Lab 4: Mechanical Equivalent of Heat

● Graded

Student

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Total Points

90 / 97 pts

Question 1

Data tables — **5** / 5 pts

✔ **– 0 pts** Correct

Question 2

Regression plot — **7** / 7 pts

✔ **– 0 pts** Correct

Question 3

LINEST results — **5** / 5 pts

✔ **– 0 pts** Correct

Question 4

Four line summary of six values — **5** / 5 pts

✔ **– 0 pts** Correct

Question 5

Four line summary of slope — **5** / 5 pts

✔ **– 0 pts** Correct

Question 6

Four line summary of y-it — **5** / 5 pts

✔ **– 0 pts** Correct

Question 7

Sample Calculations — **10** / 10 pts

✔ **– 0 pts** Correct

Question 8

Questions

11 / 15 pts

– 0 pts Correct

– 4 pts Point adjustment

1 And therefore you can do 1/4 the number of cranks to get the same amount of work (-1)

2 When the ribbon is wrapped around the calorimeter with the weight attached, it might compress the calorimeter a bit, so that D2 < D1. Taking the average of these two values would help avoid this systematic error (-1)

3 By Newton's Third Law, the force the ribbon exerts on the calorimeter is the same magnitude as the force the calorimeter exerts on the ribbon. The force is exerted over the same distance, so the work done on the ribbon by the calorimeter is the same as the work done on the calorimeter by the ribbon. Therefore the ribbon receives the same amount of heat as the calorimeter in a given trial. (-2)

Question 9

Error analysis worksheet

12 / 15 pts

– 0 pts Correct

– 3 pts Point adjustment

4 This would be a systematic error, as it would always lead to a too-small value for the work. -1

5 units!! And what about mass measurement? -2

6 As long as you recorded the correct number of cranks and the correct temperature, this should not have lead to appreciable error.

7 This is a very reasonable explanation. Nice job.

Question 10

Challenge

25 / 25 pts

✔ **– 0 pts** Correct

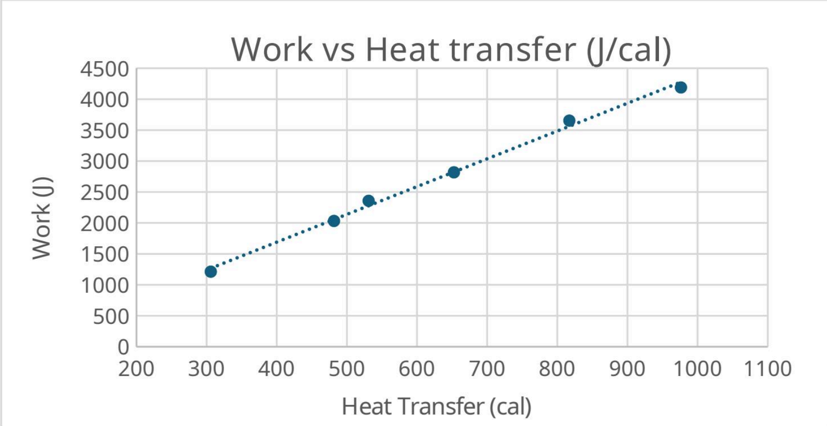
Question assigned to the following page: 1

m_{cal} (g)	Hanging mass (kg)	T_{Room} (◦C)	*D of cal.* (m)	Gravity (m/s^2)	Specific heat of water (cal/g*c)	Specific heat of brass (cal/g*c)
362.7	5	22.8	0.05426	9.81	1	0.094

Trial #	$T_{Initial}$ (◦C)	T_{Final} (◦C)	m_{Br} + m_{water} (g)	m_{water} (g)	Heat Transfer (cal)	Work done (J)	Work done/heat transfer (J/cal)
1	18.3	27.3	419.4	56.7	817.1442	3653.8449212	4.47148119169
2	19.1	26.5	416.8	54.1	652.63412	2817.7248019	4.31746474109
3	20.1	25.5	417.8	55.1	481.64652	2031.7718898	4.21838797843
4	19.6	26.1	410.3	47.6	531.0097	2357.8587363	4.44033081944
5	17.1	28.6	413.5	50.8	976.2787	4188.9617975	4.29074381888
6	21.1	24.5	418.6	55.9	305.97892	1212.3741729	3.96228005817

Initial count value	Final count value	N (# of cranks)
5443	5880	437
5880	6217	337
6217	6460	243
6463	6745	282
6796	7297	501
7297	7442	145

Questions assigned to the following page: 2, 3, 4, 5, and 6



St.dev (J/cal)	0.18361
Mean (J/cal)	4.28345
SE (J/cal)	0.07496
AE (J/cal)	0.14692

	Slope (J/cal)	Y-int (J)
Mean	4.4898678464	-106.7389935
SE	0.1496258739	99.52002593
AE	0.2932667129	195.05925082

Slope of Work/Heat Transfer (J/cal)
Result: 4.5 +/- 0.3
Range: 4.2 to 4.8
Expected: 4.184
Agree? No

average of Work/Heat Transfer (J/cal)
Result: 4.28 +/- 0.15
Range: 4.13 to 4.43
Expected: 4.184
Agree? Yes

Y-int of Work(J)
Result: -110 +/- 200
Range: -310 to 110
Expected: 0
Agree? Yes

Question assigned to the following page: 8

Questions:

1. As the ribbon moves against the brass, friction causes it to heat up. This heat then transfers to the brass and water, increasing their temperatures. The heat transfer can be calculated using $Q = mc\ \Delta T$, where m is the mass, c is the specific heat capacity, and ΔT is the temperature change. In a typical trial, the ribbon receives about 817 calories of heat, showing how mechanical energy turns into thermal energy.

2. If the mass were 20 kg, the ribbon would press harder against the brass, creating more friction. This would increase the work done, given by $W = \pi\ Mg\ ND$, where M is the mass, g is gravity, N is the number of cranks, and D is the calorimeter's diameter. More work would mean greater heat transfer, following $Q = mc\ \Delta T$, causing the brass and water to warm up more. However, too much friction could make cranking harder or less smooth, affecting the experiment.

3. The manufacturer suggests using the average diameter (D1+D2)/2 because the ribbon adds a small extra thickness to the calorimeter. This increases the actual surface the ribbon moves across, slightly changing the effective diameter. Using the average help measures the work done more accurately, making the experiment's results more precise.

Question assigned to the following page: 9

Error:

1. Thermometer (+/- .1)
   Caliper Measurement (+/- .1)

2. The most prominent sources of random error in this lab came from some fluctuations in temperature readings and the inconsistencies in cranking count/speed. While cranking the apparatus, we'd often speed up and slow down the speed, at times leading to the temperature slightly reaching higher (+/- .1°C) than the target temp, leading to a slightly larger crank count thus the inaccurate final temperature. Furthermore, when the counter wasn't fully pressed to count, it is very likely that in at least 2-3 trials there was a slightly lower than intended count due to missed clicks during the trial.

3. Based on the experimental results, there is evidence of systematic error because the measured slope of work-to-heat transfer was higher than expected. The recorded slope was 4.5 +/- 0.3 J/cal, while the expected value was 4.184 J/cal. This suggests that some heat was lost to the surroundings, causing the measured heat transfer to be lower than it should be. Small inconsistencies in friction and cranking speed may have also affected the work measurements. Since this error appeared in all trials, it suggests a consistent issue in the experiment setup.

4. The most likely source of systematic error came from the copper ribbon shifting while cranking. If the ribbon moved, the friction against the calorimeter would change, affecting how much heat was generated. Since heat transfer is calculated using $Q = mc\Delta T$, any change in friction would cause ΔT to fluctuate. If the ribbon didn't stay fully in contact with the brass, some of the work input could have been lost as mechanical energy instead of fully converting it into heat. This happened in every trial since the ribbon naturally shifted slightly as we cranked, meaning the friction force was not perfectly consistent. As a result, some trials had lower heat transfer values than expected, while others were closer to the theoretical value. Because this issue occurred across all trials in the same way, it introduced a systematic error, making the results consistently less accurate.

Question assigned to the following page: 7

Sample Calculations:

$$W = \pi M g N D$$

$$\Rightarrow \pi(5\,kg)(9.81\,m/s^2)(437)(.05426\,m)$$

$$\cong 3653.85\,J$$

$$Q = m_{water} C_{water} \Delta T + m_{Br} C_{Br} \Delta T$$

$$\Rightarrow 56.7g(1\,cal/g)(27.3°C - 18.3°C) + .094\,cal/g\,(362.7g)(27.3°C - 18.3°C)$$

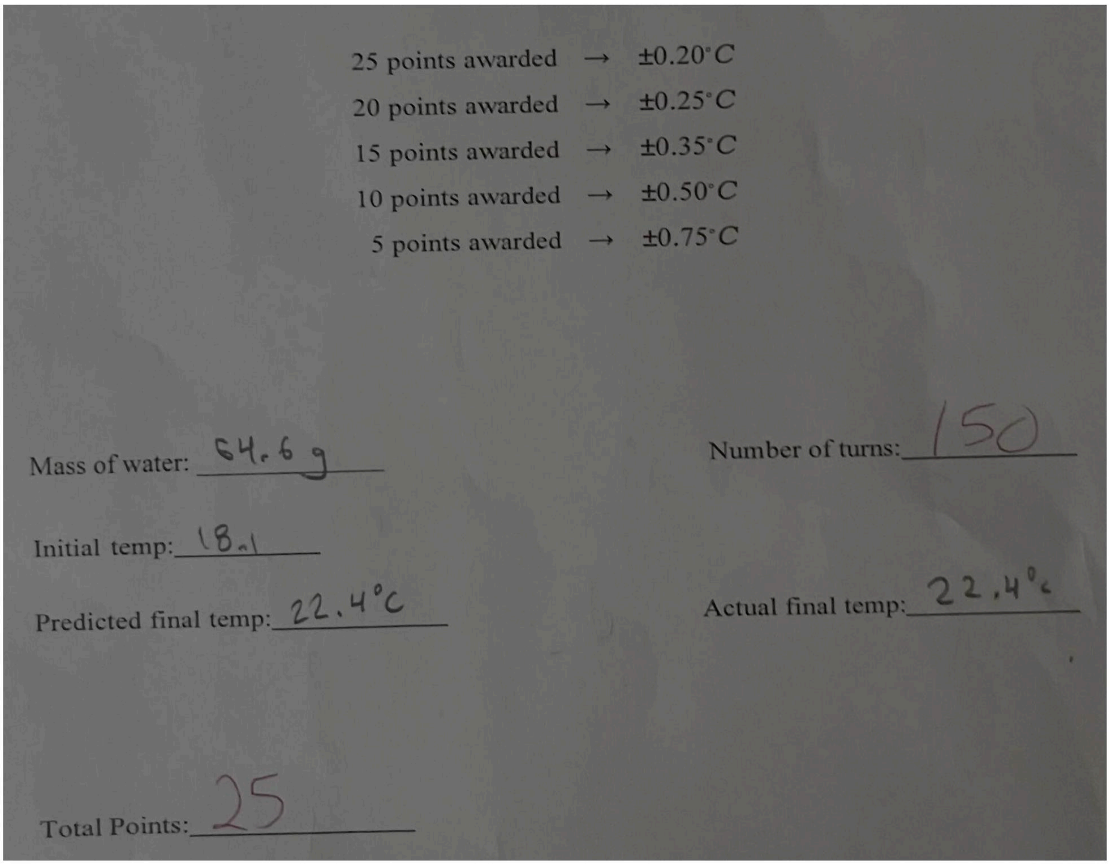
$$\cong 817.14\,cal$$

$$\frac{W}{Q} = 1 \equiv 4.187\,J/cal$$

$$\Rightarrow \frac{3653.85\,J}{817.14\,cal} \cong 4.472\,J/cal$$

Question assigned to the following page: 10

Challenge:



25 points awarded	→	±0.20°C
20 points awarded	→	±0.25°C
15 points awarded	→	±0.35°C
10 points awarded	→	±0.50°C
5 points awarded	→	±0.75°C

Mass of water: 64.6 g

Number of turns: 150

Initial temp: 18.1

Predicted final temp: 22.4°C

Actual final temp: 22.4°c

Total Points: 25