$$\sum F_x = ma_x$$
$$\sum F_y = ma_y$$

$$\mathrm{KE}_i + \mathrm{PE}_i = \mathrm{KE}_f + \mathrm{PE}_f - \mathrm{Work}_{\mathrm{noncons}}$$

$$\mathrm{KE}_i + \mathrm{PE}_i = \mathrm{KE}_f + \mathrm{PE}_f - 0$$

$$3600\,J + 39200\,J = \frac{1}{2}mv_f^2 + 23520\,J - 0\,J$$

$$F_{\mathrm{fric}} = \mu_k mg\cos(\theta) = 76.1\,N$$

$$\mathrm{W}_{\mathrm{fric}} = \int \vec{F}_{\mathrm{fric}} \cdot \vec{dx}$$

$$3600\,J + 39200\,J = \frac{1}{2}mv_f^2 + 23520\,J - (-1141.4\,J)$$

$$\text{force of gravity}: \quad \vec{F}_g = -mg\,\hat{j}$$

$$\text{grav potential energy}: \quad \mathrm{GPE}(B) - \mathrm{GPE}(A) = -\int_A^B \vec{F}_g \cdot \vec{dx}$$

$$\vec{F} = -\frac{\partial(\mathrm{PE})}{\partial\vec{x}}$$

$$\vec{F} \simeq -\frac{(\text{change in PE})}{(\text{displacement})} \quad \text{in dir of displacement}$$

$$\mathrm{PE}(x) = 3.2\times 10^3\,x^2\,\frac{\mathrm{J}}{\mathrm{m}^2}$$

$$\mathrm{KE}_i + \mathrm{GPE}_i = \mathrm{KE}_f + \mathrm{GPE}_f$$

$$\frac{1}{2}mv_i^2 + mgh_i = \frac{1}{2}m(0)^2 + mgh_f$$

$$\frac{1}{2}mv_i^2 + \mathrm{GPE}_i = 0 + \mathrm{GPE}_f$$

$$\frac{1}{2}mv_i^2 = \mathrm{GPE}_f - \mathrm{GPE}_i$$

$$\text{GPE}_f - \text{GPE}_i = -\int_{h_i}^{h_f} \frac{GM_E m}{y^2}(-\hat{j}) \cdot \vec{dy} = \int_{h_i}^{h_f} \frac{GM_E m}{y^2} dy$$

$$\text{GPE}_f - \text{GPE}_i = \frac{GM_E m}{h_i} - \frac{GM_E m}{h_f}$$

$$\frac{GM_E m}{h_f} = \frac{GM_E m}{h_i} - \frac{1}{2} m v_i^2$$

$$h_f = \frac{1}{\frac{1}{h_i} - \frac{v^2}{2GM_E}}$$

$$\text{GPE}_f - \text{GPE}_i = \frac{GM_E m}{h_i} - \frac{GM_E m}{h_f}$$

$$= \frac{GM_E m}{h_i} - \frac{GM_E m}{\infty} = \frac{GM_E m}{h_i}$$

$$\frac{1}{2} m v_{esc}^2 = \frac{GM_E m}{h_i}$$

$$v_{esc} = \sqrt{\frac{2GM}{R}}$$

$$R = \frac{2GM}{c^2}$$