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High School Physics

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Thermodynamics

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Questions:

1) Ice Melting in Water

An urn of cross sectional area A is filled with water. The temperature of the water is $T_w = 0^0 C$. The sides of the urn are insulated whilst the bottom is not and is resting on a heated surface of power H. The heat from the heated surface travels through the bottom of the urn.
The bottom of the urn has thickness D and is made of copper. The heated surface is switched on, and at that exact moment, an ice cube, of mass m_{Ice}, is added to the urn. After a time of t_1 has passed, the ice cube is removed from the urn. The mass of the ice cube is now half its original mass. Assume that the thermal conductivity of copper (k), the heat capacity of the ice (C_{Ice}), and the latent heat for melting ice (L) is given.

a. What was the temperature of the ice cube when it was removed from the urn?
b. What was the ice cube's temperature at $t = 0$?
c. Had the ice cube not been removed from the urn, how long would it have taken for the ice cube to fully melt?
d. Now the heated surface is removed, and the bottom of the urn is also insulated. The ice cube is added to the urn. Will the ice cube's mass increase, decrease, or remain the same?

2) A Ball is Falling

A lead ball, of mass m, is dropped from a height h. After hitting the floor, the ball bounces back to a height of $\frac{h}{10}$. The heat capacity of the lead is C_{pb}, the latent heat of the lead is L_{fus}, and melting point is T_{mpb}.

a. How much heat is transferred to the ball due to it hitting the floor?
b. What is the change in internal energy due to the ball hitting the floor?
c. The temperature of the ball before its fall is T_0.
Calculate its temperature after it hits the ground.
d. After hitting the floor, the lead ball will always bounce to $\frac{1}{10}\text{th}$ of its original height.
All the energy from the collision with the ground has transferred to the ball.
From what height must the ball be dropped, such that it will completely melt?

3) Oven Insulation

See the oven diagram blow.

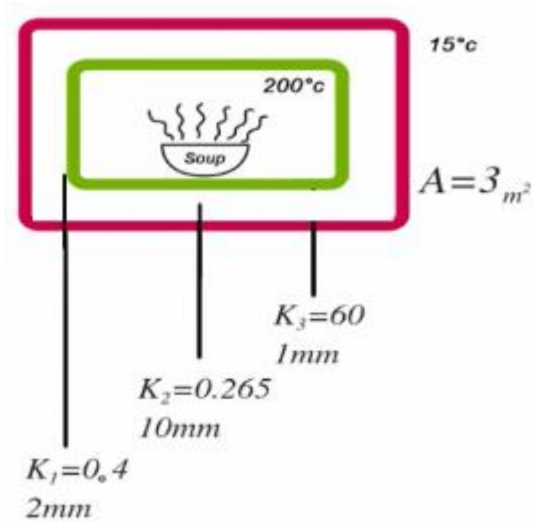
a. What is the oven's thermal resistance?

b. How much energy is required in order to keep the oven at $200°C$?

Now we are told that the oven is not insulated.

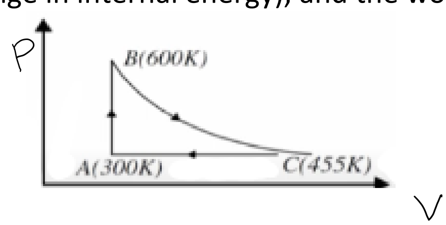
c. How much energy is required, now, in order for the oven to stay at $200°C$?

d. If the same energy as in part b. is put into the system, what will be the temperature inside the oven?



4) Cycle Calculations

For each stage in the following diagram, calculate the heat (or change in heat), the internal energy (or change in internal energy), and the work done by the system.



Answer Key:

1) a. $T_{Ice} = 0°C$ b. $T_i = -\frac{Ht_1 - \frac{1}{2}L_{Ice}m_{Ice}}{m_{Ice}C_{Ice}}$ c. $t_2 = \frac{m_{Ice}C_{Ice}\Delta T + h_{Ice}m_{Ice}}{H}$

d. Increase.

2) a. $Q = \Delta E = mgh - mg\frac{h}{10}$ b. $Q = mgh - mg\frac{h}{10}$ c. $T_f = \frac{\frac{9}{10}gh}{c} + T_0$

d. $h = \frac{10}{9mg}\left(mC_{pb}\left(T_{mpb} - T_0\right) + L_{fus} \cdot m\right)$

3) a. $R_T \simeq 0.013$ b. $\dot{Q} = \frac{\Delta T}{R} \simeq 14,260\text{W}$ c. $\dot{Q} \simeq 185,000\text{W}$ d. $29.26°C$

4) **AB:** $W = 0,\ \ U = Q = 3,740J$, **BC:** $Q = 0,\ \ \Delta U = W = -1,807J$,
CA: $\Delta U = -1,932J,\quad \Delta Q = -3,220J,\quad W = -1,288J$