Lesson 3 Part 1
Class Notes
Work, Power and the Roller Coaster

Work: Something has to be done to get a coaster started. In most of our examples, energy, or power, will be added to get the coaster to the top of the first hill. This is done by doing work on the coaster.

- A simplified definition of work is force applied through a displacement, or distance. ($W=Fd$)

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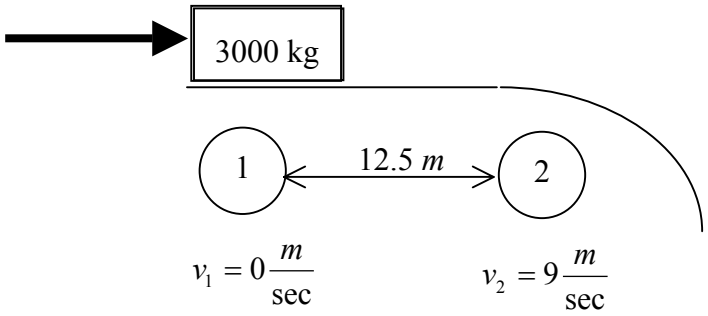
1. Now, when the force and displacement are it the ***same direction***, work adds energy to the coaster.

   Example 1: What is amount of work done on a train by a catapult that pushes the 3,000 kg car from an initial velocity of $0\,{}^{m}/_{\text{sec}}$ to a final velocity of $9\,{}^{m}/_{\text{sec}}$ in a distance of 12.5 m.



$$KE_1 + PE_1 + W_{1-2} = KE_2 + PE_2$$

$$v_1 = 0 \qquad \therefore KE_1 = 0$$

$$h_1 = h_2 \qquad \therefore PE_1 = PE_2$$

$$\cancel{KE}^{0}_{1} + \cancel{PE_1} + W_{1-2} = KE_2 + \cancel{PE_2}$$

$$W_{1-2} = KE_2$$

$$= \frac{1}{2}mv_1^2 = \frac{1}{2}\cdot 3000kg\left(9\frac{m}{\text{sec}}\right)^2$$

$$= 121500\frac{kg\cdot m^2}{\text{sec}^2} = 121500\frac{kg\cdot m}{\text{sec}^2}\cdot m$$

$$= 121500\,Newton\cdot m$$

$$W_{1-2} = 121{,}500\,N\cdot m \quad \text{or} \quad Joules$$

NOTE: A positive number means that energy is being added to the system.

Calculate the amount of force the catapult produced.

Algebraic Method:

$$W_{1-2} = F \cdot d_{1-2}$$

$$\frac{W_{1-2}}{d_{1-2}} = \frac{F \cdot \cancel{d_{1-2}}}{\cancel{d_{1-2}}}$$

$$F = \frac{W_{1-2}}{d_{1-2}}$$

$$= \frac{121500N \cdot \cancel{m}}{12.5\cancel{m}}$$

$$F = 9,725N$$

OR

Non-Algebraic Method:

$$W_{1-2} = F \cdot d_{1-2}$$

$$121500N \cdot m = F \cdot (12.5m)$$

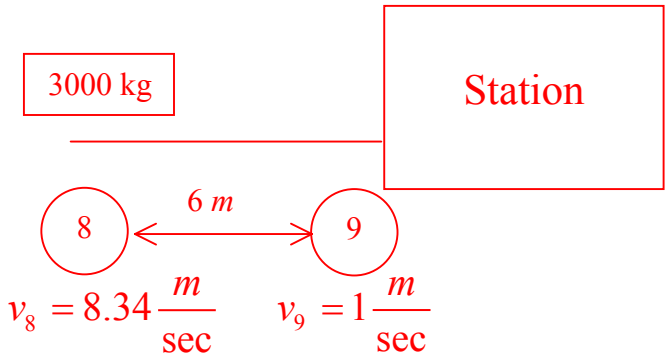
$$F = \frac{121500N \cdot m}{12.5m}$$

$$F = 9,725N$$

NOTE: A positive number means that the force is in the same direction that the car is moving. The coaster is speeding up.

2. When the force acting on the coaster and the displacement of the coaster are in ***opposite directions***, work removes energy from the coaster.

Example 2: Just before entering the station at the end of a ride, brakes are applied to the 3,000 kg train to slow it down from $8.34\frac{m}{\text{sec}}$ to $1\frac{m}{\text{sec}}$ in a distance of 6 meters. How much work is done by the breaking system?



$$KE_8 + PE_8 + W_{8-9} = KE_9 + PE_9$$

$$h_8 = h_9 \qquad \therefore PE_8 = PE_9$$

$$KE_8 + \cancel{PE_8} + W_{8-9} = KE_9 + \cancel{PE_9}$$

$$KE_8 + W_{8-9} = KE_9$$

$$\tfrac{1}{2}mv_8^{\,2} + W_{8-9} = \tfrac{1}{2}mv_9^{\,2}$$

$$W_{8-9} = \tfrac{1}{2}mv_9^{\,2} - \tfrac{1}{2}mv_8^{\,2}$$

$$= \tfrac{1}{2}m\left(v_9^{\,2} - v_8^{\,2}\right)$$

$$= \tfrac{1}{2}\cdot(3000kg)\left[\left(1\tfrac{m}{\text{sec}}\right)^2 - \left(8.34\tfrac{m}{\text{sec}}\right)^2\right]$$

$$W_{8-9} = -102{,}833.4\,N\cdot m \text{ or } Joules$$

NOTE: The negative sign means energy is being removed from the system.

Calculate the amount of force the breaks exerted on the car.

$$W_{1-2} = F \cdot d_{1-2}$$
$$-102{,}833.4N \cdot m = F \cdot (6m)$$
$$F = \frac{-102{,}833.4N \cdot m}{6m}$$
$$F = -17{,}138.9\,N$$

NOTE: The negative sign means the force is in the opposite direction that the car is moving. The coaster is slowing down.