

# Homework 7 - Energy

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## 1 Book

### 1.1 6.19

$$m_{\text{asteroid}} = 2.4 \times 10^{15} \text{ kg}$$

$$v_{\text{asteroid}} = 20 \text{ km s}^{-1} = 2 \times 10^4 \text{ m s}^{-1}$$

(a) How much kinetic energy did this meteor deliver to the ground?

$$E = \frac{1}{2}mv^2$$

$$E = \frac{1}{2}(2.4 \times 10^{15} \text{ kg})(2 \times 10^4 \text{ m s}^{-1})^2$$

$$E = 4.8 \times 10^{23} \text{ kg m s}^{-1}$$

$E = 4.8 \times 10^{23} \text{ J}$

(b) How does this energy compare to the energy released by a 1.0 Mt nuclear bomb?

$$E_{\text{asteroid}} = 4.8 \times 10^{23} \text{ J}$$

$$E_{\text{bomb}} = 4.184 \times 10^{15} \text{ J}$$

$$\frac{E_{\text{asteroid}}}{E_{\text{bomb}}} = \frac{4.8 \times 10^{23} \text{ J}}{4.184 \times 10^{15} \text{ J}} = 1.147 \times 10^8$$

The kinetic energy of the asteroid is  $1.147 \times 10^8 \text{ J}$  as much kinetic energy from a 1.0 Mt nuclear bomb.

## 1.2 6.29

$$E_A = 27 \text{ J}$$

$$m_B = \frac{1}{4} m_A$$

- (a) If object  $B$  also has 27 J of kinetic energy, is it moving faster or slower than object  $A$ ? By what factor?

$$E_A = 27 \text{ J}$$

$$E_A = E_B$$

$$\frac{1}{2} m_A v_A^2 = \frac{1}{2} m_B v_B^2$$

$$m_A v_A^2 = \left( \frac{1}{4} m_A \right) v_B^2$$

$$4v_A^2 = v_B^2$$

$$v_B = \sqrt{4v_A^2}$$

$$v_B = 2v_A$$

The velocity of  $v_B$  is two times  $v_A$ , implying that object  $B$  is moving twice as fast as object  $A$ . (The factor would be 2)

- (b) By what factor does the speed of each object change if total work  $-18 \text{ J}$  is done on each?

$$W_{\text{total}} = -18 \text{ J}$$

$$W_{\text{total}} = E_A - E_B$$

$$-18 \text{ J} = E_A - 27 \text{ J}$$

$$E_A = 9 \text{ J}$$

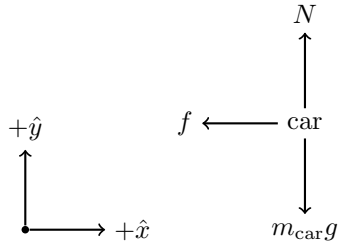
$$\begin{aligned}
\frac{\frac{1}{2}m_{A_f}v_{A_f}^2}{\frac{1}{2}m_{A_i}v_{A_i}^2} &= \frac{E_{A_f}}{E_{B_i}} \\
\frac{v_{A_f}^2}{v_{A_i}^2} &= \frac{9 \text{ J}}{27 \text{ J}} \\
v_{A_f}^2 &= \frac{1}{3}v_{A_i}^2 \\
v_{A_f} &= \frac{1}{\sqrt{3}}v_{A_i}
\end{aligned}$$

As negative work is done upon the object  $A$  calculated above, it makes sense that the resulting (final) velocity would be less than the initial velocity (in this case specifically by the factor of  $\frac{1}{\sqrt{3}}$ ).

It can also be concluded that due to object  $A$  and  $B$  having both the same kinetic energy ( $E_A = E_B$ ) and work done upon them, the factor calculated will be the same.

### 1.3 6.31

- (a) Use the work-energy theorem to calculate the minimum stopping distance of the car in terms of  $v_0$ ,  $g$ , and the coefficient of kinetic friction  $\mu_k$  between the tires and the road.



$$\begin{aligned}
\sum F_y &= 0 \\
N &= m_{\text{car}}g
\end{aligned}$$

$$\begin{aligned}
W &= -fd \\
W &= -\mu Nd \\
W &= -\mu m_{\text{car}}gd
\end{aligned}$$

$$\begin{aligned}
W &= E_f - E_i \\
-\mu m_{\text{car}}gd &= 0 - \frac{1}{2}m_{\text{car}}v_i^2 \\
d &= \frac{v_i^2}{2\mu g}
\end{aligned}$$

$$\boxed{d = \frac{v_i^2}{2\mu g}}$$

(b) By what factor would the minimum stopping distance change if

(i) the coefficient of kinetic friction were doubled?

$$\mu = 2\mu$$

$$\begin{aligned} W &= E_f - E_i \\ -2\mu m_{\text{car}} g d_1 &= -\frac{1}{2} m_{\text{car}} v_i^2 \\ d_1 &= \frac{v_i^2}{4\mu g} \end{aligned}$$

$$\begin{aligned} d : d_1 \\ \frac{v_i^2}{2\mu g} : \frac{v_i^2}{4\mu g} \\ 1 : \frac{1}{2} \end{aligned}$$

$$\boxed{\frac{1}{2}}$$

(ii) the initial speed were doubled?

$$v_i = 2v_i$$

$$\begin{aligned} W &= E_f - E_i \\ -\mu m_{\text{car}} g d_1 &= -\frac{1}{2} m_{\text{car}} (2v_i)^2 \\ d_1 &= \frac{2v_i^2}{\mu g} \end{aligned}$$

$$\begin{aligned} d : d_1 \\ \frac{v_i^2}{2\mu g} : \frac{2v_i^2}{\mu g} \\ 1 : 4 \end{aligned}$$

$$\boxed{4}$$

(iii) both the coefficient of kinetic friction and the initial speed were doubled?

We can use parts (i) and (ii) to find the ratio as the  $W$  and  $E_f$  would simply expand to include the calculated values above and simplify to the expression below:

$$4 \cdot \frac{1}{2} = 2$$

$$\boxed{2}$$

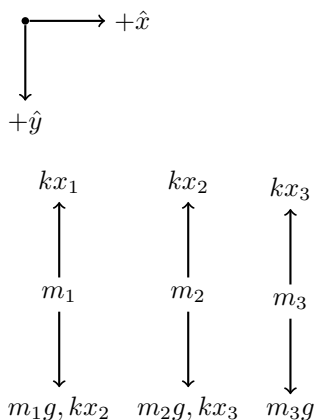
## 1.4 6.33

$$m_1 = m_2 = m_3 = 8.50 \text{ kg}$$

$$k = 7.80 \text{ kN m}^{-1} = 7.80 \times 10^3 \text{ N m}^{-1}$$

$$x = 12.0 \text{ cm}$$

(a) Draw a free-body diagram of each mass.



(b) How long is each spring when hanging as shown?

$$\begin{aligned} \sum F_y^{(m_3)} &= 0 \\ kx_3 &= m_3g \\ x_3 &= \frac{m_3g}{k} \\ x_3 &= \frac{(8.50 \text{ kg})(10 \text{ m s}^{-2})}{7.80 \times 10^3 \text{ N m}^{-1}} \\ x_3 &= 0.011 \text{ m} = 1.1 \text{ cm} \end{aligned}$$

$$\begin{aligned}
\sum F_y^{(m_2)} &= 0 \\
kx_2 &= m_2g + kx_3 \\
x_2 &= \frac{m_2g + kx_3}{k} \\
x_2 &= \frac{(8.50 \text{ kg})(10 \text{ m s}^{-2}) + (7.80 \times 10^3 \text{ N m}^{-1})(0.011 \text{ m})}{7.80 \times 10^3 \text{ N m}^{-1}} \\
x_2 &= 0.022 \text{ m} = 2.2 \text{ cm}
\end{aligned}$$

$$\begin{aligned}
\sum F_y^{(m_1)} &= 0 \\
kx_1 &= m_1g + kx_2 \\
x_1 &= \frac{m_1g + kx_2}{k} \\
x_1 &= \frac{(8.50 \text{ kg})(10 \text{ m s}^{-2}) + (7.80 \times 10^3 \text{ N m}^{-1})(0.022 \text{ m})}{7.80 \times 10^3 \text{ N m}^{-1}} \\
x_1 &= 0.033 \text{ m} = 3.3 \text{ cm}
\end{aligned}$$

Spring 1:  $12.0 \text{ cm} + x_1 = 15.3 \text{ cm}$   
 Spring 2:  $12.0 \text{ cm} + x_2 = 14.2 \text{ cm}$   
 Spring 3:  $12.0 \text{ cm} + x_3 = 13.1 \text{ cm}$

## 1.5 6.45

$$\begin{aligned}
F(x) &= 18.0 \text{ N} - (0.530 \text{ N m}^{-1})x \\
m &= 5.00 \text{ kg} \\
v_0 &= 0 \\
x_0 &= 0 \\
x_1 &= 11.0 \text{ m} \\
v_1 &=? \\
E_i &= 0
\end{aligned}$$

What is its speed after it has traveled 11.0 m?

$$\begin{aligned}
W &= \int_{x_0}^{x_1} (F(x)) dx \\
W &= \int_0^{11.0 \text{ m}} (18.0 \text{ N} - (0.530 \text{ N m}^{-1})x) dx \\
W &= [(18.0 \text{ N})x - (0.265 \text{ N m}^{-1})x^2] \Big|_0^{11.0 \text{ m}} \\
W &= [(18.0 \text{ N})(11.0 \text{ m}) - (0.265 \text{ N m}^{-1})(11.0 \text{ m})^2] - 0 \\
W &= 165.935 \text{ J}
\end{aligned}$$

$$W = E_f - E_i, \quad E_i = 0 \text{ as } v_0 = 0$$

$$W = E_f$$

$$W = \frac{1}{2}mv_f^2$$

$$v_f = \sqrt{\frac{2W}{m}}$$

$$v_f = \sqrt{\frac{2(165.935 \text{ J})}{5.00 \text{ kg}}}$$

$$v_f = 8.15 \text{ m s}^{-1}$$

$v_f = 8.15 \text{ m s}^{-1}$
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**1.6    6.48**

$$d = 5.0 \text{ km}$$

$$v_{\text{run}} = 10 \text{ km h}^{-1}$$

$$E_{\text{run}} = 700 \text{ W}$$

$$v_{\text{walk}} = 3.0 \text{ km h}^{-1}$$

$$E_{\text{walk}} = 290 \text{ W}$$

**1.7    6.51**

**1.8    7.5**

**1.9    7.9**

**1.10    7.35**

**1.11    7.40**

**1.12    7.58**

## **2    Lab Manual**

**2.1    871**

**2.2    876**

**2.3    884**

**2.4    885**