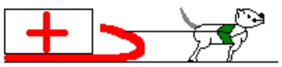
Physics I

Power

$Power = \frac{Work}{time}$ or $Power = Fv\cos\angle_F^v$

1 HP = 746 W

Problem 1.- Calculate the power delivered by a dog who pulls a sled a constant speed of 2.5 m/s. Consider the mass of the sled to be 45 kg and the coefficient of friction between sled and ice to be $\mu = 0.085$



Solution: We can use the equation $\text{Power} = \text{F}\text{v}\cos\angle_\text{F}^\text{v}$

The problem gives v=2.5 m/s and the force can be easily calculated using the equation:

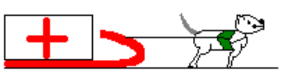
$$F_{friction} = \mu_K F_{Normal} = 0.085mg = 0.085 \times 45 \times 9.8 = 37.5N$$

The angle is zero, so the cosine is one, then:

$\text{Power} = 37.5\text{N} \times 2.5\text{m/s} =$ **94.7 watts**

We can call this a DP (dog power) instead of its counterpart HP.

Problem 1a.- Calculate how many dogs you need to pull a loaded sled at constant speed of 1.5 m/s knowing that the mass of the sled plus its cargo is 450 kg and the coefficient of friction between sled and ice is $\mu = 0.085$
Consider that 1 DP (dog power) is 94 watts.



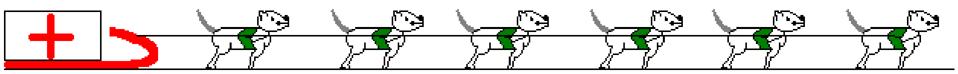
Solution: We can use the equation $\text{Power} = \text{F}\text{v}\cos\angle_\text{F}^\text{v}$

The problem gives v=1.5 m/s and the force can be easily calculated using the equation:

$$F_{friction} = \mu_K F_{Normal} = 0.085mg = 0.085 \times 450 \times 9.8 = 375N$$

The angle is zero, so the cosine is one, then: $\text{Power} = 375N \times 1.5m/s =$ **562 watts.**

The number of dogs we need is $\frac{562watts}{94watts/dog} =$ **6 dogs.**



Problem 2.- At what rate (power) is a 45.0 kg boy using energy when he runs up a flight of stairs 10.0 m high in 8.0 s?

Solution: By definition, power is work divided by time: P=W/t, but the work done here is the change in potential energy (mgh) so:

$$P = \frac{mgh}{t} = \frac{45kg(9.8m/s^2)(10m)}{8.0s} = \textbf{551 W}$$

Problem 2a.- At what rate (power) is a firefighter using energy when he climbs up the stairs of a building 40.0 m high in 68 s? Consider the mass of the firefighter to be 75 kg and the gear he is carrying an additional mass of 30 kg.

Solution: The amount of work is given by: $W = mgh$, because the work is done against the force of gravity. Be careful to include the mass of the gear in that calculation, so:

$$W = (75kg + 30kg)(9.8m/s^2)(40.0m) = 41{,}160 \text{ J}$$

By definition, the power is work divided by time, so:

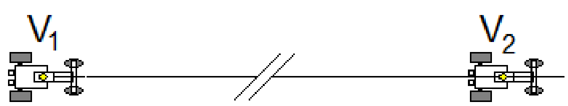
If the time is t=68s $\quad P = \frac{Work}{time} = \frac{41{,}160J}{68s} = \textbf{605 W}$

Problem 3.- How much power do you need to pump 100 kg of water per second to a height of 15.3 m? Assume 100% efficiency.

Solution: The definition of power is:

$$Power = \frac{Energy}{time} = \frac{mgh}{time} = \frac{100kg(9.8m/s^2)(15.3m)}{s} = \textbf{15 kW}$$

Problem 4.- An 800-kg sports car accelerates from rest to 100km/h in 6.0s. How much average power is delivered by the engine? Give the answer in HP.



Solution: By definition, power is work divided by time: P=W/t, but the work done here is equal to the change in kinetic energy ($\frac{1}{2}mv^2$) so:

$$v = 100\frac{km}{h}\left(\frac{1h}{3600s}\right)\left(\frac{1000m}{1km}\right) = 27.8m/s$$

$$P = \frac{\frac{1}{2}mv^2}{t} = \frac{800kg(27.8m/s)^2}{2(6.0s)} = 51{,}400W$$

Converting to HP:

$$P = 51{,}400W\left(\frac{1HP}{746W}\right) = \mathbf{69\ HP}$$

Problem 5.- A Ferrari 612 Scaglietti has an engine that delivers a power of 540 HP at 7,250 rpm. Find the torque in Nm at this peak condition.

Solution: $Power = \tau\omega \rightarrow \tau = \frac{power}{\omega}$

We need the power in watts: $power = 540HP\left(\frac{746W}{1HP}\right) = 402{,}840\text{ W}$

The angular velocity in radians per second:

$$\omega = 7250\frac{rev}{\min}\left(\frac{1\min}{60s}\right)\left(\frac{2\pi rad}{1rev}\right) = 759\text{ rad/s},$$

The torque is: $\tau = \frac{402{,}840W}{759rad/s} = \mathbf{530\ Nm}$

Problem 6.- An 80kg skydiver leaps out of an air balloon and quickly reaches a terminal speed of 110 m/s. Calculate the power delivered by air resistance.

Solution: If the skydiver reaches terminal velocity there is no more acceleration, so the weight is equal to the force of air resistance: $F_{air}=mg$. The power is P=Fv so:

For a terminal velocity of 110m/s:

P = mgv = (80kg)(9.8m/s^2)(110m/s) = **86,300 W**

Problem 7.- A cyclist does work at 600 W while riding. How much force is applied on the bicycle if its speed is 8.0 m/s?

Solution: $P = Fv \rightarrow F = \frac{600\text{W}}{8\text{m/s}} = \mathbf{75\ N}$