Homework 7 - Energy

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Contents

1 Book

1.1 6.19

$$m_{\text{asteroid}} = 2.4 \times 10^{15}\,\text{kg}$$
$$v_{\text{asteroid}} = 20\,\text{km}\,\text{s}^{-1} = 2 \times 10^{4}\,\text{m}\,\text{s}^{-1}$$

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

$$E = \frac{1}{2}mv^2$$
$$E = \frac{1}{2}(2.4 \times 10^{15}\,\text{kg})(2 \times 10^{4}\,\text{m}\,\text{s}^{-1})^2$$
$$E = 4.8 \times 10^{23}\,\text{kg}\,\text{m}\,\text{s}^{-1}$$

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

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

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

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

> The kinetic energy of the asteroid is 1.147×10^8 J as much kinetic energy from a 1.0 Mt nuclear bomb.

1.2 6.29

$$E_A = 27\,\text{J}$$
$$m_B = \frac{1}{4}E_A$$

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

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

$$\begin{aligned} E_A &= E_B \\ \frac{1}{2}m_A v_A^2 &= \frac{1}{2}m_B v_B^2 \\ m_A v_A^2 &= \left(\frac{1}{4}m_A\right) v_B^2 \\ 4v_A^2 &= v_B^2 \\ v_B &= \sqrt{4v_A^2} \\ v_B &= 2v_A \end{aligned}$$

> 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 J is done on each?

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

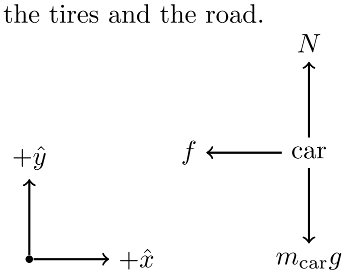
$$\begin{aligned} W_{\text{total}} &= E_A - E_B \\ -18\,\text{J} &= E_A - 27\,\text{J} \\ E_A &= 9\,\text{J} \end{aligned}$$

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

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 μ_k between the tires and the road.



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

$$
\begin{aligned}
W &= -fd \\
W &= -\mu N d \\
W &= -\mu m_{\text{car}} g d
\end{aligned}
$$

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

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

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

(i) the coefficient of kinetic friction were doubled?

$$\mu = 2\mu$$

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

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

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

(ii) the initial speed were doubled?

$$v_i = 2v_i$$

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

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

$$\boxed{4}$$

(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:

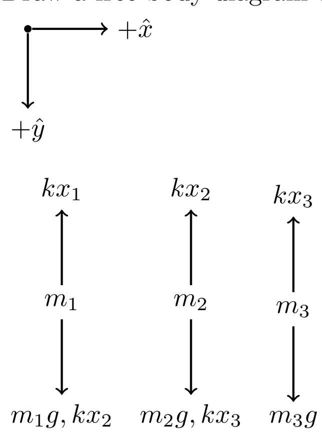
$$4 \cdot \frac{1}{2} = 2$$

$$\boxed{2}$$

1.4 6.33

$$\begin{aligned} m_1 = m_2 = m_3 &= 8.50\,\mathrm{kg} \\ k &= 7.80\,\mathrm{kN\,m^{-1}} = 7.80 \times 10^3\,\mathrm{N\,m^{-1}} \\ x &= 12.0\,\mathrm{cm} \end{aligned}$$

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



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

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

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

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

1.5 6.45

1.6 6.48

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

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