615-4695 (10-114) Energy Transfer Apparatus

Warranty and Parts:
We replace all defective or missing parts free of charge. Additional replacement parts may be ordered toll-free. We accept MasterCard, Visa, checks and School P.O.s. All products warranted to be free from defect for 90 days. Does not apply to accident, misuse or normal wear and tear.

How to Teach with Energy Transfer Apparatus:
Concepts Taught: Gravitational potential energy; electrical energy; work
Curriculum Fit: Physics Sequence; Momentum and Energy; Motors and Generators. **Grades 6-8 and up.**

Additional Materials Needed:

- Ammeter
- **615-4005** (2 cell) or **615-4010** (4 cell) D Cell Battery holder with banana plug terminals
- 1 to 4 D Cell Batteries, the motor can accept 1 – 6 V
- Banana plug wires
- Stopwatch
- Photogate Timer (optional)
- Ruler or meter stick
- Top loading balance
- Paper Clip

Theory:
What is gravitational potential energy?
What is electrical energy?
What is work?
What is current?
What is voltage?
What is efficiency?
What is power?

Experiment 1: Energy Transformation Apparatus

Procedure:

1. Extend the spool over the edge of a lab bench, bookshelf or table. The motor should be mounted high enough from the ground so that there is sufficient room for the spool to wind and unwind freely. This height should be at least 1 m (2 m is better). You may wish to place the motor on the base or the motor attached to the ring stand close to a wall, so that you will be able to mark off the distances on the wall from when the loop with washers is raised a fixed distance in cm from its starting point when the thread is fully suspended. Record these three distances.
   Starting Distance = _________________________ (cm)
   Final Distance = ____________________________(cm)
   Total Distance = ____________________________(cm)

2. Attach a length of nylon thread to the center of the spool, so that it hangs down freely when completely unwound from the spool. The thread can be attached by using tape or by slightly separating the spool halves and capturing the thread in the center when reassembled. The length of thread should be at least 90 cm. Record this length.

Nylon Thread Length = ___________________________(cm)

3. Fashion a loop at the free end of the nylon thread, so that a paper clip may be attached.
4. Insert the D-cell batteries into the battery holder. The motor can accept 1-6V.
5. Place several washers on the paper clip hook as indicated below.

#	washers
2	washers
3	washers
4	washers
5	washers
6	washers
7	washers
8	washers
9	washers
10	washers
11	washers

6. Connect the D-cell battery holder (with batteries) to the plastic base with motor with banana plug wires. Also have the ammeter connected to the lead wire to measure the current (Amps).

**You will be performing several trials, each time varying the number of washers attached to the paper clip. The maximum number of washers that can be lifted by the motor will vary by the type of battery (alkaline/rechargeable/etc.), the age of the battery and the type of washers used. With the supplied washers and a new alkaline battery, expect to lift anywhere between 10 and 20 washers depending on the washers mass. The chart below is an example; you should test your motor to see what the maximum number of washers that can be lifted is and adjust your tests accordingly.

7. One student should use a stop watch or photogate timer to time how long it takes for each of the number of washers listed in step 5 (above) to reach the final distance. The other student should record the average values in the table that follows. Also, the average current and the voltage through the motor for each trial should be recorded. Multiple trials (minimum three trials) of each weight set (i.e., number of washers) are desirable. Remember that the number of washers you use may be substantially different from the quantities listed in the chart below.

# Washers	Average Time (sec)	Average Current (amperes)	Average Voltage (Volts)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			

8. Students should calculate work from the results shown in step 7. Record results in the following table.

Work = Current x Time x Voltage

$W = I \times t \times V$

W = work (watt·sec)
I = current (Amps)
t = time (seconds)
V = voltage (Volts)

Students may wish to measure the battery's voltage (optional).

Battery's Voltage = _________________________(Volts)

# Washers	Work (watt·sec)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	

9. Students should calculate power from the results shown in step 7. Record results in table below.

Power = Current x Voltage

P = I x V

P = power (watts)
I = current (Amps)
V = voltage (Volts)

# Washers	Power (watts)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	

10. Weigh one washer on a top loading balance. Record the mass.
Mass of washer = ____________________________(g)

11. Multiply this weight by the number of washers used in each trial to obtain the total mass per trial. Record the masses in the table below.

# Washers	Mass (g)	Mass (kg)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		

12. Calculate the gravitational potential energy for each of the trials performed, using the mass values recorded in step 11.

PE_{grav} = mass * g * height
PE_{grav} = m * g * h

PE_{grav} = potential energy in kg·m^2/s^2 (Joules or N·m)
g = acceleration due to gravity = 9.8 m/sec^2
m = mass (kg)
h = height (meters)

# Washers	PEgravitational (Joules or N·m)
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	

13. Calculate the efficiency of the motor. Efficiency is the ratio of the increase in the potential energy of the washers to the energy supplied to the motor.

$$\text{Efficiency (E)\%} = \frac{PowerOut}{PowerIn}(100)$$

Power Out = PE_{grav}
Power In = charge x EMF

EMF = Electromotive Force (or Voltage)
Power In = q x V
V = EMF (Volts)

q = charge
q = current x time

q = I x t

I = current (amperes)
t = time (sec)

Therefore, Energy to Motor = I x t x V (watt·sec)

$$\text{Efficiency (E)\%} = \frac{mgh}{ItV} \; x \; 100$$

# Washers	Mass (kg)	Energy to Motor (watt·sec)	PEgravitational (N·m)	Efficiency (%)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				

14. Plot the efficiency (E)% versus mass for the values in the table listed in step 13.

Related Products:

612-1315 Energy Transformation Kit – Demonstrate the First Law of Thermodynamics by showing how mechanical energy is converted to heat. Includes two precision machined 454 gram balls, hardened with chrome-plated steel.

612-1055 Investigating Energy Transfer – Observe how surface color affects the rate of energy absorption by an object. Measure temperature change in two containers connected by a metal bar. Observe how conduction affects the temperature of objects in a system.