Homework 7 - Energy

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Contents

1 Book

1.1 6.19

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

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

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

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

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

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

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

> 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?

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

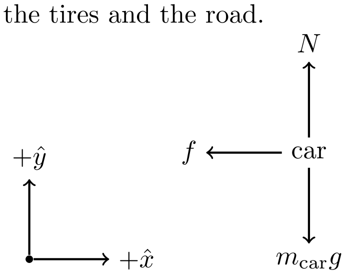
$$\begin{aligned}
W_{\text{total}} &= E_A - E_B \\
-18\,\text{J} &= E_A - 27\,\text{J} \\
E_A &= 9\,\text{J}
\end{aligned}$$

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

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.



$$\sum F_y = 0$$
$$N = m_{\text{car}}g$$

$$W = -fd$$
$$W = -\mu N d$$
$$W = -\mu m_{\text{car}}gd$$

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

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

(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

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

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

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

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

2.1 871

2.2 876

2.3 884

2.4 885