Introduction to Hydroelectric Power Generation

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Duration
2 hours

Grade Level
12th Grade

Student Learning Objectives
1. Students will be able to explain the science behind hydroelectric power generation and be able to name other methods used to generate electricity.
2. Students will be able to calculate flow rate and pressure head given information about an elevated, free-flowing water source.
3. Students will be able to estimate the yearly power production of a hydroelectric power generation unit, which uses rooftop rainwater as a water source.
4. Students will be able to discuss and chose an appropriate generator for the rooftop rainwater application and decide whether or not the application is economical.

Teaching Plan

Introduction: Hydroelectric power generation is one of many ways in which electricity can be generated. In 2009, the three most heavily used sources for generating electricity were coal, natural gas, and oil. These sources not only release emissions that are harmful to the environment, they are resources that are quickly running out. Therefore, different ways of generating power will need to be explored. Hydroelectric power works to harvest the inherent energy of moving water by directing the water through turbine converting the energy of the moving water into mechanical energy. The mechanical energy is then converted into electricity in the generator.

Source: [http://upload.wikimedia.org/wikipedia/commons/a/a4/Water_turbine.jpg](http://upload.wikimedia.org/wikipedia/commons/a/a4/Water_turbine.jpg)
In order to chose the appropriate generator for a specific application, the flow rate and pressure head of your water source must be known. To illustrate this, an example of a product with its performance chart should be shown. An example of this can be found at: http://www.nooutage.com/lv1400.htm.

Activity: Harvesting Energy from Rooftop Rainwater

In this activity, the students will do a calculation to estimate how much energy they could harvest from water collected on the rooftop of their school. They will also use this scenario to pick out what they believe to be an appropriate generator for this application.

Materials:
- Average Rainfall Data for the Area
- Approximate Surface Area of the School (can measure prior to activity)
- Performance Charts for a Few Different Hydroelectric Generators

Equations:

\[ \text{FlowRate} \left( \frac{ft^3}{hr} \right) = \text{RateOfRain} \left( \frac{ft}{hr} \right) \times \text{SurfaceArea} \left( \frac{ft^2}{hr} \right) \]  
(1)

\[ \text{Power} \left( \frac{ft - lbs}{hr} \right) = \frac{\text{Force} (lbs) \times \text{Distance} (ft)}{\text{Time} (hr)} \times \text{Efficiency} \]  
(2)

\[ \text{Density}, \text{water} = 62.4 \left( \frac{lbs}{ft^3} \right) \]  
(3)

Procedure:

1. Introduce the concept of pressure head, and explain to the students that it is equal to the height of the water source. In the case of a rooftop rainwater source, the pressure head would be equal to the height of the school building assuming that the turbine is located at ground level.
2. Have the students calculate the pressure head of the rainwater source. They can do this by measuring the height of the school or estimating based on schematics of the school or objects of known height.
3. Propose the scenario of a steady, moderately heavy rainfall, during which rain is coming down at a rate of 0.25 inches/hr. Using the surface area of the school and assuming that all of the water falling on the school could be directed to the generator, calculate the flow rate of water that could be expected using Equation 1. Explain that when choosing a generator for this application, one must be aware that the generator must be able to handle a flow rate from a heavy rain, otherwise water may collect on the school and collapse the roof.
4. Using the flow rate and pressure calculations, have the students pick out an appropriate and efficient generator for this application using the generator performance charts. Note the cost of these generators.
5. Using Equations 2-3 and the average rainfall for the area, have the students calculate the expected power generation of the generator over the course of the year. Explain that using the average rainfall for the area and the
approximate surface area of the school, an average flow rate can be calculated. This average flow rate can be converted to a rate of force using the density of water in lbs/ft$^3$ (Equation 3). Then, by Equation 2 the yearly power generation is equal to the rate of force multiplied by the distance or the height of the school multiplied by the generator efficiency. Different efficiencies taken from products discussed in Step 4 can be tried.

6. Given the cost of the generator and the yearly power output of the generator, ask the students if they believe this is an economical application for the hydroelectric power generator. To further explore this topic, the price of power by kW-h can be looked up for your area.

References:

Introduction to Hydroelectric Power Generation Worksheet

1. Average Yearly Rainfall (ft) = _______________

2. Surface Area of School (ft$^2$) = _______________

3. Pressure Head of Rainwater Source
   = Height of Source Above Generator (ft) = _______________

4. Flow Rate into Generator = $0.25/12$ (ft/hr) * $SA_{school}$ (ft$^2$) = _______________

5. Efficiency of Generator = _______________

6. Force of Water = AV Yearly Rainfall (ft) * $SA_{school}$ (ft$^2$) * $d_{water}$ (lbs/ft$^3$)
   = _______________

7. Power = ($F_{water}$ (lbs) – Head (ft)) / Time (hr) * $Efficiency_{generator}$
   = _______________