CENTRAL SCIENTIFIC COMPANY

OPERATING INSTRUCTIONS

Mechanical Equivalent of Heat Apparatus
No. 32155

1. Purpose

You can use The Mechanical Equivalent of Heat Apparatus to observe the relationship between mechanical work done and heat produced. You can calculate the mechanical equivalent of heat constant, **J**, from experimental data taken using this device.

2. Description

A 14 x 27.5 x 2cm heavy steel base holds a friction assembly. The assembly is a plastic rotating disk that generates heat by producing friction against a non-rotating brass metal core when you turn the handle of the assembly.

A mounting pole projects from the base. It holds a 4kg spring scale. Together with a wire and its mount and two adjusting screws, the scale provides the proper amount of tension to the friction assembly. An extra wire is supplied.

A thermometer holder is also attached to the base. The thermometer and some grease to secure it in its hole in the brass core are included in the apparatus.

(You will need to supply a couple of C-clamps, and a precision scale to measure the mass of the core. If you do not have these items on hand, we recommend the following: The No. 88056-05 C-clamp that opens to 6cm is just one of the C-clamps sold in the lab equipment section of our catalog. We also carry a wide variety of precision balances — the 32023 Electronic Balance has a capacity to 400g with a readability within 0.01g.)

The plastic disk of the friction-producing assembly has a very low heat conductivity so it absorbs very little thermal loss from the brass core. The non-rotating brass core and disk create no friction against the thermometer, so your readings are accurate. (See Fig. 1)

Fig. 1

3. Setup

Weigh the core, including the two brass adjusting screws and the wire mounting screw. Take the brass core and plastic friction assembly off the handle by removing the wing nuts. To disassemble the brass core, remove the two adjusting screws completely. You can then pull the unit apart. Weigh both brass pieces.

Measure the diameter of the brass core at the groove on the inner ring.

Put the friction assembly together again and attach it to the handle as before.

Screw the L-shaped pole to the larger-diameter pole. Attach the larger pole to the base, with the large washers touching the base on both sides and the small locking washer against the wing nut on the underside of the base. The top of the L-shaped pole extends over the brass core. (See Fig. 2)

Fig. 2

Clamp the base to a sturdy table or counter top. Use C-clamps on the pole side of the apparatus so that you guard against the thermometer breaking by having counter space between yourself and the apparatus.

Connect the hook of the spring scale to the top of the L-shaped pole. (It just fits if you hold it upside down while you slip it over the hook.) Slightly loosen the two brass adjusting screws on the core. Connect the wire to the polished steel winding screw on the brass core and rotate the handle of the motor. The wire will ride on the groove in the inner circle of the core as you turn the handle.

While you are turning the handle alternately tighten each screw slightly until the load balance registers just under 2kg. Stop turning and check the load level — you can over-tighten the adjusting screws and increase the load level too quickly if you’re not careful. Keep the load at 2kg.

(Precaution: At this point in the procedure, you are producing heat friction by turning the handle. You may throw off your experimental data by preheating the core if you turn the handle too many times.)

Smear the thermometer bulb with grease and place the thermometer end on its holder and the thermometer bulb into its hole in the brass core.

4. Operation

Measure the temperature of the core. It should be at least as low as room temperature before you begin the experiment.

Rotate the handle about one or two rotations per second, at a 2kg load. Try to keep the load at 2kg — the steadiness of your rhythm of rotation will contribute to the accuracy of your calculations of Joule's Constant. Stop every 50 rotations or so to take a temperature reading. Do not exceed a 4° temperature rise because you will get a heat leak from the brass core to the surrounding air or to the plastic disk that would be enough to interfere with the accuracy of your calculations. About 200 rotations should be sufficient. Read the final temperature after waiting a bit for thermal overshoot in the core to cool down (the temperature reading on the thermometer may fall a little).

5. Calculations

The mechanical work equation $W = F \bullet D \bullet p \bullet n$

where W = the work done by rotating the handle
D = the diameter of the metal core
F = the force given to the core (obtained from the spring scale)
n = the count of the rotations
p = 3.1416

and the generated heat equation $Q = m \bullet c \bullet (t' - t)$

where Q = the generated heat in calories
m = the mass of the core
c = the specific heat constant of brass (0.0925 cal/g • °K)
t' = the temperature of the core at the end of the experiment
t = the temperature of the core at the beginning of the experiment

are combined to give Joule's Constant, **J**, or the mechanical equivalent of heat.

$$J = F(w,Q) = F(F \bullet D \bullet p \bullet n, m \bullet c \bullet (t' - t))$$

6. **Data Sample:** The sample is taken at a room temperature of 24.4°C.

m	180.4g
D	3.8cm
c	0.092 cal/g • °K
g	980cm/sec
t	23.0°C
t'	26.1°C
n	100
f	2.0kgW
p	3.14
Q	51.8 cal
W	233.9 joules
J	4.52 joules/cal
error	F(J - 4.19,4.19) = 7.9%

7. Troubleshooting

The relative error shouldn't be more than 10% in any sample. There are steps you can take to reduce it if it is.

- Use a more precise balance scale and a thermistor -type thermometer.
- Start the experiment from -2℃ below room temperature and end it at +2℃ above room temperature. This action will void the heat leak from the core to the air.
- Normally, the heat equivalent of the plastic disks is ignored to simplify the experiment. Considering the thermal conductivity of the plastic will increase the precision of your calculation of Joule's Constant. The thermal conductivity of the plastic disk is about 2300 x F(10^{-4} cal,cm^2 • sec • °K).

The thermal conductivity of the brass core is

5.5 x F(10^{-4} cal,cm^2 • sec • °K) .

8. **Maintenance**: Oil the rotating shaft if needed. Take care that the rotating surface is not damaged. Otherwise, the Mechanical Equivalent of Heat Apparatus needs no special maintenance. If you should experience any difficulty with a Mechanical Equivalent of Heat Apparatus, please contact Central Scientific company, giving details of the problem. To ensure better service, please do not return any apparatus to Central Scientific Company until we have sent you authorization.

9. **Accessories**:

Item Description	Catalog No.
C-Clamp, 6cm opening, 11cm depth	88056-05
Electronic Balance, 400g capacity, 0.01g readability	32023

Written 4/89