3.1) INSTRUCTOR'S GUIDE TO ENERGY MEASUREMENT

Overview:

Sample Results for Part A

Set-up	kWh	Wh	J electr.	Mass (g)	Δ temp.(°C)	J heat	Effic.
Hot plate	0.040	40	144,000	500	20	42,000	29%
Electr. kettle	0.040	40	144,000	500	55	115,500	80%

Sample Results Part B (using a multimeter)

Set-up	V	A	W	Sec	J electr.	kg	Dist. (m)	J work	Effic.
30 rpm motor	13	0.01	0.10	61	6.3	0.16	0.74	1.2	19%
Cordless drill	9.5	1.3	12.4	10	124	0.50	1.0	4.9	4%

Sample Results Part B (using a DC wattmeter)

Set-up	V	Ah	J electr.	kg	Dist. (m)	J work	Effic.
Cordless drill	12	0.002	86	0.32	0.91	2.9	3.3%

Answers to selected questions (based on the sample result in the tables):

1. a) (40 Wh) × (3600 J/Wh) = 144,000 J

   b) (500 g) × (20°) × (4.2 J/g°C) = 42,000 J   c) 29%
2. a) (40 Wh) × (3600 J/Wh) = 144,000 J

   b) (500 g) × (55°) × (4.2 J/g°C) = 115,500 J   c) 80%
3. The hot plate, because heat escapes around the container.
4. This is not possible because heat is also lost due to resistance in the wiring.
5. (9.5 V) × (1.3 A) × (10 s) = 124 J (multimeter chart, cordless drill)

   (12 V) × (0.002 Ah) × (3600 J/Wh) = 86 J (DC wattmeter chart, cordless drill)
6. (0.50 kg) × (9.8 m / s^2) × (1.0 m) = 4.9 J (multimeter chart, cordless drill)

   (0.32 kg) × (9.8 m / s^2) × (0.91 m) = 2.9 J (DC wattmeter chart, cordless drill)
7. (4.9 J / 124 J) × 100 % = 4% (multimeter chart, cordless drill)

   (2.9 J / 86 J) × 100 % = 3.3% (DC wattmeter chart, cordless drill)
8. Answers may vary. The slower speed should be more efficient, but measurements can be highly variable.
9. Photovoltaic calculations:

   Step 1) 0.10 watts ÷ 0.0013 m^2 = ***77 watts per m^2***

   Step 2) 790 watts ÷ 77 watts per m^2 = ***10 m^2***

   Step 3) ($300 / m^2) × (10 m^2) = ***$3,000***

   Step 4) (6 hours per day) × (0.790 kW consumed) × ($0.18 per kWh) = ***$0.85 per day***

   Step 5) ($3,000) ÷ ($0.85 saved per day) ≈ *3,500 total 6-hour sunny days needed*

   ÷ (365 days per year) ≈ ***10 years***

Logistics: Part A & B can be completed within two hours. You can set up these three activities in different "stations" where lab groups are rotated. Make sure you use batteries that are appropriate for the motor or drill. The photovoltaic activity is more of a demonstration. Just confirm the set-up is functional before starting your class.

Degree of Difficulty: 1—These procedures do not require any form of rehearsal. Just make sure you know how to set up the apparatus before your students try it.

Product Guidelines: If you choose you use a DC watt meter and your photovoltaic is small, you might need an auxiliary cable (Fig. 1) to read the panel when voltage is below 4 volts. This cable is powered by a 9-volt battery (Fig. 2) and is plugged into the wattmeter (Fig. 3). The auxiliary power connector cable depicted below was purchased online from Powerwerx.

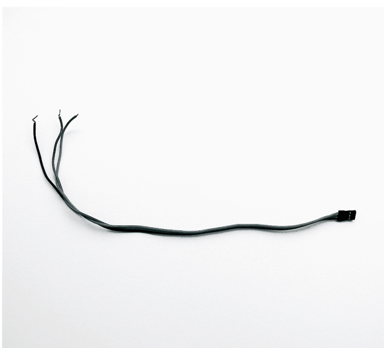

Fig. 1

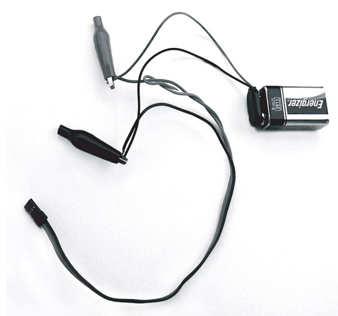

Fig. 2

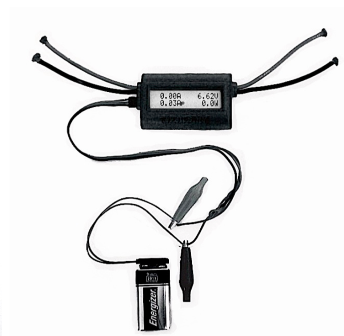

Fig. 3

Powerwerx Website: https://powerwerx.com/watt-meter-analyzer-inline-dc-mc4

Materials:

Part A**:** a plug-in wattmeter; a thermometer; a hotplate; a 1-liter Pyrex glass beaker; an electric tea kettle that holds at least 1 liter.

Part B: A battery-powered electric drill or for more efficiency a low-speed high-torque 12-volt electric motor (about 30 rpm); a shaft for pulling up a mass; a string that can hold up to 200 grams; a 100-200 gram mass; balance; a tape measure or meter stick; a stopwatch; a DC watt meter (or multimeter); connecting wires and alligator clips.

Part C: a photovoltaic cell large enough to power a small motor; and two multimeters or a DC wattmeter and (if your photovoltaic is less than 10 watts) an auxiliary cable and 9-volt battery to power the watt meter when the watts are very low (See Lab 3.5 for more detail on this product), alligator leads, and alligator clips. If you use a larger photovoltaic that generates over 10 watts you will not need the auxiliary cable, but you will need a bigger electric load (like a 12-volt car fan).