Q-1.2: Assume that the gas in the tire is an ideal one and that its initial temperature was 20 °C. What is the temperature of the tire if, after some running, the pressure is 2.5·10^5 Pa? What is now the contact area? (assume the volume of the tires to be constant)

> The ideal gas law tells us that $PV = Nk_B T$ so
>
> $P/T = Nk_B/V$,
>
> where N = Number of molecules, k_B = Boltzmann constant $= 1.38 \cdot 10^{23} \;\; J/K$
>
> In this case Nk_B/V = constant so
>
> $$\frac{P_i}{T_i} = \frac{P_f}{T_f} \Rightarrow T_f = \frac{P_f}{P_i} T_i = \frac{2.5 \cdot 10^5 \;\; Pa}{2 \cdot 10^5 \;\; Pa} \cdot 293 \;\; K = 366.25 \;\; K$$
>
> $$A_{contact,new} = \frac{F_{tire}}{P_{tire,final}} = \frac{F_{tire}}{\frac{5}{4} P_{tire,initial}} = \frac{4}{5} A_{conntact,initial} = 160 \;\; cm^2$$

Name: ________________________________

Exercise 2

Most of the people is neutrally buoyant, hence we can assume that a person has approximately the same density as water $D_{person}=D_{water}=1\ gr/cm^3$. Consider a person who has a mass of 80 Kg. Calculate the buoyancy force acting on a person when he/she lies at the bottom of a in a pool full of

Q-2.1: Air (Density of air: $D_{air}=0.001\ gr/cm^3$)

The buoyancy force is equal to the weight of the volume of air displaced by the person.

$$F_{buoy,air} = m_{displ,air}g = D_{air}V_{person}g \text{ where } D_{air} = 0.001\frac{gr}{cm^3} = 10^{-3}\frac{10^{-3}Kg}{\left(10^{-2}\right)^3 m^3} = \frac{10^{-6}}{10^{-6}}\frac{Kg}{m^3} = 1\frac{Kg}{m^3}$$

We can obtain V_{person} from the mass and the density $\Rightarrow$ $V_{person} = \frac{M_{pers}}{D_{pers}} = \frac{80\ \ Kg}{10^3\ Kg/m^3} = 8\cdot 10^{-2} m^3$

Then $F_{buoy,air} = m_{displ,air}g = D_{air}V_{person}g = \frac{Kg}{m^3}\cdot 8\cdot 10^{-2}m^3 \cdot 10\ \ \frac{m}{s^2} = 0.8\ \ N$

Q-2.2: Dead Sea water ($D_{dsw}=1.2\ gr/cm^3$)

The buoyancy force is equal to the weight of the volume of death sea water displaced by the person.

$$F_{buoy,dsw} = m_{displ,dsw}g = D_{dsw}V_{person}g \text{ where } D_{dsw} = 1.2\frac{gr}{cm^3} = 1.2\frac{10^{-3}Kg}{\left(10^{-2}\right)^3 m^3} = \frac{10^{-3}}{10^{-6}}\frac{Kg}{m^3} = 1.2\cdot 10^3\frac{Kg}{m^3}$$

Then $F_{buoy,dsw} = m_{displ,dsw}g = D_{dsw}V_{person}g = 1.2\cdot 10^3\frac{Kg}{m^3}\cdot 8\cdot 10^{-2}m^3 \cdot 10\ \ \frac{m}{s^2} = 960\ \ N$

Q-2.3: Calculate the intensity and the direction of the net force acting on the person in both cases.

The net force is in both cases equal to the difference between the buoyancy force exert by the fluid and the weight of the person. $W_{person} = mg = 800\ \ N$

$F_{net,air} = F_{buoy,air} - W_{person} = 0.8N - 800N = 799.2N \Rightarrow$ N.B. the buoyancy force of air is basically negligible.

$F_{net,dsw} = F_{buoy,dsw} - W_{person} = 960N - 800N = 160N \Rightarrow$ the person will tend to float

Q-2.4: If the person wants to dive at the bottom of the poll full of death sea water, how many 2 Kg lead weights she/he has to attach to her/his belt in order to be buoyancy neutral (zero net force). Neglect the buoyancy force of the weights.

The net force acting on the person must be zero.

Neglecting the buyancy force of the lead weights, all we need is that

$$F_{net} = F_{buoy,dsw} - W_{person} - N_{weights}\cdot W_{lead} = 0$$

$$W_{lead} = mg = 20\ \ N \Rightarrow\ N_{weights} = \frac{F_{buoy,dsw} - W_{person}}{W_{lead}} = \frac{160\ \ N}{20\ \ N} = 8$$

Name: ________________________________

Exercise 3

A 1 Kg rod of gold [specific heat=0.031 cal/(g °C)] falls freely (no air friction) through 100 m and it is stopped suddenly by the collision with the floor.

Q-3.1: What is the greatest temperature rise you would expect for the rod?

$$GPE = mgh = 1\ Kg \cdot 10\frac{m}{s^2} \cdot 100\ m = 10^3 J$$

At most all the GPE is transformed in heat released to the rod

$$\Delta T = \frac{Q}{cm} = \frac{GPE}{cm} = \frac{mgh}{cm} = \frac{gh}{c}$$

$$c = 3.1 \cdot 10^{-2}\ cal/(g \cdot {}^0C) = 3.1 \cdot 10^{-2} \cdot 4.2 \cdot 10^3\ J/(Kg \cdot K) \approx 130\ J/(Kg \cdot K)$$

Then $\Delta T = \frac{gh}{c} = 10\frac{m}{s^2} \cdot 100\ m \cdot \frac{1}{130}\frac{Kg \cdot K}{J} \approx 7.7\ K$

Q-3.2: If the coefficient of thermal expansion of gold is approximately $14 \cdot 10^{-6}\ K^{-1}$ what is the change in length of the rod after the fall if its initial length was 0.50 m?

$$\Delta L = \alpha L \Delta T = \frac{14 \cdot 10^{-6}}{K} \cdot 0.5\ m \cdot 7.7\ K \approx 54 \cdot 10^{-6} m = 54 \cdot \mu m$$

Q-3.3: Suppose that the rod has actually dropped into a furnace. Calculate the total heat (expressed in J) necessary to completely melt the rod and raise its temperature by ten degrees above the melting temperature (T_{melt}=1064 °C) if the rod had before the fall had a temperature of 1265.3 K. [Latent heat of gold L=63 KJ/Kg].

After the fall the ball has a temperature $T_{ground} = 1265.3 + 7.7 = 1273\ K$

First of all we need to add enough heat to arrive to the melting point

$T_{melt} = 1064\ {}^0C = 1337\ K$ so

$$Q_{to-melting-pnt} = cm\Delta T_{melt} = 130\ \frac{J}{Kg \cdot K} \cdot 1\ Kg \cdot (1337 - 1273)\ K = 8320\ J$$

Now we have to add the heat necessary to melt the rod

$$Q_{melt} = mL = 1\ Kg \cdot 63\ \frac{KJ}{Kg} = 63\ KJ = 63000\ J$$

Finally we need to rise the temperature by 10 degrees

$$Q_{to-final-pnt} = cm\Delta T_{fin} = 130\ \frac{J}{Kg \cdot K} \cdot 1\ Kg \cdot 10\ K = 1300\ J$$

So the total heat is $Q_{tot} = Q_{to-melting-pnt} + Q_{melt} + Q_{to-final-pnt} = 72620\ J$

Name: ________________________________

Exercise 4

A heat engine takes in 1000 J of energy at 727 °C and exhaust 600 J at 227 °C.

Q-4.1: What are the actual and maximum theoretical efficiencies of this heat engine?

$$\eta_{real} = \frac{W_{out}}{Q_{in}} = \frac{Q_{in} - Q_{out}}{Q_{in}} = \frac{1000 - 600}{1000} = 0.4 \Rightarrow 40\%$$

$$\eta_{ideal} = 1 - \frac{T_{cold}}{T_{hot}} = 1 - \frac{727 + 273}{227 + 273} = 1 - \frac{1000}{500} = 0.5 \Rightarrow 50\%$$

Q-4.2: If the hot region temperature is decreased to 501 °C how one would have to change the temperature of the cold region in order to get the same ideal theoretical efficiency?

$$\eta_{ideal} = 1 - \frac{T_{cold}}{T_{hot}} \Rightarrow T_{cold} = T_{hot} - \eta_{ideal} T_{hot} = 774 \ K - 0.5 \times 774 \ K = 387 \ K$$

Q-4.3: If in the new conditions the real efficiency is the same as before but the heat engine now takes in 1100 J of heat from the hot region, how much heat is exhausted to the cold region?

$$\eta_{real} = \frac{W_{out}}{Q_{in}} = \frac{Q_{in} - Q_{out}}{Q_{in}}$$

$$Q_{out} = Q_{in}\left(1 - \eta_{real}\right) = Q_{in} \times 0.6 = 660 \ J$$