1.

	K (Joules)	Gal Gas	Tons TNT	Fat Men
Car	$7.7 \cdot 10^5$	$5.9 \cdot 10^{-3}$	$1.8 \cdot 10^{-4}$	$8.5 \cdot 10^{-9}$
707 Plane	$4.5 \cdot 10^9$	35	1.1	$5.0 \cdot 10^{-5}$
Freight Train	$2.7 \cdot 10^9$	21	0.65	$3.1 \cdot 10^{-5}$

$K = \frac{1}{2} m v^2 \Rightarrow 1\ \text{mph} = 0.447\ \text{meters/sec}$

Note: chemical energy >> kinetic for reasonable speeds

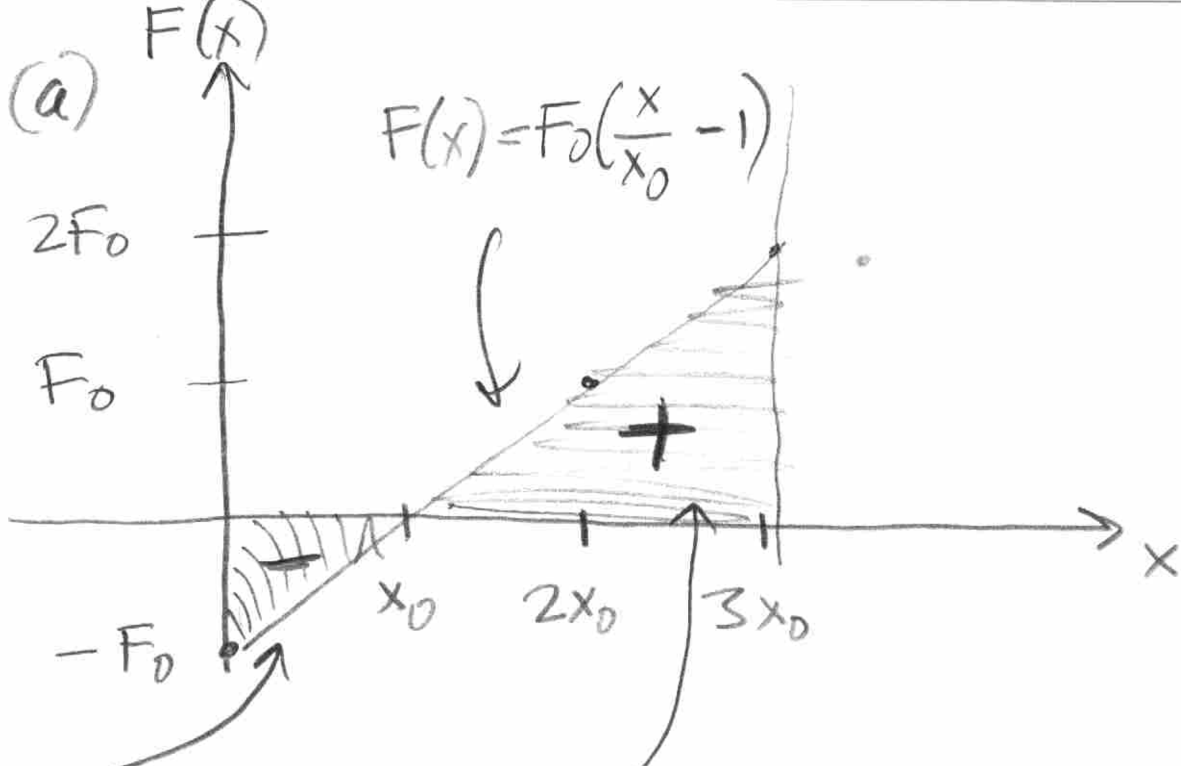
(a) 1000 >> 1 Ton TNT
fuel energy <u>way</u> bigger
$\simeq \frac{1}{22}$ of an atomic bomb (Fat Man)
the explosive fuel was the weapon

(b) $W = F \cdot d = \mu \cancel{m} g d = \frac{1}{2} \cancel{m} v^2$

$\boxed{d = \frac{v^2}{2\mu g} = 123\,m \ (\mu = \tfrac{1}{4}),\ 1230\,m\ (\mu = \tfrac{1}{40})}$

TOPS

2. (a)



$$W = -\frac{1}{2} F_0 x_0 = -\frac{1}{2} x_0 F_0$$

$$W = \frac{1}{2} \cdot 2F_0 \cdot 2x_0 = 2 x_0 F_0$$

$$\boxed{W_{tot} = \left(2 - \frac{1}{2}\right) x_0 F_0 = \frac{3}{2} x_0 F_0}$$

(b)

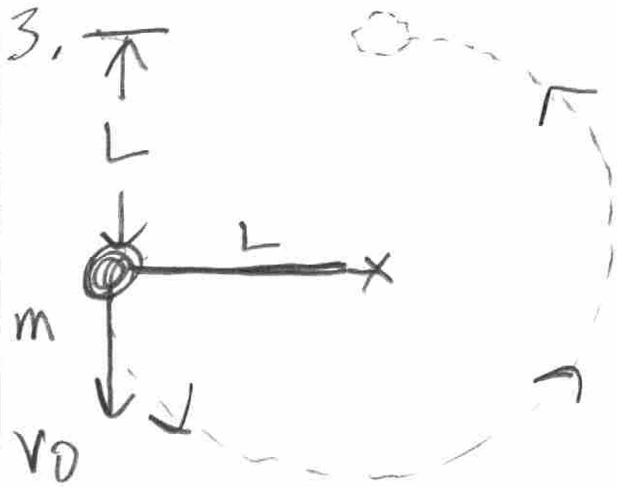
$$\int_0^{3x_0} F(x)\,dx = F_0 \int_0^{3x_0} \left(\frac{x}{x_0} - 1\right) dx$$

$$= F_0 \left[\frac{1}{2}\frac{x^2}{x_0} - x\right]_0^{3x_0}$$

$$= F_0 \left[\frac{1}{2}\frac{(3x_0)^2}{x_0} - 3x_0\right]$$

$$\boxed{W_{tot} = F_0 \left[\frac{9}{2} x_0 - 3x_0\right] = F_0 \cdot x_0 \left[\frac{9}{2} - \frac{6}{2}\right] = \frac{3}{2} x_0 F_0}$$

3.



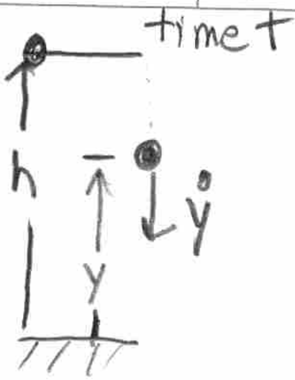
Up by a net displacement L

$$\frac{1}{2}\cancel{m}v_0^2 = \cancel{m}gL$$

$$\boxed{v_0 = \sqrt{2gL}}$$

Note: no work done by rod, since, its force on ball always $\perp$ to infinitesimal displacement

4. (a)

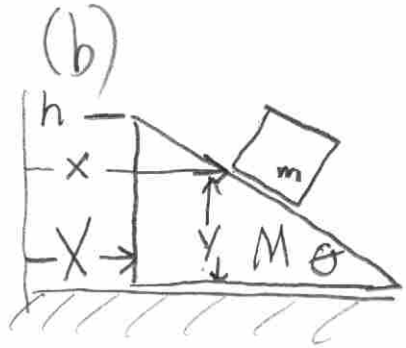


$$K_a + U_a = K_b + U_b$$

$$0 + mgh = \frac{1}{2}m\dot{y}^2 + mgy$$

$$\boxed{\dot{y}^2 = g \cdot 2(h-y)}$$

(b)



$$\tan\theta = \frac{(h-y)}{(x-X)}$$

$$x - X = (h-y)\cot\theta$$

$$\dot{x} - \dot{X} = -\dot{y}\cot\theta \quad \text{(i)}$$

(ii) $$m\dot{x} + M\dot{X} = 0$$

(iii) $$K_a + U_a = K_b + U_b$$

$$0 + mgh = \frac{1}{2}m(\dot{x}^2 + \dot{y}^2) + \frac{1}{2}M\dot{X}^2 + mgy$$

$$\frac{1}{2}m(\dot{x}^2 + \dot{y}^2) + \frac{1}{2}M\dot{X}^2 = mg(h-y)$$

use (ii) $\dot{X} = -\frac{m}{M}\dot{x}$ plug into (i)

$$\dot{x} - \left(-\frac{m}{M}\dot{x}\right) = -\dot{y}\cot\theta$$

$$\dot{x} = \frac{-\dot{y}}{\left(1+\frac{m}{M}\right)}\cot\theta \quad \text{plug into (iii)}$$

$$\frac{1}{2}m\left(\frac{\dot{y}^2}{\left(1+\frac{m}{M}\right)^2}\cot^2\theta + \dot{y}^2\right) + \frac{1}{2}M\left(-\frac{m}{M}\left(\frac{-\dot{y}}{\left(1+\frac{m}{M}\right)}\cot\theta\right)\right)^2 = mg(h-y)$$

$$\cancel{m}\dot{y}^2\left(\frac{\cot^2\theta}{(1+\frac{m}{M})^2} + 1 + \cancel{M}\cdot\frac{m}{\cancel{M^2}_{M}}\frac{\cot^2\theta}{(1+\frac{m}{M})^2}\right) = 2\cancel{m}g(h-y)$$

$$\dot{y}^2\left(\frac{(1+\frac{m}{M})}{(1+\frac{m}{M})^2}\cot^2\theta + 1\right) = 2g(h-y)$$

$$\dot{y}^2\left(\frac{\cot^2\theta + (1+\frac{m}{M})}{(1+\frac{m}{M})}\right) = g \cdot 2(h-y)$$

$$\boxed{\dot{y}^2 = \frac{g(1+\frac{m}{M})}{\cot^2\theta + (1+\frac{m}{M})} \cdot 2(h-y)}$$

i.e. $$\ddot{y} = \frac{-(1+\frac{m}{M})}{\cot^2\theta + (1+\frac{m}{M})} g$$

(c) $m/M \to 0$

$$\ddot{y} \to \frac{-1}{\cot^2\theta + 1} g =$$

$$\frac{-1}{\frac{\cos^2\theta}{\sin^2\theta} + 1} g = \frac{-1}{\frac{\cos^2\theta + \sin^2\theta}{\sin^2\theta}} g$$

$$\boxed{\ddot{y} \to -g\sin^2\theta}$$