Flipping Physics Lecture Notes:

Average Power Delivered by a Car Engine - Example Problem

Example: A 1400 kg Prius uniformly accelerates from rest to 3.0×10^1 km/hr in 9.25 seconds and 42 meters. If an average force of drag of 8.0 N acts on the car, what is the average power developed by the engine in horsepower?

Knowns:

$$m = 1400kg;\ v_i = 0;\ \Delta t = 9.25\text{sec};\ \Delta x = 42m;\ v_f = 30\frac{km}{hr} \times \frac{1hr}{3600\text{sec}} \times \frac{1000m}{1km} = 8.\bar{3}\frac{m}{s}$$

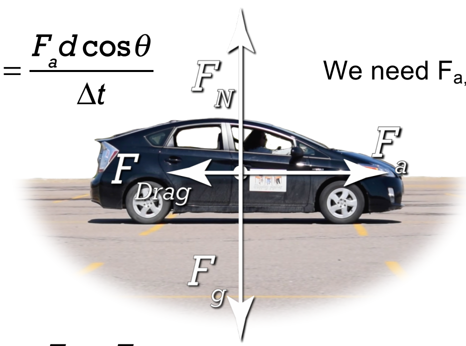
$$F_{Drag} = 8.0N;\ P_{\text{average by engine}} = ?\ \&\ P = \frac{W}{\Delta t} = Fv\cos\theta$$

We can use either of these equations because we are solving for *average* power. If the question asked for *instantaneous* power at a particular point along the trip, then we would need to use $P = Fv\cos\theta$ and use *instantaneous* velocity in the equation.

Average power delivered by a car engine. Let's illustrate that using a force applied to the car.

And let's use the equation $P_{F_a} = \frac{W_{F_a}}{\Delta t} = \frac{F_a d\cos\theta}{\Delta t}$ We need F_a, d, and θ.

Draw Free Body Diagram:



$$\sum F_y = F_N - F_g = ma_y = m(0) = 0 \Rightarrow F_N = F_g = mg$$ *(We did not need to do this step!!)*

$$\sum F_x = F_a - F_{Drag} = ma_x \Rightarrow F_a = ma_x + F_{Drag}$$ We need a_x to solve for F_a.

$$a_x = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{\Delta t} = \frac{8.\bar{3} - 0}{9.25} = 0.9009\frac{m}{s^2}$$

$$F_a = ma_x + F_{Drag} = (1400)(0.9009) + 8.0 = 1269.26\text{N}$$

The force applied is to the right and the displacement is to the right, therefore the angle, θ, in the work equation is zero degrees. $\theta = 0^\circ$.

$$P_{F_a} = \frac{W_{F_a}}{\Delta t} = \frac{F_a d\cos\theta}{\Delta t} = \frac{(1269.26)(42)\cos(0)}{9.25} = 5763.13\text{watts}$$

$$P_{F_a} = 5763.13\text{watts} \times \frac{1hp}{746watts} = 7.7256 \approx \boxed{7.7\text{hp}}$$

Larger Acceleration Example:

$$m = 1400kg;\ v_i = 0;\ \Delta t = 5.43\sec;\ ;\Delta x = 42m;\ v_f = 56\frac{km}{hr}\times\frac{1hr}{3600\sec}\times\frac{1000m}{1km} = 15.\bar{5}\frac{m}{s}$$

$$v_f = 56\frac{km}{hr}\times\frac{mi}{1.609km} = 34.804 \approx 35\frac{mi}{hr};\ F_{Drag} = 26N;\ P_{average\ by\ engine} = ?$$

$$a_x = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{\Delta t} = \frac{15.\bar{5} - 0}{5.43} = 2.86474\frac{m}{s^2}\ \ \&\ \ F_a = ma_x + F_{Drag} = (1400)(2.86474) + 26 = 4036.64\mathrm{N}$$

$$W_{F_a} = F_a d\cos\theta = (4036.64)(42)\cos(0) = 169539J \approx 170000J$$ (Larger Acceleration Example)

$$W_{F_a} = F_a d\cos\theta = (1269.26)(42)\cos(0) = 53309J \approx 53000J$$ (Original, Smaller Acceleration Example)

$$\&\ \frac{169539 - 53309}{53309}\times 100 = 218.03 \approx 220\%\ \ \&\ \ \frac{5.43 - 9.25}{9.25}\times 100 = -41.297 \approx -41\%$$

In other words, in order to decrease the time of the event by 41%, you need to use 220% more energy. That's a lot of unnecessary horses, hay and poop on the road.