

Lesson 5

Class Notes

Work, Power and the Roller Coaster (Continued)

Work: In the previous lesson we defined work as a force applied through a displacement, or distance. ($W=Fd$)

Power: Power and work are often confused with one another or used interchangeably. The difference is one of time. The rate at which work is done is power. Intuitively, the faster a weight is lifted overhead the more

power is consumed. $\left(P = \frac{W}{t} \frac{\text{newton-meters}}{\text{sec}} = \frac{\text{joules}}{\text{sec}}, \text{watts} \right)$

We often wish to have the units of power converted to horsepower (Hp). This can easily be done using the following conversion factors:

$$1kw = 1000watts$$

$$1kw = 1000 \frac{\text{joules}}{\text{sec}}$$

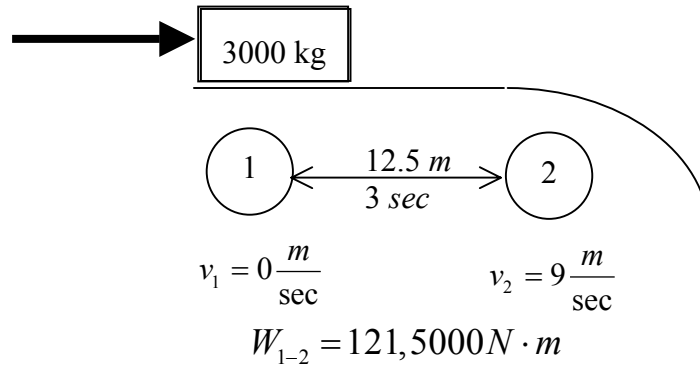
$$1kw = 1.34Hp$$

For example, convert $2,000 \frac{N \cdot m}{\text{sec}}$ to Hp .

$$2,000 \frac{N \cdot m}{\text{sec}} = 2,000 \frac{\text{joules}}{\text{sec}} = 2,000 \left(\frac{\cancel{\text{joules}}}{\cancel{\text{sec}}} \right) \left(\frac{1 \cancel{kw}}{1000 \frac{\cancel{\text{joules}}}{\cancel{\text{sec}}}} \right) \left(\frac{1.34Hp}{1 \cancel{kw}} \right)$$

$$2,000 \frac{N \cdot m}{\text{sec}} = 2.68Hp$$

We found in example 1 of the previous lesson that a $121,500 N \cdot m$ of work was done by a catapult to speed the coaster train up to $9 \frac{m}{sec}$.



- Suppose that the car was attached to the catapult for 3 seconds, how much power was consumed? Give answer in horsepower (Hp).

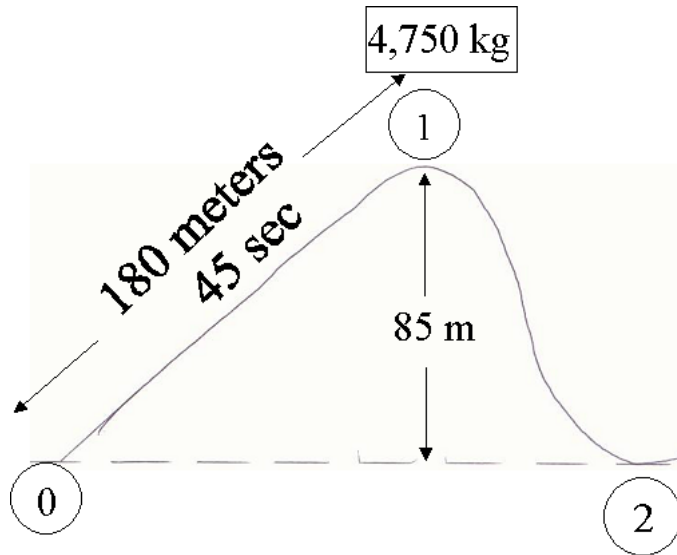
$$\begin{aligned}
 P &= \frac{W}{t} \\
 &= \frac{121,500 N \cdot m}{3 \text{ sec}} = 40,500 \frac{N \cdot m}{\text{sec}} \\
 &= 40,500 \frac{joules}{\text{sec}} \\
 &= \left(40,500 \frac{joules}{\text{sec}} \right) \left(\frac{1 \cancel{\text{kW}}}{1000 \frac{joules}{\text{sec}}} \right) \left(\frac{1.34 \text{Hp}}{1 \cancel{\text{kW}}} \right) \\
 P &= 54.27 \text{Hp}
 \end{aligned}$$

- Suppose that the car was attached to the catapult for $\frac{1}{3}$ sec, how much power was consumed?

$$\begin{aligned}
 P &= \frac{W}{t} \\
 &= \frac{121,500 N \cdot m}{\frac{1}{3} \text{ sec}} = 364,500 \frac{N \cdot m}{\text{sec}} \\
 &= \left(364,500 \frac{joules}{\text{sec}} \right) \left(\frac{1 \cancel{\text{kW}}}{1000 \frac{joules}{\text{sec}}} \right) \left(\frac{1.34 \text{Hp}}{1 \cancel{\text{kW}}} \right) \\
 P &= 488.4 \text{Hp}
 \end{aligned}$$

An Example Problem:

1. Diagram.



2. **Find v_1 :** The train is pulled to the top of the first hill with a chain driven by electric motors. The train travels the 180 meters in 45 sec. Find the velocity at the top of the first hill.

$$d = v \cdot t \Rightarrow v = \frac{d}{t}$$

$$v_1 = \frac{180m}{45\text{sec}}$$

$$v_1 = 4 \frac{m}{\text{sec}}$$

3. **Find W_{0-1} :** How much work is done to lift the train to the top of the first hill? (Assume the velocity at the bottom of the hill just as the train hooks onto the chain lift is zero).

$$PE_0 + W_{0-1} = KE_1 + PE_1$$

$$v_0 = 0 \quad \therefore KE_0 = 0$$

$$h_0 = 0 \quad \therefore PE_0 = 0$$

$$\cancel{KE_0} + \cancel{PE_0} + W_{0-1} = KE_1 + PE_1$$

$$W_{0-1} = \frac{1}{2}mv_1^2 + mgh_1$$

$$W_{0-1} = m\left(\frac{1}{2}v_1^2 + gh_1\right)$$

$$W_{0-1} = (4750kg) \left[\frac{1}{2} \left(4 \frac{m}{sec}\right)^2 + \left(9.8 \frac{m}{sec^2}\right)(85m) \right]$$

$$W_{0-1} = 3,994,750 \text{ newton-meters or joules}$$

4. **Find Power (P):** What is power (in horsepower) of the motors needed to accomplish part 5.

$$P = \frac{W}{t}$$

$$P = \frac{3,994,750 \text{ joules}}{45 \text{ sec}}$$

$$P = 88,772.2 \text{ joules/sec}$$

$$P = \left(88,772.2 \frac{\text{joules}}{\text{sec}} \right) \left(\frac{1 \cancel{\text{kw}}}{1000 \cancel{\text{joules/sec}}} \right) \left(\frac{1.34 \text{ hp}}{1 \cancel{\text{kw}}} \right)$$

$$\boxed{P = 119 \text{ hp}}$$