PRELIMINARY EXAMINATION

DEPARTMENT OF PHYSICS
UNIVERSITY OF FLORIDA
Part D, 9 January 2001, 14:00 - 17:00

D1. (a) (2 points) Estimate at what temperature carbon burns in stars (through the $C^{12} + C^{12}$ reaction). You may wish to recall that the electron binding energy for hydrogen is 13.6 eV.

(b) (2 points) Estimate above what temperature hydrogen is ionized in stellar envelopes.

(c) (6 points) Calculate the degree of ionization ($\alpha = n_+/n_H$) assuming that the temperature is 11,000 K and that the density is 10^{-8} g/cm^3. To generate the solution, set up the ionization equilibrium equation (Saha equation), and you can disregard the internal excited states of H. The Saha equation, in general form, may be written as

$$\frac{\alpha^2}{1-\alpha} = \frac{1}{n}\left(\frac{m_e k_B T}{2\pi\hbar^2}\right)^{3/2} e^{-I_o/(k_B T)} \quad ,$$

where I_o is the ionization energy of H.

You may want to recall that the free energy of a perfect monoatomic gas is

$$F = Nk_BT \ln\left(g\left(\frac{M\,k_B\,T}{2\pi\hbar^2}\right)^{3/2} \frac{V}{eN}\right)$$

where g is the internal partition function.

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D2. A large coal-fired electric power plant has a delivery capacity of 1000 MW. The boilers deliver steam to the turbine at 600 C. After passing through the turbine the steam is eventually condensed to water at 100 C. If needed, you may take the specific heat of water to be 1.0 cal/(g C) at a pressure of 1 bar and that the specific heat of steam to be 0.5 cal/(g C).

(a) (3 points) What is the maximum theoretical (Carnot) efficiency of this engine?

(b) (3 points) If the overall efficiency of this plant is 40%, how much waste heat is produced in a 24-hour period, assuming that the plant is operating at full capacity?

(c) (2 points) The waste heat (in part (b) above) is removed by water from an external source flowing through cooling towers. This water enters at a temperature of 20 C and is discharged at 40 C. What quantity of cooling water is required per day?

(d) (2 points) Explain why the spent steam emerging from the turbine is condensed to water. Why would not less waste heat be generated by simply pumping the "cool" steam back to the boiler?

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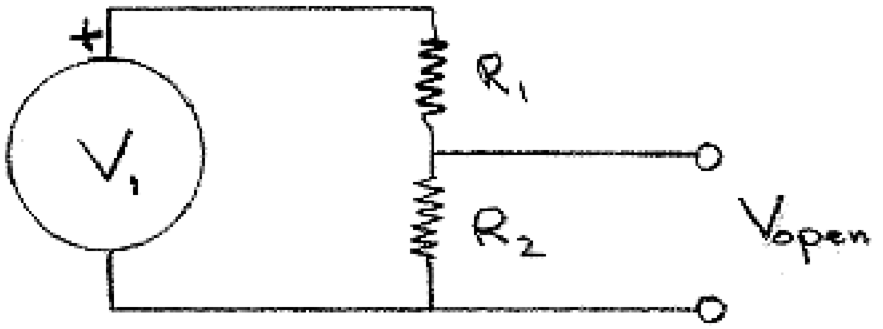
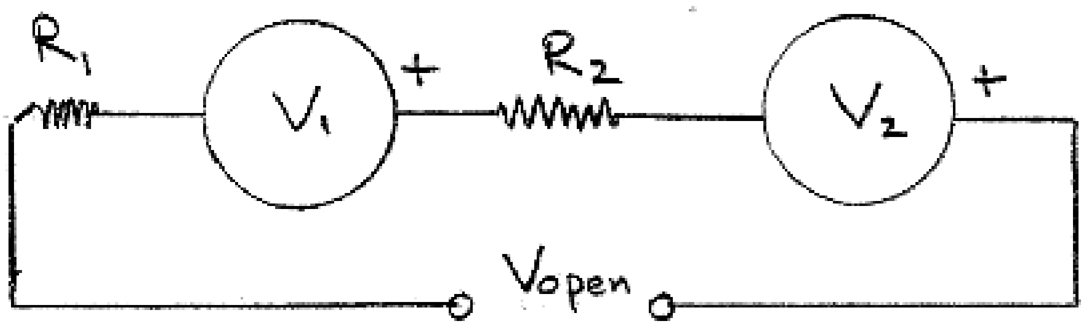
D3. Thévenin's theorem states that any two-terminal network of resistors and voltage sources is equivalent to a single resistor R_{th} in series with a single voltage source V_{th}. To find the Thévenin equivalents V_{th} and R_{th} for a given circuit, calculate the open circuit voltage V_{open} appearing across the output terminals when no load is attached, and separately calculate the short circuit current I_{short} that will flow through a wire of zero resistance connected across the terminals. The Thévenin equivalents V_{th} and R_{th} can then be calculated from $V_{th} = V_{open}$ and $R_{th} = V_{open}/I_{short}$.

Find the Thévenin equivalents V_{th} and R_{th} for the following circuits. Assume the batteries are ideal voltage sources, unless internal resistances are indicated, and ignore chemical effects that, in real life, would cause their voltages to change as the currents are drawn.

(a) (3 points) A voltage divider.



(b) (3 points) Two batteries with voltages V_1 and V_2 ($V_1 \neq V_2$) and internal resistances R_1 and R_2 ($R_1 \neq R_2$) connected in series.



(c) (4 points) The same two batteries described in (b), but now connected in parallel.