EFFICIENCY CALCULATIONS

The 2nd Law of Thermodynamics states that no energy transfer is 100% efficient. During energy transfers some energy is always converted into a form that is not useful. **Heat is usually a by product of most energy transformations owing to friction.**

Efficiency Calculations	
% Efficiency= $\frac{\text{Output Energy}}{\text{Input Energy}}$ x 100	**Energy = Joules (J)** **Efficiency has no units (%)**

Ep= mgh — **m is mass in kg**; **g is gravity 9.8 m/s/s**; **h is the height in meters**

Ek=1/2 m v^2 — **v is velocity in m/s**; **m is mass in kg**

Output and Input energy may be given to you in a problem, but more often they need to be calculated using E_p and E_k. Efficiency measures the percentage of initial energy (input energy) is converted into the intended energy (output energy)

Practice Questions:

1. What does it mean to be 80% efficient? What percentage of the input energy was converted to usable energy? 80%. How much energy was wasted? 20%.

2. 84 J of elastic potential energy is stored in a compressed spring. The spring is 75% efficient in transforming the elastic potential energy into kinetic energy that will be used when the spring is released to catapault a 0. 5 kg block. What will be the kinetic output energy?

75% of input Energy (84J)

= 0.75 x 84J

= 63J (output)

check → $\frac{63J}{84J}$ x 100% = 75% Efficient

84J ← Input

3. In cellular respiration 1 mol of glucose is broken down in the following reaction:

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6H_2O + 6CO_2 + 2870.0 \text{ kJ}$$

This energy is then stored in ATP for the body's use whenever it needs energy.

$$2870 \text{ kJ} \longrightarrow 36 \text{ ATP} + 1098 \text{ kJ}$$ ← this could be heat, ie., Energy not used as stored energy

What is the efficiency of the energy transformation involved in making ATP?

$$\frac{\text{output Energy}}{\text{input Energy}} \times 100\% = \frac{(2870-1098)}{2870 \text{ kJ}} \times 100 = 61.74\%$$

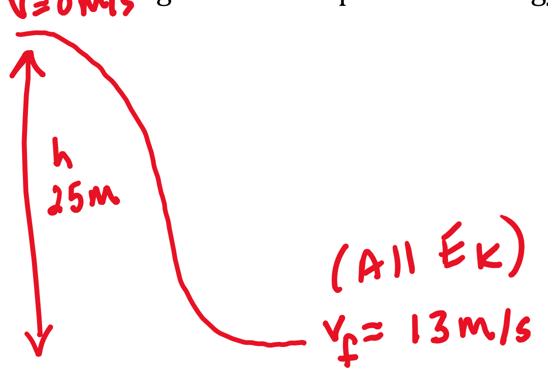
What percentage of energy is lost to heat?

$$\frac{1098 \text{ kJ}}{2870 \text{ kJ}} \times 100\% = 38.26\%$$ or

$$100\% - 61.74\% = 38.26\%$$

All Ep

4. Jack pedaled up a hill and gained a vertical distance of 25 m. Then he turned around and coasted down the hill, reaching a speed of 13 m/s at the bottom of the hill. The combined mass of Jack and his bike is 68 kg. What was the efficiency of the transformation of his gravitational potential energy into kinetic energy, going down the hill?

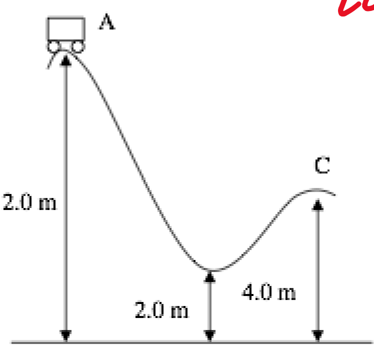


$$\text{Input} = E_p = mgh$$
$$= (68 \text{ kg})(9.8 \text{ m/s}^2)(25 \text{ m})$$
$$= 16660 \text{ J}$$

$$\text{output} = E_k = \frac{1}{2}mv^2$$
$$= \frac{1}{2}(68 \text{ kg})(13 \text{ m/s})^2$$
$$= 5746 \text{ J}$$

$$\text{Efficiency} = \frac{\text{output}}{\text{Input}} \times 100\% = \frac{5746 \text{ J}}{16660 \text{ J}} \times 100 = 34.5\%$$

5. The roller coaster shown below has a mass of 525 kg and is travelling at 2.10 m/s at point A, and is later travelling at 12.7 m/s at the lowest point. What is the efficiency of the roller coaster between point A and the lowest point?



point A = Input

Lowest point = output

(A): P.E + K.E

$= mgh + \frac{1}{2}mv^2$

$= (525)(9.8)(12) + \frac{1}{2}(525)(2.10)^2$

$= 61740\,J + 1157.625\,J$

$= 62897.625\,J$ (INPUT)

Lowest point = P.E + K.E

$mgh + \frac{1}{2}mv^2$

$(525)(9.8)(2) + \frac{1}{2}(525)(12.7)^2$

$10290\,J + 42338.625$

$= 52628.625\,J$ (output)

$\text{Efficiency} = \frac{\text{out}}{\text{IN}} \times 100\,\%$

$= 83.67\,\%$

6. This time the roller coaster has an efficiency of 41%. If the roller coaster shown below has a mass of 525 kg and is travelling at 2.10 m/s at point A:

a. what will its speed be at point C?

41% of 62897.625 J

$= 0.41\,(62897.625\,J) = 25788.02625\,J$ of usable energy.

(C)

Energy = P.E + K.E

$25788.02625\,J = (525\,kg)(9.8\,m/s^2)(4.0\,m) + \frac{1}{2}(525)v^2$

$25788.02625\,J = 20580 + 262.5\,v^2$

$5208.02625 = 262.5\,v^2$

$19.84 = v^2$

$4.5\,m/s = v$

b. what will its speed be at the lowest point?

$25788.02625\,J = (525)(9.8)(2) + \frac{1}{2}(525)v^2$

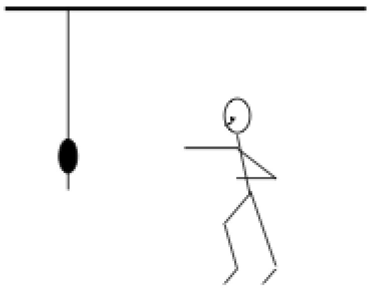
same $= 10290 + 262.5\,v^2$

$15498.026 = 262.5\,v^2$

$59.0401 = v^2$

$\boxed{7.7\,m/s \doteq v}$

b. An 80.0 kg student running at 3.50 m/s grabs a rope that is hanging vertically. How high will the student swing if it is 30% efficient?



AT MAX height, he stops moving, so $E_k = 0$

$E_k = \frac{1}{2}(80\,kg)(3.50)^2 = 490\,J$

Energy that is transformed into P.E:

$0.30 \times E_k = 147\,J$

$E_p = mgh$

$147\,J = (80\,kg)(9.8\,m/s^2)h$

$0.1875\,m = h$