University of California, Berkeley
Physics 7B, Lecture 001, Spring 2009 (*Xiaosheng Huang*)

Final Exam
Thursday, 5/14/2009
8:00 – 11:00 AM

Name:_______________________SID: ________________________

D/L Section:__________________GSI: ________________________

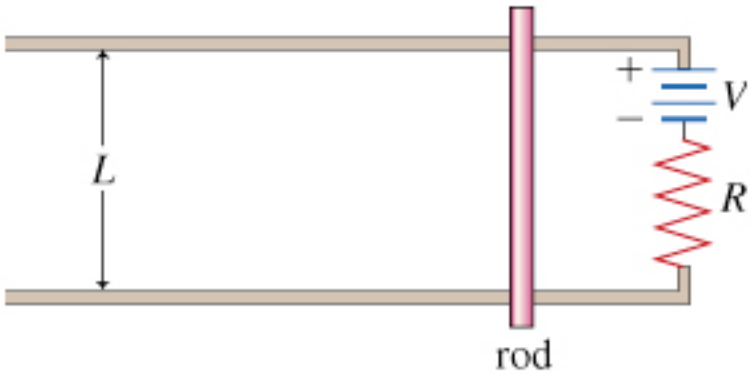
Physical Constants:
Avogadro's number, N_A: 6.02×10^{23}
Gas Constant, R: 8.315J/mol·K
Boltmann's Constant, k_B: 1.38×10^{-23} J/K
Stefan-Boltzmann Constant, σ: 5.67×10^{-8} W/m^2·K^4
Standard Temperature and Pressure (STP): T=273K, P=1atm=1.01×10^5 Pa
Atomic mass unit (1u): 1.6605×10^{-27} kg
Speed of light, c: 3.00×10^8 m/s
Mass of electron, m_e: 9.11×10^{-31} kg
Elemental charge, e: 1.60×10^{-19} C
Permittivity of free space, ε_0: 8.85×10^{-12} C^2/N·m^2
Permeability of free space, μ_0: $4\pi\times10^{-7}$ T·m/A

Note: *You are allowed three formula sheets (3½" by 5", double sided) and a calculator (without wireless capabilities). Do NOT just write down an answer in the answer box; show your steps. Formulaic answers may only involve the quantities given in a problem and constants. Please pay attention to whether you are asked to give a numerical answer or a formulaic answer. Best of Luck!*

#1	
#2	
#3	
#4	
#5	
#6	
#7	
Total	

"Joy and amazement of the beauty and grandeur of this world of which man can just form a faint notion ..."
-Albert Einstein

1. (15 pts.) A conducting rod with mass m is free to slide on two parallel rails separated by a distance L with negligible friction. At the right end of the rails, a voltage source of strength V in series with a resistor of resistance R makes a closed circuit together with the rails and the rod. The rails and the rod are taken to be perfect conductors. The rails extend to infinity on the left. There is a uniform magnetic field of magnitude B, pervading all space, perpendicular to the plane of rod and rails. The rod is released from rest, and it is observed that it accelerates to the left.



a) In what direction does the magnetic field point?

Answer:

b) What is the acceleration of the rod as a function of time, $a(t)$? Express your answer in terms of the velocity of the rod, $v(t)$, and other relevant quantities given in the problem.

Answer:

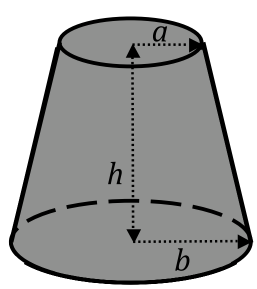
c) What is the terminal velocity, v_t, reached by the rod?

Answer:

Bonus (5 pts.): *d*) Find the velocity of the rod as a function of time, $v(t)$.

Answer:

2. (10 pts.) A resistor has the shape of a truncated cone. The radius of one end surface is a and the other is b, with $b>a$. The height of the resistor is h. If it has uniform resistivity ρ, find the total resistance.



Answer:

3. (15 pts.) Suppose we have a system of four coins. The heads side of each of the coins is a little heavier than the tails side. For convenience, let us set the reference point of the potential energy to be the value when the light (tails) side is up. That is, when the tails side is up, the potential energy of the coin is zero. When the heavy (heads) side is up, the potential energy is ε. Treat all four coins as identical.

a) For the macrostate of 2 heads and 2 tails, find the number of microstates. (You can compute the number or tabulate (enumerate) all the possibilities—but you have to show how you arrive at your answer.)

Answer:

For the macrostate described in *a*),

b) What is the entropy of the system?

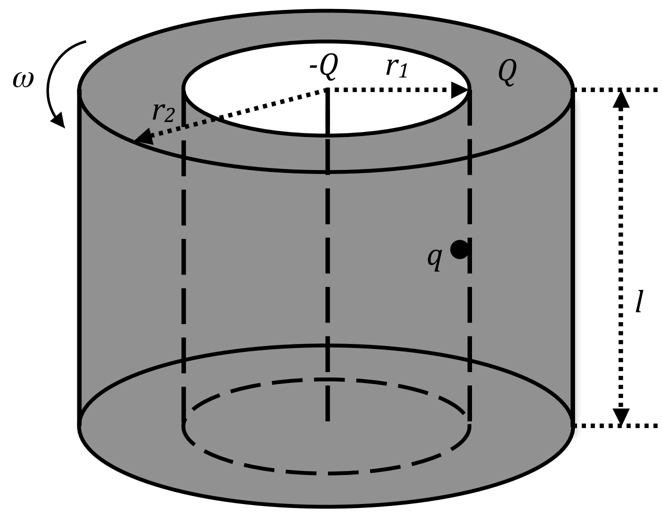
Answer:

c) By using $1/T=(\partial S/\partial U)_N$, where N is the total number of coins and U the total energy of the system, estimate the temperature of the system. Suppose $\varepsilon=1\times10^{-4}$ J. (*Hint*: If one of the coins is flipped from heads to tails, how do the entropy and the total energy change?) In reality, this, or any other, definition of temperature works well only when there are many (typically around the Avogadro's number of) coins. Here we simply want to illustrate the principles.

Formulaic Answer:

Numerical Answer:

4. (20 pts.) A straight wire is surrounded by a concentric cylindrical shell with inner and outer radii r_1 and r_2. Both the wire and the cylinder are of length l. Assume that $l >> r_1$, r_2. The cylindrical shell carries a total amount of electric charge Q, which is uniformly distributed throughout the shell. The wire carries $-Q$, uniformly distributed along its length. The cylindrical shell spins around its axis with an angular velocity ω.



a) Find the magnitude and direction of the magnetic field for $r<r_1$.

Answer:

b) Find the magnitude and direction of the electric field for $r<r_1$.

Answer:

A small positive charge q is stuck on the inner wall of the cylindrical shell. This charge is so small that the electric and magnetic fields are virtually unperturbed by its presence.

c) Find the direction and magnitude of the electric force on q.

Answer:

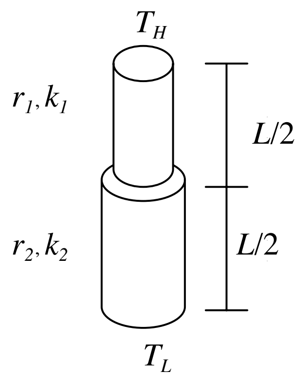
d) Find the direction and magnitude of the magnetic force on q.

Answer:

e) Find the angular velocity at which the electric force and the magnetic force are equal. Is this possible? (*Hint*: $\mu_0\varepsilon_0 = 1/c^2$ and nothing can have a linear velocity, v, that is greater than the speed of light, c.)

Answer:

5. (10 pts.) One way heat can enter a cryogenic experiment is through the wires that are required to make electrical measurements.



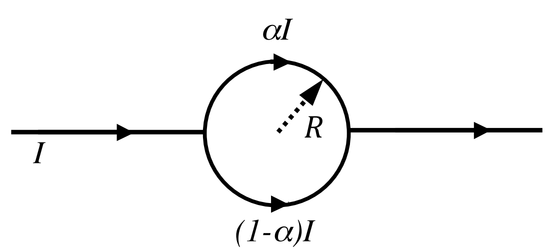
a) Find the heat leak, $\dot{Q}$=dQ/dt, from a round wire of length L. The top half has radius r_1 and thermal conductivity k_1 and the bottom half has radius r_2 and thermal conductivity k_2. The top end of the wire is connected to a temperature T_H and the bottom end goes to the experiment at low temperature T_L.

Answer:

b) Assume a Carnot refrigerator removes the heat from the cold experiment at the rate $\dot{Q}$ calculated in part *a*) and delivers it to ambient temperature T_H. Find the power required for the electric motor operating the refrigerator. (Express your answer in terms of $\dot{Q}$ and other relevant quantities that are given in this problem.)

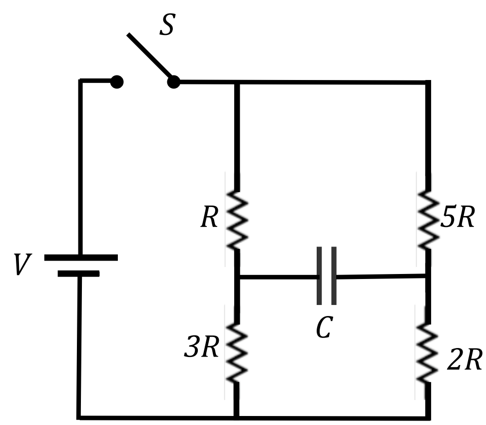
Answer:

6. (10 pts.) A circular conducting ring of radius R is connected to two straight exterior wires ending at two ends of a diameter. The current I splits into unequal portions (α<1) while passing through the ring. What is **B** at the center of the ring?



Answer:

7. (20 pts.) In the circuit below, switch S is closed at time t=0.



a) After the capacitor is fully charged, what is the voltage across it?

Answer:

b) How much charge is on it?

Answer:

c) Switch *S* is now opened. How long does it take for the capacitor to discharge until it has only a fraction $1/e$ of its initial charge, where $e \approx 2.718$?

Answer:

d) Going back to t=0 when the switch was first closed, it would take a certain amount of time to charge up the capacitor. What is $Q(t)$? You are only required to set up the equations necessary for finding $Q(t)$ but you do not need to solve them. Your answer should have equal number of unknowns and independent equations.

Answer:

The End

Have A Great Summer!