**PHSX 101L** **Experiment 8** **Name:**_____

Title: Thermal Equivalent of Mechanical Work

Object: To experimentally measure the thermal equivalent (in calories) produced by a known amount of mechanical work (in joules), and thus calculate the number of joules in one calorie.

Historical Note: The discipline of physics began gradually even before Aristotle—they called it "natural philosophy" back then. There were what we would now call furtive efforts to describe their universe. By the time of Aristotle the universe was considered to be composed of the Sun, the Moon, many twinkly things a few thousand feet in the air (some of which had strange motions), and the Earth. The Earth was thought to be composed of combinations of four substances: earth, water, air, and fire. Our understanding has improved since then. We know about the several (approximately 100) elements and their combinations, we know that water is but one of those many combinations, we have studied the mixture of gasses which make up the air, but we still stumble a lot about Aristotle's "fire." By the time of the Renaissance, the "fire" was thought to be a fluid substance, then called "caloric," which flowed from one object to another by virtue of a temperature difference, and the amount of which was constant/conserved in the universe. Count Rumford (née Benjamin Thompson, 1753-1814), while he was supervising the boring of canon, realized that this concept was nonsense, but for a century few would acknowledge the validity of his very important discovery.

Currently most physics textbooks do acknowledge this—they say that there is no such thing as "caloric"—and then the authors go right on talking about "heat" as if it were a fluid which moves from one place or object to another: they teach that "heat" moves from hot things to cold things, that "heat rises," and about the amount of "heat" inside an object or system.

There is no such thing as "heat"—there are hot *things* but no object or substance called "heat." Hot *air* rises, for example, but heat doesn't rise since it doesn't exist. (The word "heat" can be correctly used as a verb, but we'll avoid its use as a noun.)

The result is that physics has retained much of the old language of thermodynamics and made it very difficult to talk or write about. Thus the language of this presentation seems a little strained—it is correct but admittedly not the way most physics texts would present it.

Theory: The energy of an object can be increased by doing work on the object. Historically the unit of measure for thermal energy has been the calorie (defined historically as the amount of "heat" required to raise the temperature of one gram of water one degree Celsius, from 14.5 °C to 15.5 °C), but the official unit of mechanical work is the joule (defined as the product of one newton of force acting through one meter of distance).

If we do work on an object by exerting a force and moving the object through a distance the product of these two quantities will give the number of joules of work, which can then be compared to the number of calories of thermal energy (so use grams for $m$ and °C for $\Delta T$).

$$\text{(work in joules)} = \text{(thermal energy in calories)} \quad (1)$$

$$\text{(force in newtons)(distance in meters)} = \text{(specific heat)(mass)(temperature rise)} \quad (2)$$

Procedure: The apparatus consists of an aluminum cylinder around which is wrapped a nylon cord. With a weight hanging on the cord to provide a known tension force, the cylinder is rotated by means of a crank, and the number of turns is counted. The frictional force created as the cord rubs against the surface of the cylinder does work, which raises the temperature of the aluminum cylinder. A thermistor embedded in the aluminum cylinder makes it possible to determine the temperature of the cylinder by measuring its resistance with an ohmmeter. From a graph of resistance versus temperature, we can determine the cylinder's temperature.

Apparatus: Draw a diagram of the apparatus used.

Results: Trial 1 Trial 2

1. Specific heat of aluminum: _____
2. Mass of aluminum cylinder: _____
3. Initial resistance: _____ _____
4. Final resistance: _____ _____
5. Initial temperature: _____ _____
6. Final temperature: _____ _____
7. Thermal energy (in calories): _____ _____

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8. Mass hanging on cord: _____
9. Weight of hanging mass: _____
10. Cylinder: Dia.: _____ Circumf.: _____
11. Number of revolutions: _____ _____
12. Total distance: _____ _____
13. Work done (in joules): _____ _____

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14. Time spent cranking: _____ _____
15. Joules per calorie found here: _____ _____
16. Accepted value for joules per calorie: _____
17. Percent difference between 15 and 16: _____ _____

Questions:

1. What technique did you use to minimize thermal energy loss or gain from the room? Did trial 2 yield a better result than trial 1? Why or why not?

2. Approximately what power (in watts) was provided by the person turning the crank?

3. How long would it take to heat water for a bath using this technique? (Assume 40 liters of water being heated from 15°C to 39°C.)

Conclusions: