Physics 7B, Fall 2007, Section 2, Instructor: Prof. Adrian Lee
Final Examination, Monday December 17, 2007

Please do work on these pages. You can use the backs and extra paper is supplied. You may use three double-sided 3.5” x 5” index card of notes and a calculator. Test duration is 3 hours. Please be explicit in your derivations, show your work, and box your answers!

Name ___________________________

Disc. Section _____________________

SID ____________________________

#1______ (40)

#2______ (20)

#3______ (30)

#4______ (30)

#5______ (40)

Total______ of 160

1. (*Giancoli, 20.66*) A real heat engine working between heat reservoirs at T_L = 400K and T_H = 850K produces W = 600J of work per cycle for a heat input of Q_{in} = 1600J. The heat output is labeled Q_{out}. In all subparts, please write your answer in terms of variables before putting in numbers. (*40 pts*)

a) What is the efficiency of this real engine? If the engine were a Carnot engine operating between the same two heat baths, what would the efficiency be? You can use the efficiency formula for a Carnot engine. (*10 pts*)

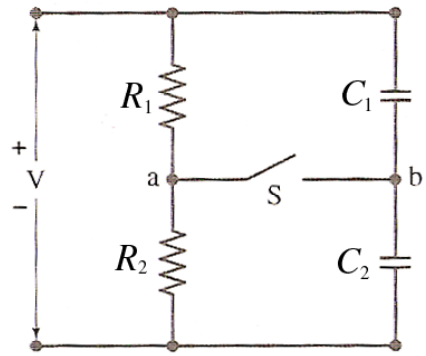
b) Calculate the total entropy change of the universe for each cycle of the real engine. (*10 pts*)

c) Calculate the total entropy change of the universe for a Carnot engine operating between the same two temperatures. Do not simply assert the answer, but provide a proof. (*10 pts*)

d) Show that the difference in work done by these two engines per cycle is $T_L \Delta S$, where ΔS is the entropy increase per cycle of the real engine. You can do this part numerically. i.e. you do not have to prove this from scratch. (*10 pts*)

Extra Paper. Indicate problem worked on.

2. Two resistors and two uncharged capacitors are arranged as shown in the figure below. Then, a potential difference, V, is applied across the combination as shown. (*30 pts*)



a) What is the potential at point a with S open? (*5 pts*)

b) What is the potential at point b with S open? (*5 pts*)

c) When the switch closed, what is the final potential at point b? (*10 pts*)

d) What is the total amount of charge that flows through the switch after it is closed? (*10 pts*)

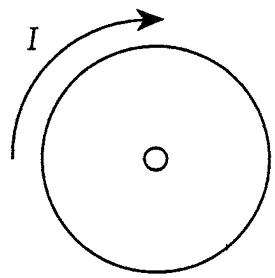
Extra work page (number your problems)

3. (*Giancoli, 30.3*)

Determine the mutual inductance per unit length between two long solenoids, one inside the other, whose radii are r_1 and r_2 ($r_2 < r_1$) and whose turns per unit length are n_1 and n_2, respectively. (*20 pts*)

Extra work page (number your problems)

4. A small circular metal ring of radius r is concentric with a large circular metal ring of radius $10r$. An unpictured power supply makes the current flow clockwise around the large ring. By adjusting the power supply, you can alter I, the current in the large ring. The graph below shows I(t). Notice that I increases linearly from I_0 to $2I_0$ from time $t = 0$ to time $t = T$. (*30 pts*)



a) Sketch a rough, qualitative graph of the current in the small ring as a function of time. On your graph, let 'positive' current correspond to current flowing CW in the ring. (*5 pts*)

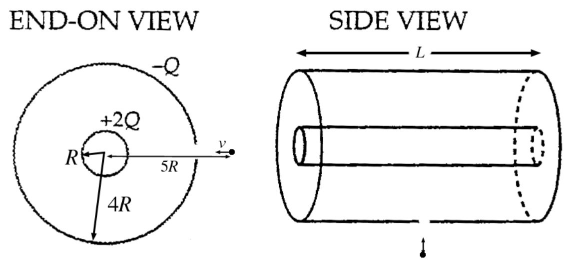
b) The small ring is made of a copper wire of cross-sectional area a. What is the resistance of the small ring? Let ρ_{Cu} be the resistivity of copper. Call your answer R. (*5 pts*)

c) Using the Biot-Savart rule, find the magnetic field, $\boldsymbol{B}$ (magnitude and direction) due to the large ring at the center of the small ring when the current in the large ring is 1.5 I_0. The direction can be described by words such as “into the page” or “out of the page.” (*10 pts*)

d) When the current in the large ring is 1.5 I_0, what is the current in the small ring? Neglect the small ring’s self inductance. Answer in terms of R, r, I_0, T, and any universal constants. The B field can be taken as uniform over the small ring. (*10 pts*)

Extra work page (number your problems)

5. Consider two concentric conducting cylindrical shells, both much longer than they are wide. The inner cylinder has radius R, while the outer one has radius $4R$. Both cylinders have length L. The inner cylinder carries a charge $+2Q$ and the outer one carries a charge $-Q$. A particle of mass M and change $-q$, is initially a radial distance $5R$ from the axis of the cylinder and in the middle of their lengths. It is initially moving with velocity v directly towards the axis of the cylinders. You can neglect gravity. (*40 pts*)



a) How fast is the particle moving when it reaches the outer cylinder? (Hint: What is the particle's kinetic energy when it reaches the outer cylinder?). (*15 pts*)

b) The particle passes through a small hole in the outer cylinder. How fast is it moving when it reaches the inner cylinder? (You may use the variable v_a for the answer from part (a)) (*15 pts*)

c) The whole experiment is repeated, except the space between the two cylinders is filled with a dielectric. When the particle reaches the outer cylinder is it moving faster, slower, or the same as in part (a)? Explain your reasoning. (*5 pts*)

d) When the particle reaches the outer cylinder is it moving faster, slower, or the same as in part (b)? Explain your reasoning. The dielectric doesn't obstruct the particle. (*5 pts*)

Extra work page (number your problems)