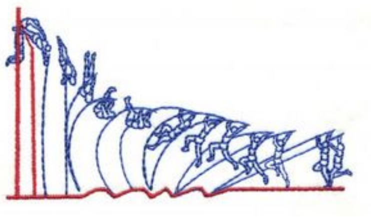
Work, Energy & Power – Tutorial

1. A 500 kg car accelerates from 0 to 20 m/s in a time of 15 s.
   overall efficiency of the engine = 25%.
   energy density of the fuel = 34 MJ/litre
   Ignoring the effects of friction and air resistance, calculate:
   (i) the average power needed to produce this acceleration. *(6.7 kW)*
   (ii) the volume of fuel used. *(0.012 litre)*

2. In a simple model of the pole vault, assume that the vaulter runs down the runway to gain KE, uses the bending of the pole to transform the KE into elastic energy, and finally allows this elastic energy to be released again as gravitational potential energy to gain the height to clear the bar.

   If this transfer worked perfectly, calculate the height of bar which could be cleared if the sprinting speed was 10 m/s. *(5.1 m)*

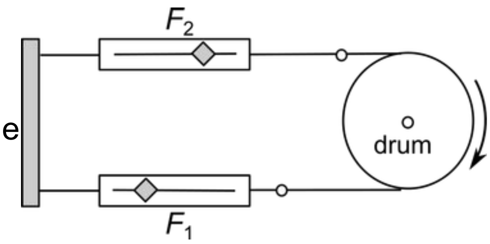
3. When a car brakes, most of the kinetic energy is dissipated in heating the brake discs or drums.

   energy needed to raise temperature of an object =
   mass × specific heat capacity × change of temperature

   A car, mass 700 kg, brakes from a speed of 12m/s to rest.
   Estimate the increase in temperature of the four brake discs, each of mass 5.0kg,
   specific heat capacity of the metal of the discs = 500J/kg/K
   (5.4ºC)

4. An airliner, mass 2.0×105 kg touches down on the run way at a velocity of 48 m/s.
   The pilot applies reverse thrust which gives a braking force of 2.2×10^4 N.
   The pilot also applies the wheel brakes which gives an additional 1.9×10^4 N braking force.
   Dynamic friction adds an extra 8.0×10^3 N of braking force.
   You may assume that all these forces remain constant.
   The total length of the runway from the point of touchdown to the end of the runway is 4.5km.
   Calculate:
   (a) the total stopping force acting on the plane. *(4.9×10^4 N)*
   (b) the work which has to be done to stop the plane. *(2.3×10^8 J)*
   (c) the length of runway needed to stop the plane using the existing stopping forces. *(4.7 km)*
   (d) the additional braking force needed in order to stop the plane in the available runway length, which is 4.5 km. *(2 kN)*

5. The power output of a motor can be measured using a band brake as shown.
The two spring balances measure the tension in the ropes on either side of the drum driven by the motor.
Frictional force acting on the drum = $F_2 - F_1$.



The spring balance readings are 90 N and 15 N.
The radius of the drum is 8.0 mm.

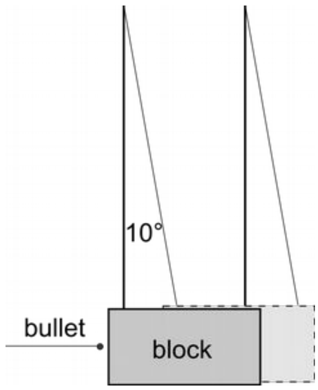
(a) Calculate the work done by the motor for every revolution of the drum. *(3.77 J)*

(b) The motor is turning at 1200 revolutions per minute.
Calculate the power of the motor. *(75 W)*

6. William Thompson, later Lord Kelvin (after whom the absolute scale of temperature is named) was for 50 years Professor of Physics at Glasgow University.

On occasion he would demonstrate the law of conservation of momentum to his students by suspending a wood block, pendulum style, from the ceiling at one end of the lecture hall and firing a gun at it from the other end. (The authorities eventually banned the demonstration on grounds of safety.)

The mass of the block shown is 3.0 kg, the length of the pendulum 1.0 metre, and the pendulum is deflected through an angle of 10°.



(a) Calculate the speed of the block immediately after the impact of the bullet. *(0.546m/s)*

(b) The mass of the bullet was 3.0 g.
Calculate the speed of the bullet. *(550m/s)*