ENGINEERING 2C03

DAY CLASS — Dr. Wm. Garland

DURATION: 3 hours

McMASTER UNIVERSITY FINAL EXAMINATION — April 11, 2001

Special Instructions:

1. Closed Book. All calculators and up to 6 single sided 8 ½" by 11" crib sheets are permitted.
2. Do all questions.
3. The value of each part is as indicated. TOTAL Value: 100 marks

THIS EXAMINATION PAPER INCLUDES 2 PAGES AND 8 QUESTIONS. YOU ARE RESPONSIBLE FOR ENSURING THAT YOUR COPY OF THE PAPER IS COMPLETE. BRING ANY DISCREPANCY TO THE ATTENTION OF YOUR INVIGILATOR.

1. [10 marks] What is the required resistance of an immersion heater that will increase the temperature of 1.5 kg of water from 10 °C to 50 °C in 10 min while operating at 110 V? The heat capacity of water is 4186 J / kg °C.

2. [10 marks] Assume that a galvanometer has an internal resistance of 60.0 Ω and requires a current of 0.500 mA to produce full-scale deflection. What resistance must be connected in parallel with the galvanometer if the combination is to serve as an ammeter that has a full-scale deflection for a current of 0.100 A?

3. [15 marks] A 4.00 MΩ resistor and a 3.00 μF capacitor are connected in series with a 12.0 V power supply.
   a. What is the time constant for the circuit?
   b. Express the current in the circuit and the charge on the capacitor as functions of time.

4. [10 marks] A series RLC circuit consists of an 8.00 Ω resistor, a 5.00 μF capacitor, and a 50.0 mH inductor. A variable frequency source of amplitude 400 V (rms) is applied across the combination. Determine the power delivered to the circuit when the frequency is equal to one half the resonance frequency.

5. [10 marks] An automobile tire is inflated using air originally at 10 °C and normal atmospheric pressure. During the process, the air is compressed to 28 % of its original volume and the temperature is increased to 40 °C.
   a. What is the tire pressure?
   b. After the car is driven at high speed, the tire air temperature rises to 85 °C and the interior volume of the tire increases by 2%. What is the new tire pressure in pascals (absolute)?

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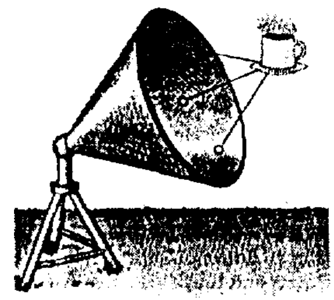
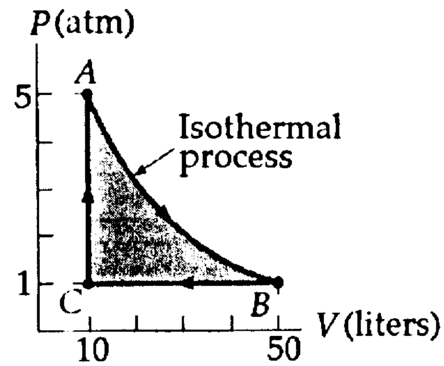
6. [10 marks] A "solar cooker" consists of a curved reflecting mirror that focuses sunlight onto the object to be heated (see the figure). The solar power per unit area reaching the Earth at some location is 600 W/m^2, and the cooker has a diameter of 0.60 m. Assuming that 40% of the incident energy is converted into thermal energy, how long would it take to completely boil off 0.50 liters of water initially at 20 °C? The heat capacity of water is 4186 J / kg °C and the latent heat of vapourization for water is 2260 kJ/kg. Neglect the heat capacity of the container.



7. [15 marks] One mole of an ideal monatomic gas is taken through the cycle shown in the figure. The process AB is a reversible isothermal expansion. For the cycle:
   a. calculate the work done by the gas,.
   b. calculate the thermal energy added to the gas.



8. [20 marks] A large concrete slab of thickness 1 m has just been poured on the ground. The ground temperature is a constant T_0 and the surface air temperature is T_1. During the curing process, heat (q) is generated in the concrete. Assume the initial temperature of the concrete is the average of the air and ground temperatures. The governing partial differential equation for the transient heat diffusion process is

$$\rho c \frac{\partial T(x,t)}{\partial t} = q + k \frac{\partial}{\partial x}\left(\frac{\partial T(x,t)}{\partial x}\right)$$

where T is temperature, x is distance into the slab, t is time, q is heat generated per unit volume per unit time, ρ is the density, c is the heat capacity and k is the conductivity. Given that the concrete surface temperatures are that of the soil and air and that the soil and air remain at their initial temperatures, devise a numerical solution to find T as a function of x and t as follows:
   a. Sketch the physical setup, showing the spatial grid that you have chosen and the initial temperature distribution in the soil, concrete and air.
   b. Derive the finite difference form of the above partial differential equation.
   c. Devise a solution scheme to calculate T for each grid point in space as time evolves.
   d. Sketch an educated guess at the temperature distribution in the slab as time evolves.
   e. Eventually, the curing process stops. What is the eventual temperature distribution in that case?

The End