Quiz # 6

Physics 222, Section 002

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1. If we were to conduct a 'Joule Equivalent of Electrical Energy' experiment identical to the one we actually did, except that we use a liquid that has half the specific heat capacity of water, but having the same mass, then (you may choose more than one):
   - (a) We must heat the system for a longer time before it reaches the same temperature as the one that used water.
   - ✓ (b) We must heat the system for a shorter time before it reaches the same temperature as the one that used water.
   - (c) The equivalent of electrical energy calculated using the new set up would increase.
   - (d) The equivalent of electrical energy calculated using the new set up would decrease.
   - (e) The heat capacity of the system would increase.

2. In yet another the 'Joule Equivalent' experiment, suppose we forgot to stir the water regularly as we heated the system, what consequence(s) should we expect, assuming that the temperature sensor lies at a distance from the heating element?
   Hint: Our estimate of J is inversely proportional to the slope of the T versus t graph.
   - (a) A bigger slope of the T versus t graph.
   - ✓ (b) A smaller slope of the T versus t graph.
   - ✓ (c) An apparent lack of conservation of energy.
   - (d) A smaller estimate of J.
   - ✓ (e) A larger estimate of J.

3. In today's experiment we will use an instrument known as the Helmholtz coils. **Choose a single incorrect statement** about these coils:
   - (a) Near the center of the coils the magnetic field is (to a good approximation) uniform.
   - ✓ (b) Ideally, the most accurate measurement of the e/m ratio using this apparatus is done when the radius of the electron's path is almost the same as the coil's radius.
   - (c) The magnetic fields produced by the two coils are directed in such a way that they reinforce each other.
   - (d) The current passing through the coils has to be constant during a single measurement.
   - (e) The direction of the Helmholtz magnetic field is perpendicular to the direction of the electrons' motion.

Explanation of Solution

1. **(2 points)** Choice **(b)** is only correct. Here is why. If we deliver an amount of heat Q to some material of mass m and specific heat c, then its temperature will be raised by an amount ΔT:

$$Q = m\, c\, \Delta T$$

   If the two experiments are identical except for the specific heat capacity then to get the same temperature difference ΔT using the same current I and voltage V, we have to heat for a different period of time t, since $Q = I\, V\, t$, therefore:

$$\Delta T_1 = \Delta T_2 \Rightarrow \frac{Q_1}{mc_1} = \frac{Q_2}{mc_2} \Rightarrow \frac{IVt_1}{c_1} = \frac{IVt_2}{c_2} \Rightarrow \boxed{t_2 = \frac{c_2}{c_1} t_1}$$

   and since $c_2 < c_1$ then we have $t_2 < t_1$.

2. **(2 points per choice)** Choices **(b)**, **(c)**, and **(e)** are correct. To say why, let's start by considering the conservation of energy equation (in Joules) that we're using:

$$Q = Jmc\Delta T = IV\Delta t \Rightarrow \boxed{J = \frac{IV}{mc\left(\Delta T / \Delta t\right)}}$$

   Because we are not stirring, and because the system is isolated, we expect a smaller change in temperature over a given period Δt compared to the situation when we are stirring, and therefore $\Delta T/\Delta t$ would be less, and hence (b) is correct, but not (a).

   As for (c), given that we know the energy we're putting into the system, IVT, and the mass and specific heat capacity c, we expect a certain change in temperature as predicted by energy conservation. But upon measurement, we read a smaller change, and we thus observe an "apparent" loss of energy.

   Finally, because $\Delta T/\Delta t$ is less than the case when the liquid is stirred, and from the equation above, the estimate of J we get is larger, which means that (e) is correct, but not (d).

3. **(2 points)** As we go away from the center of the coils towards the coils themselves, the field is not as uniform, and hence, our equations no longer accurately describe the situation.