

# Midterm Key

1. a) Strong, gluon  
E+M, photons  
Weak,  $w^+, w^-, z^0$   
Gravity, graviton

b) i)  $\omega = \sqrt{\frac{k}{m}} = \boxed{4 \text{ s}^{-1}}$

ii)  $T = \frac{2\pi}{\omega} = \boxed{1.57 \text{ s}}$

c) proton:  $\boxed{uud}$   
neutron:  $\boxed{udd}$

d)  $\Delta \vec{p} = 0 \Rightarrow m_{ne} \vec{v}_{ne} = -m_{bb} \vec{v}_{bb} \Rightarrow \vec{v}_{ne} = -\frac{m_{bb}}{m_{ne}} \vec{v}_{bb} = \boxed{0.3 \text{ m/s}}$

2. a)  $\Delta \vec{p} = \vec{F} \Delta t = \boxed{1.8 \frac{\text{kg m}}{\text{s}} \hat{i} + 1.2 \frac{\text{kg m}}{\text{s}} \hat{j}}$

b)  $\vec{a}_{\text{avg}} = \frac{\vec{F}}{m} = \boxed{60 \frac{\text{m}}{\text{s}^2} \hat{i} + 40 \frac{\text{m}}{\text{s}^2} \hat{j}}$

c)  $W = \vec{F} \cdot \Delta \vec{r} = 18 \text{ J} - 6 \text{ J} = \boxed{12 \text{ J}}$

d)  $\vec{p}_i = m \vec{v}_i = 0.6 \frac{\text{kg m}}{\text{s}} \hat{i} - 0.45 \frac{\text{kg m}}{\text{s}} \hat{j} \Rightarrow \vec{p}_f = \vec{p}_i + \Delta \vec{p} = \boxed{2.4 \frac{\text{kg m}}{\text{s}} \hat{i} + 0.75 \frac{\text{kg m}}{\text{s}} \hat{j}}$

3. a)  $KE = \frac{1}{2} m v^2 = \boxed{160 \text{ J}}$

b)  $PE = mgh = \boxed{90 \text{ J}}$

c)  $E_T = 250 \text{ J} \Rightarrow$  when the ball reaches the ground all the energy is kinetic

$\Rightarrow E_T = \frac{1}{2} m v_f^2 \Rightarrow v_f = \sqrt{\frac{2E_T}{m}} = \boxed{50 \text{ m/s}}$

d)  $y = y_0 + v_{0y} t + \frac{1}{2} a t^2 \Rightarrow 0 = 45 \text{ m} - \frac{10 \text{ m/s}^2}{2} t^2 \Rightarrow \boxed{t = 3 \text{ s}}$

e)  $d = v_{0x} t = \boxed{120 \text{ m}}$

$$4. a) E_0 = mc^2 = \boxed{9 \times 10^{19} \text{ J}}$$

$$b) \Delta p = F \Delta t = \boxed{3 \times 10^{11} \frac{\text{kg m}}{\text{s}}} \text{ since } p_i = 0$$

$$c) E_f = \sqrt{(mc^2)^2 + (pc)^2} = \sqrt{(9 \times 10^{19} \text{ J})^2 + (9 \times 10^{19} \text{ J})^2} = (9 \times 10^{19}) \sqrt{2} \text{ J} = \boxed{1.27 \times 10^{20} \text{ J}}$$

$$d) \gamma = \frac{E_f}{mc^2} = \sqrt{2} = \boxed{1.414}$$

$$e) \frac{v}{c} = \sqrt{1 - \frac{1}{\gamma^2}} = \frac{1}{\sqrt{2}} = \boxed{0.707}$$