Physics 200A FINALS Shankar 180mins
December 13, 2005
Formulas and figures at the end. Do problems in 4 books as indicated

I. **Book I** A camper is trying to boil water. The 55 g aluminum pan has specific heat $c = .92J/(gC^0)$, and holds $2000g$ of water. both at 5^oC.

(i) What will be the temperature after 5 minutes if the pan is on a 2300 Watt heater?

(ii) Next day she starts out doing the same except now rain at 15^oC is falling at the rate of $0.5g/s$. What will be the final temperature after 5 mins of heating? Assume that the pan and water are at the same temperature at the end. **20**

II. **Book I** An oil pipe has a narrow segment (called venturi) where the radius drops to half the regular value. If the flow rate in the main pipe is 1.9 m/s, and the pressure difference between the venturi and main pipe is 16kPa, what is the density of the oil?**10**

III. **Book I** An ideal gas with $\gamma = 5/3$ is taken through the cycle ABCA as shown in Figure 1 where A has coordinates $A = (1m^3, 250\ kPa)$. It expands adiabatically to triple its volume to reach B, is heated at constant volume to C and compressed isothermally back to A. Find (i) P_B, (ii) P_C , the pressures at B and C (iii) net work done and (iv) net heat input. **20**

IV. **Book II** Sketch the three lowest frequency modes of a string fixed at one end and free to vibrate at the other. How are the two higher frequencies related to the fundamental f_0? **10**

V. **Book II** A 250 g mass resting on a frictionless table is connected to a spring with $k = 27N/m$, which in turn is anchored on a vertical wall. The mass is pulled by 15 cm (from its equilibrium position $x = 0$) and released. (i) What is the total energy in the system? (ii) What is the speed when $x = 10\ cm$? (iii) Suppose the friction were nonzero. What coefficient of friction μ_k will ensure that upon release at $x = 15cm$ it comes to rest precisely upon reaching $x = 0$ for the first time? (We are treating the force of friction as independent of velocity.) **20**

VI. **Book II** A uniform cable hangs vertically under its own weight. What is the speed of waves y meters from the lower end? **10**

VII. **Book III** A painter of weight 600N, climbs a ladder of weight 200N, and length 8m, which rests against a frictionless wall. The coefficient of static friction between the ground and ladder is $\mu_s = .35$. If the ladder makes an angle of a 50^0 with the floor, what is the maximum height to which he can climb before the ladder slips? (First draw a free body diagram for the ladder (whose CM is at its midpoint). **25**

VIII. **Book III** An observer S who lives on the x-axis sees a flash of red light at $x = 1210m$. Then, after $4.96\mu s$, a flash of blue at $x = 480m$. Use subscripts R and B to label the coordinates of the events.
(i) What is the velocity relative to S of an observer S' who records the events as occurring at the same place?
(ii) Which event occurs first according to S' and what is the measured time interval between these flashes? For the former you do not need to do a calculation. For the latter I suggest using the space-time interval, **20**

IX: **Book IV** Show that a photon cannot break up into an electron and a positron. For our purposes the electron and positron are identical particles with four-momenta (with $c = 1$) $P_1 = m_0(\gamma_1,\ \gamma_1\mathbf{v}_1)$ and $P_2 = m_0(\gamma_2,\ \gamma_2\mathbf{v}_2)$ where $\gamma = 1/\sqrt{1-v^2}$. The photon four-momentum is $K = (\omega, \mathbf{k})$ with $\omega = |\mathbf{k}|$. I suggest you use energy-momentum conservation and the dot products of four vectors to show that this process is kinematically forbidden. **15**

X. **Book IV** A vine of length $17m$ hangs vertically at one side of a gorge of width $10m$ (See Figure 2). Tarzan runs up, grabs the vine swings over the gorge and drops on the other edge. What is the minimum speed he have must have when he grabs the vine? What is the tension on the vine when he first grabs it assuming he does so with the minimum speed? Assume he weighs 100kg . **20**

XI. **Book IV** A circular disc of mass 440g and radius 3.5cm is rotating at 180 rpm around a shaft of negligible radius. A second concentric disc of mass 270g and radius 2.3cm, initially at rest, drops on top of this one from above and the two spin together. Find the final speed in RPM and the fraction of

Kinetic Energy that is lost. What conservation law did you use and why? **10**

Data Sheet

$$c = 3 \cdot 10^8 \ m/s \qquad g = 9.8 m/s^2$$

$$x' = \frac{x - ut}{\sqrt{1 - u^2/c^2}} \qquad t' = \frac{t - ux/c^2}{\sqrt{1 - u^2/c^2}}$$

$$P = m_0\left(\frac{1}{\sqrt{1 - v^2}}, \frac{\mathbf{v}}{\sqrt{1 - v^2}}\right), \qquad P \cdot P = m_0^2, \qquad \text{c=1 here}$$

$$A \cdot B = A_0 B_0 - \mathbf{A} \cdot \mathbf{B} \quad \text{dot product of four vectors A and B}$$

$$\text{Spacetime interval} = s^2 = (ct)^2 - x^2$$

$$A_1 v_1 = A_2 v_2 \qquad P + \frac{1}{2}\rho v^2 + \rho g h = constant$$

$$\rho_{water} = 10^3 kg/m^3$$

$$\tau = I\alpha \qquad \tau = Fr\sin\theta$$

$$I = \sum_j m_j r_j^2 \qquad I_{discCM} = I_{cylinder} = \frac{1}{2} M R^2$$

$$v = \sqrt{T/\mu} \qquad v = \lambda f$$

$$c_{water} = 1 \ cal/(g^0 C) \qquad 1 \ cal = 4.2 J$$

$$\Delta Q = m C \Delta T$$

$$PV = nRT$$

$$W_{Adiabatic} = \frac{P_1 V_1 - P_2 V_2}{\gamma - 1}$$

$$\Delta U = \Delta Q - p dV \quad \text{Law I}$$

$$W = \int_1^2 P(V) dV$$

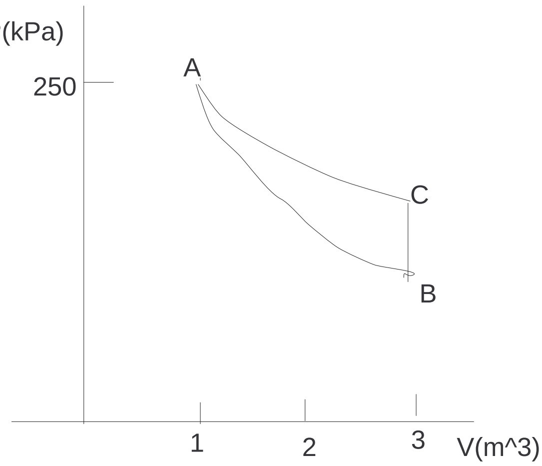

FIG. 1. The segment AB is adiabatic and CA is isothermal despite my rendering.

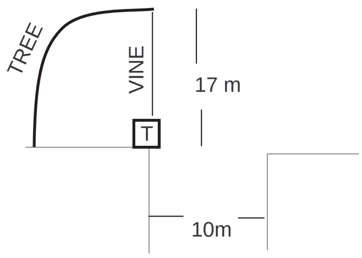

FIG. 2. "T" stands for Tarzan (whose height is to be neglected compared to that of the vine, 17 long)