School: ____________________________ Names: ____________________________

Total Score: _______ Place: ________ ____________________________

Science Olympiad
Physics Lab: Work, Energy and Power
Lab Component (40 points)

Lab Component: Design and Construct a [student] Wind-Powered Apparatus to Raise a Mass to a predetermined height in order to maximize the power produced. Team will have 25 minutes from the beginning of the competition to build the device. Moderator will time performance and verify mass, time and height performance.

Equipment:

1. 1 pair scissors
2. 8 – 4"x 6" index cards
3. 1 - 9" x 3/16" diameter dowel
4. 1 – drinking straw
5. 1 – roll masking tape
6. 2 m string (considered 0.000 kg for calculations)
7. 2 – 1"x1"x1" wooden blocks (0.010kg)
8. 1 – small plastic Dixie cup (0.002 kg)

Quantity	Mass (kg)	Height (m)	Time (s)	Work (J)	Power (W)
Measured Value				---------	---------
Moderator init				---------	---------
Calculated Value	---------	---------	---------		
Pts Earned [correct calculation]	---------	---------	---------	__ / 5	__ / 5
Pts Earned [performance]	---------	---------	---------	__ / 10	__ / 20

Total Points: ________

Performance Table

Work (J)	>0.01	>0.02	>0.03	>0.04	>0.06	>0.08	>0.10	>0.14	>0.14	>0.16
Work Points	1	2	3	4	5	6	7	8	9	10
Power (W)	>0.018	>0.020	>0.022	>0.024	>0.026	>0.028	>0.030	>0.032	>0.036	>0.040
Power Points	2	4	6	8	10	12	14	16	18	20

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School: GM Key Names: ____________________

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Science Olympiad
Physics Lab: Work, Energy and Power
Knowledge Component (@ 3 pts / question = 60 points)

1. A power plant produces 500 MW of power. How much energy is produced in one second? $5e^{8}$ J

$E = P\Delta t = 5e^{8} W * 1 \text{ sec}$

2. A power plant operates in four stages. The efficiency in the successive stages are: 80%, 40%, 12% and 65%. What is the overall efficiency of the power plant?

$Eff = .80 * .40 * .12 * .65$ 2.5 %

3. A coal power plant with 30% efficiency burns 10 million kilograms of coal a day. (Take the heat of combustion of coal to be 30 MJ / kg.)

a) What is the power output of the plant? $1e^{9}$ W

$P = (.3)(1e^{7} kg)(3e^{7} J/kg) / (24 \text{ HR} * \frac{3600 \text{ sec}}{\text{HR}})$

b) At what rate is thermal energy being discarded by the plant? $2.4e^{9}$ W

$\left(\frac{1.0 - .3}{.3}\right)(1e^{9} W)$

4. Sunlight of intensity 700 W / m^2 is captured with 70% efficiency by a solar panel, which then sends the captured energy into a house with 50% efficiency. If the house loses thermal energy through poor insulation at a rate of 3.0 kW, find the area of the solar panel needed in order to keep the temperature of the house constant.

$(.7)(700 W/m^2)(A)(.5) = 3.0e^{3} W$ 12 m^2

$A = 12 m^2$

5. A solar heater is to warm 150 kg of water by 30K. The intensity of solar radiation is 6000 W / m^2 and the area of the panels is 4.0 m^2. The specific heat capacity of the water is 4.2 x 10^3 J / kg K. Estimate the time this will take, assuming a solar panel efficiency of 60%.

$(.6)(6e^{3} W/m^2)(4.0 m^2)T = (150 kg)(30 K)\left(\frac{4.2e^{3} J}{kg K}\right)$ $1.3e^{3}$ sec

$T = 1.3e^{3} \text{ sec}$

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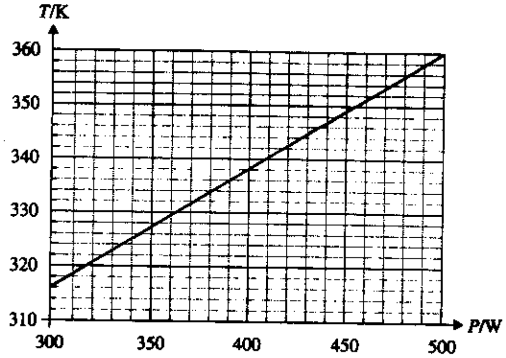


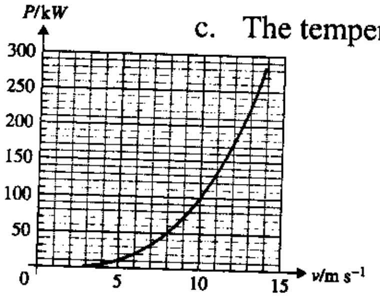
6. The above graph shows the variation with incident solar power P of the temperature of a solar panel used to heat water when thermal energy is extracted from the water at a rate of 320 W. The area of the panel is 2.0 m^2 and the intensity of the solar radiation incident on the panel is 400 W / m^2. Calculate:

   a. The power incident on the panel ____800____ W

   $P = (2.0\,m^2)(400\,W/m^2)$

   b. The efficiency of the panel ____40____ %

   $Eff = \frac{320W}{800W}$



   c. The temperature of the water INTERSECTION LINE @ 400W ____338____ K

7. The above graph shows the power curve of a wind turbine as a function of the wind speed. If the wind speed is 10 m/s, calculate the energy produced in the course of one year assuming that the wind blows at this speed for 1000 hours in the year. FM GRAPH: 1e5 W ____3.6e11____ J

   $(1e^5 W)(1e^3 HR)\left(\frac{3600\,SEC}{1\,HR}\right)$

8. The formula for wind power as a function of the air density, cross sectional area of the wind turbine blades and the wind velocity is given by $P = \frac{1}{2}\rho A v^3$

State the expected increase in the power extracted from the wind turbine when

   a. the length of the blades is doubled: ____4x____

   $A = \pi r^2 : (2r)^2 \rightarrow 4r^2$

   b. the wind speed is doubled: ____8x____

   $P \propto V^3 \quad (2V)^3 \rightarrow 8V^3$

   c. both the length of the blades and the wind speed are doubled: ____32x____

   $(4x)(8x)$

   d. State one reason why the actual increase in the extracted power will be less than your answers above

   FRICTION, TURBULENCE
   NOT ALL POWER EXTRACTED

Points this page

9. Air density 1.2 kg / m^3 and speed 8.0 m/s is incident on the blades of a wind turbine. The radius of the blades is 1.5 m. Immediately after passing through the blades, the wind speed is reduced to 3.0 m / s and the density of the air is 1.8 kg m^3. Calculate the power extracted from the wind.

$2e^3$ W

$$\left(\frac{1}{2}\right)\left(\frac{1.2\,kg}{m^3}\right)\left(\pi(1.5m)^2\right)\left(8.0\frac{m}{s}\right)^3$$

$$-\frac{1}{2}\left(\frac{1.8\,kg}{m^3}\right)\left(\pi(1.5m)^2\right)\left(3.0\frac{m}{s}\right)^3$$

10. Find the power developed when water in a waterfall with a flow rate of 500 L / s falls from a height of 40m.

$2.0e^5$ W

$$P = \frac{mgh}{\Delta t} = \frac{\rho \Delta V g h}{\Delta t} = \left(\frac{1000\,kg}{m^3}\right)\left(\frac{1\,m^3}{1000\,L}\right)\left(\frac{500\,L}{sec}\right)\left(\frac{9.8\,N}{kg}\right)(40m)$$

11. A force of 4.0 N is required to stretch a spring 0.2 m. The spring obeys Hooke's law. Find the energy stored in the spring when it is stretched to 0.8m.

6.4 J

$$K = 4.0N/0.2m = 20N/m$$

$$E_{el} = \frac{1}{2}kx^2 = \frac{1}{2}\left(\frac{20N}{m}\right)(0.8m)^2$$

12. The potential difference between the Earth and the bottom of a thundercloud is 35 million Volts. The bottom of a line thunderclouds is 1500 m above the earth and the area of the cloud bottoms is 110 km2. Modeling this Earth-cloud system as a huge capacitor, calculate: $\epsilon_0 = 8.85e^{-12}\,c^2/Nm^2$

a. The capacitance of the Earth-cloud system

$6.5e^{-7}$ F

$$C = \frac{\epsilon_0 A}{d} = \frac{(8.85e^{-12}\,c^2/Nm^2)(1.1e^8\,m^2)}{1.5e^3\,m}$$

b. The charge stored in the "capacitor"

23 C

$$Q = CV = (6.5e^{-7}F)(3.5e^7V)$$

c. The energy stored in the "capacitor"

$4.0e^8$ J

$$U = \frac{1}{2}CV^2 = \frac{1}{2}(6.5e^{-7}F)(3.5e^7V)^2$$

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