**Chapter 18 Problem 30** †

**Given**
$flowrate = \frac{\Delta m}{\Delta t} = 10^6\ kg/s$
$h = 50\ m$
$Power = 400\ MW$

**Solution**
Find the temperature increase of the water.

Begin with the first law of thermodynamics.

$$\Delta U = Q - W$$

When we consider the rate at which energy is extracted and used, the first law of thermodynamics can be written as

$$\frac{\Delta Q}{\Delta t} = \frac{\Delta U}{\Delta t} + \frac{\Delta W}{\Delta t} \tag{1}$$

$\frac{\Delta W}{\Delta t}$is the same as the power generated by the generator. $\frac{\Delta U}{\Delta t}$ is the rate at which potential energy is lost by the water going over the falls. Potential energy is given by $E_{pot} = mgh$. Therefore,

$$\frac{\Delta Q}{\Delta t} = \frac{\Delta m}{\Delta t} gh$$

(The negative sign is because there is a loss in height. Substituting into equation (1) and solving for $\frac{\Delta Q}{\Delta t}$ we get

$$\frac{\Delta Q}{\Delta t} = -\frac{\Delta m}{\Delta t} gh + Power$$

$$\frac{\Delta Q}{\Delta t} = -(10^6\ kg/s)(9.8\ m/s^2)(50\ m) + 4.00 \times 10^8\ J/s$$

$$\frac{\Delta Q}{\Delta t} = -9.0 \times 10^7\ J/s$$

This means that every second $9.0 \times 10^7\ J$ of heat causes $10^6\ kg$ of water to heat up. The heat capacity of water is given by

$$\Delta Q = mc\Delta T$$

Solving for temperature change gives

$$\Delta T = \frac{\Delta Q}{mc}$$

The specific heat of water is

$$c_{water} = 4184\ J/kg \cdot K$$

Therefore, the temperature change is

$$\Delta T = \frac{(9.0 \times 10^7\ J)}{(10^6\ kg)(4184\ J/kg \cdot K)}$$

$$\Delta T = 2.15 \times 10^{-2}\ K = 0.022^o C$$

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†Problem from Essential University Physics, Wolfson