General Physics I, Midterm Exam 1 solution

1. 5. This problem is from Page 188 (Example 7.9) of text book.

(a) The separation of two atoms is where the potential is in its minimum. To find the minimum, we set $\frac{dU(x)}{dx} = 4\varepsilon \frac{d}{dx}\left[(\frac{\sigma}{x})^{12} - (\frac{\sigma}{x})^{6}\right] = 4\varepsilon\left[\frac{-12\sigma^{12}}{x^{13}} + \frac{6\sigma^{6}}{x^{7}}\right] = 0$

$$\frac{dU(x)}{dx} = 4\varepsilon \frac{d}{dx}\left[(\frac{\sigma}{x})^{12} - (\frac{\sigma}{x})^{6}\right] = 4\varepsilon\left[\frac{-12\sigma^{12}}{x^{13}} + \frac{6\sigma^{6}}{x^{7}}\right] = 0, \quad x = (2)^{\frac{1}{6}}\sigma$$

(b) Plug in numbers given, x=2.95×10^{-10} m

(c) The potential energy curve is shown in page 189 of the text book.

(d) When x= 4.5×10^{-10} m, the two atoms are subject to a restoration form to bring them together to the equilibrium point (x=2.95×10^{-10} m)

(e) This can be proved by taking the first derivative of the potential, $\frac{dU}{dx}$>0, this is the force of the two atoms at that point, so it is a restoration force to bring them together.

2.

(a)

(1) $m_1v_{1i} + m_2v_{2i} = m_1v_{1f} + m_2v_{2f}$

(2) $v_{1i} - v_{2i} = -(v_{1f} - v_{2f})$

(3) $m_1v_{1i} - m_1v_{2i} = -m_1v_{1f} + m_1v_{2f}$

$$2m_1v_{1i} + (m_2 - m_1)v_{2i} = (m_1 + m_2)v_{2f}$$

$$v_{2f} = \frac{2m_1v_{1i} + (m_2 - m_1)v_{2i}}{m_1 + m_2}$$

$$v_{2f} = \frac{2(1.60\text{ kg})(4.00\text{ m/s}) + (2.10\text{ kg} - 1.60\text{ kg})(-2.50\text{ m/s})}{2.10\text{ kg} + 1.60\text{ kg}}$$

$$= 3.12\text{ m/s}$$

$$v_{1f} = v_{2f} - v_{1i} + v_{2i} = 3.12\text{ m/s} - 4.00\text{ m/s} + (-2.50\text{ m/s})$$

$$= -3.38\text{ m/s}$$

(b)

$$m_1v_{1i} + m_2v_{2i} = m_1v_{1f} + m_2v_{2f}$$

$$v_{2f} = \frac{m_1v_{1i} + m_2v_{2i} - m_1v_{1f}}{m_2}$$

$$v_{2f}$$

$$= \frac{(1.60\text{ kg})(4.00\text{ m/s}) + (2.10\text{ kg})(-2.50\text{ m/s}) - (1.60\text{ kg})(3.00\text{ m/s})}{2.10\text{ kg}}$$

$$= -17.4\text{ m/s}$$

3.

$$PE = mgh = (100\,g) \times (980\,cm/sec^2) \times 200\,cm = 1.96 \times 10^7\,erg$$

$$KE = \frac{1}{2}mv^2 = \frac{1}{2}\cdot(100\,g) \times (300\,cm/sec)^2 = 4.5 \times 10^6\,g\,cm^2/sec^2$$

$$= 0.45 \times 10^7\,erg$$

$$\therefore W = PE + KE$$

$$= 1.96 \times 10^7\,erg + 0.45 \times 10^7\,erg$$

$$= 2.41 \times 10^7\,erg$$

$$= 2.41\text{ Joule}$$

4.

$$F_{net} = F - mg \quad , \text{ but } F = ma$$
$$= ma$$
$$\rightarrow a = \frac{F_{net}}{m} = \frac{F - mg}{m}$$

this acceleration is delivered to the ball over a distance of 2 ft, and accelerates the ball from $V_0 = 0$ to $V_f = 48$ ft/sec

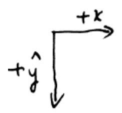
$$\therefore V_f^2 = V_0^2 + 2as$$
$$V_f^2 = 2 \cdot \left(\frac{F - mg}{m}\right) \cdot s$$
$$\Rightarrow F = \frac{m}{2s}\left(V_f^2 + 2gs\right)$$

But $W = mg$ $\therefore m = \frac{W}{g}$

$$\Rightarrow F = \frac{W V_f^2}{2gs} + W = W\left[\frac{V_f^2}{2gs} + 1\right]$$
$$= (0.25 \text{ lb})\left[\frac{(48 \text{ ft/sec})^2}{2 \cdot 32 \text{ ft/sec}^2 \; 2 \text{ ft}} + 1\right]$$
$$= 4.75 \text{ lb}$$

5.

5, When the ball bearing falls the viscous force acts oppositing the free fall motion
(take the positive direction downward)



$$mg - kv = ma$$

when reaching the terminal velocity V_t

(a) $mg - kV_T = ma = 0$

$$\therefore V_T = \left(\frac{m}{k}\right) g$$

(b) To calculate the time for the ball to reach the terminal velocity

Use $mg - kv = ma = m\frac{dv}{dt}$

$$\therefore dt = \frac{m\,dv}{mg - kv} = \frac{dv}{g - \left(\frac{k}{m}\right)v}$$
$$\Rightarrow T = \int_0^{V_T} dt = \int_0^{V_T} \frac{dv}{g - \left(\frac{k}{m}\right)v}$$

plus in the formula given for the integral

$$T_{V_T} = -\frac{m}{k} \ln\left[1 - \frac{k}{mg} V_T\right]$$

5.