I-1) $\vec{v}(t) = \frac{d}{dt} r(t) = (10t\hat{j} + (-7)\hat{k})\, m/s$

$$\vec{a}(t) = \frac{d^2}{dt^2} r(t) = \frac{d}{dt}\vec{v}(t) = \boxed{10\hat{j}\ m/s^2}$$

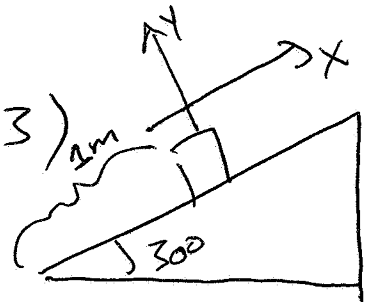
I-2) $V_f = V_0 + a\Delta t$ $\qquad a = 2m/s^2 \qquad \Delta t = t_f - t_i = 3s - 5s$

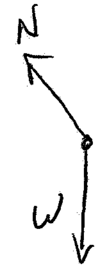
$\Delta t = -2s$

$V_f = 3m/s + (2m/s^2)(-2s)$

$$\boxed{V_f = -1m/s}$$

I-3)





$w = mg$

$\Sigma F_x = ma_x$

$a_x = \frac{-mg\sin\theta}{m} = -g\sin\theta$

$= -4.9m/s^2$

$X_f = X_0 + V_{0x}t + \frac{1}{2}a_x t^2$

$-1m = \frac{1}{2}(-4.9m/s^2)t^2$

$t = \pm .639s$ $\Leftarrow$ + answer is the one we want

so $\boxed{t = .639s}$

I-4

Two objects drop from rest separated in time by one second. How long after the first object begins to fall, will the two objects be 24.5 m apart?

Let the time at which the two objects are 24.5 m apart be t s. Then, we have,

$$d_1 = v_1 t + \frac{1}{2}at^2$$

$$d_2 = v_2(t-1) + \frac{1}{2}a(t-1)^2$$

where d_1 is the distance traveled by the first object and d_2 is the distance traveled by the second object. Taking a difference of the two equations and factoring in the fact that they start from rest we get

$$d_1 - d_2 = \frac{g}{2}\left(t^2 - (t-1)^2\right)$$

$$24.5 = 4.9(t^2 - (t^2 - 2t + 1))$$

$$t = 3$$

Or, $t = 3$ s.

I-5

Initial velocity of block, $v_i = 15$ m/s. Coefficient of friction, $\mu_k = 0.5$.

Since the block is on flat ground, the normal cancels out the weight or $N = mg$. Thus, the friction force $f_k = \mu_k N = \mu_k mg$. Thus, the block's acceleration is $a = f_k/m = \mu_k g$.

The friction force opposes the motion, thus, if we consider the direction of v as positive, the acceleration is in the negative direction. Now, final velocity of block, $v_f = 0$ m/s as it comes to rest. Thus, distance traveled can be calculated as,

$$v_f^2 = v_i^2 + 2ad$$

$$0 = 15^2 + 2(-0.5 \times 9.8)d$$

$$d = \frac{225}{4.9}$$

or $d = 22.959$ m.

I-6

Since the shell is fired horizontally its initial vertical velocity is zero. Thus, the time taken for it to fall 200 m to the ground is:

$$h = v_{iy}t - \frac{1}{2}gt^2$$

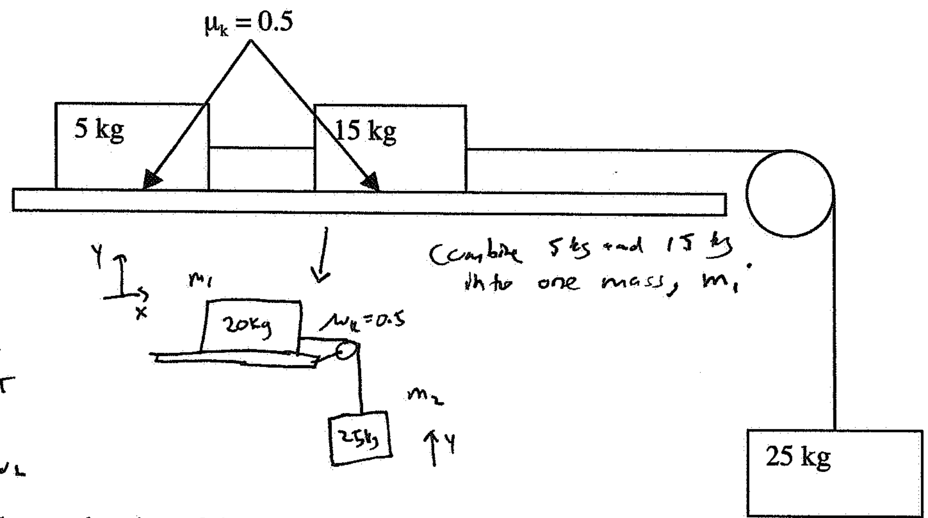
$$-200 = 0 - 4.9t^2$$

$$t = 6.389 \text{ s.}$$

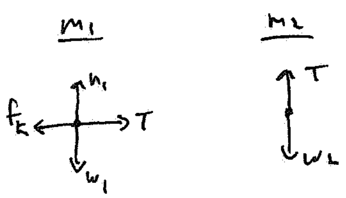
The height h is negative since the shell is falling down. Now, the horizontal velocity of the shell is 500 m/s. Since there is no acceleration in the horizontal direction, the distance traveled by the shell before it reaches the ground is $d = v_x t = 500 \times 6.389 = 3194.4$ m.

Name (1 pt): Key

II-1 (25 pts) Three blocks are connected by string and a massless pulley as shown in the figure. The blocks on the table have masses of 5 kg and 15 kg and coefficients of kinetic friction with the table of 0.5. The hanging block has a mass of 25 kg.



Combine 5 kg and 15 kg into one mass, m_1.



a) What is the acceleration of the system?

m_1:

① $\Sigma F_x = -f_k + T = m_1 a$

$\Sigma F_y = n_1 - w_1 = 0$

$f_k = \mu_k n_1 = \mu_k m_1 g$

$= (0.5)(20\text{ kg})(9.8\frac{m}{s^2}) = 98\text{N}$

m_2:

$\Sigma F_x = 0$

$\Sigma F_y = T - w_2 = -a m_2 \Rightarrow -m_2 a + w_2 = T \rightarrow$ subs into ①:

$-f_k - m_2 a + w_2 = m_1 a$

$(m_1 + m_2)a = w_2 - f_k$

$a = \dfrac{w_2 - f_k}{m_1 + m_2} = \dfrac{(25)(9.8) - 98\text{N}}{45\text{ kg}} = \boxed{3.27\frac{m}{s^2}}$

b) What is the tension in the string which connects the 15 kg and 25 kg masses?

$T - w_2 = -m_2 a$

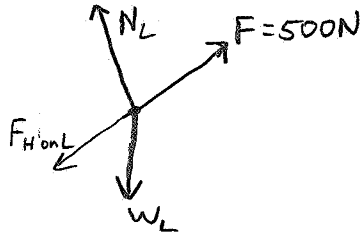
$T = -m_2 a + w_2$

$= -(25\text{ kg})(3.27\frac{m}{s^2}) + (25\text{ kg})(9.8\frac{m}{s^2}) = \boxed{163.3\text{N} = T}$

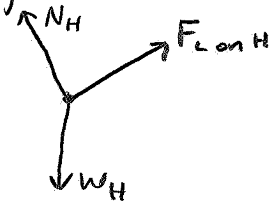
II-2.)

a.)

lower block



higher block



$$\sum F_{x_L} = F - F_{H\,on\,L} - w_L \sin\theta = m_L a$$

$$\sum F_{y_L} = N_L - w_L \cos\theta = 0$$

$$\sum F_{x_H} = F_{L\,on\,H} - w_H \sin\theta = m_H a$$

$$\sum F_{y_H} = N_H - w_H \cos\theta = 0$$

add $\sum F_{x_L}$ and $\sum F_{x_H}$ together

$$F - F_{H\,on\,L} - w_L \sin\theta + F_{L\,on\,H} - w_H \sin\theta = (m_L + m_H)a$$

since $F_{H\,on\,L} = F_{L\,on\,H}$

$$F - w_L \sin\theta - w_H \sin\theta = (m_L + m_H)a$$

$$a = \frac{F - (m_L g + m_H g)\sin\theta}{(m_L + m_H)}$$

$$a = \frac{500 - (196)\sin(30)}{20}$$

$$\boxed{a = 20.1\ m/s^2}$$

b.) $\sum F_{x_H} = F_{L\,on\,H} - w_H \sin\theta = m_H a$

$$F_{L\,on\,H} = m_H a + m_H g \sin\theta$$

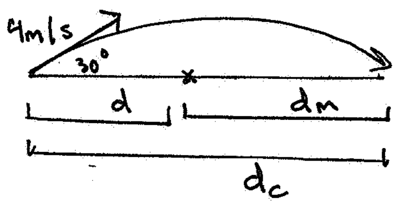
$$F_{L\,on\,H} = (5)(20.1) + (5)(9.8)\sin(30)$$

$$\boxed{F_{L\,on\,H} = 125\ N}$$

Name (1 pt):_

II-3 (25 pts) A cat is chasing a mouse. The mouse runs in a straight line at a speed of 1.5 m/s. If the cat leaps off the floor at a 30^0 angle and a speed of 4.0 m/s,

a) At what distance behind the mouse should the cat leap in order to land on the poor mouse?



$V_{ox\ cat} = V_o \cos 30° = 3.464\ m/s$ } both are constant.

$V_{ox\ mouse} = 1.5\ m/s$

Using the time from part (b):

$d_c = V_{ox\ cat} \cdot t = 3.464\ m/s \cdot 0.408\ s = 1.413\ m$

$d_m = 1.5\ m/s \cdot 0.408\ s = 0.612\ m$

$d + d_m = d_c \Rightarrow \quad d = d_c - d_m = (1.413 - 0.612)\ m = \boxed{0.801\ m}$

b) How long will the cat be in the air?

$V_{o\ cat\ y} = 4.0\ m/s \cdot \sin(30°) = 2.0\ m/s$

$\Delta y = V_{oy} t + \frac{1}{2} a_y t^2$

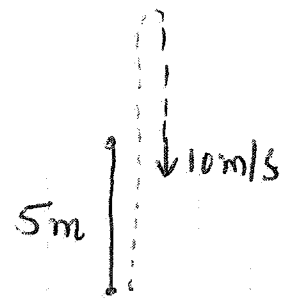
$0 = 2.0\ m/s \cdot t + \frac{1}{2} \cdot (-9.8\ m/s^2) t^2 = t\,(2.0\ m/s - 4.9\ m/s^2\ t)$

$\Rightarrow t = 0 \quad$ or $\quad t = \dfrac{2.0\ m/s}{4.9\ m/s^2} = 0.408\ sec.$

Clearly, $t=0$ is the starting point. The cat lands again after $\boxed{0.408\ sec. = t}$

3:30 Midterm Problem II - 4.

a)



$$v_f^2 = v_i^2 + 2a(s_f - s_i)$$
$$10^2 = v_i^2 - 2(9.8)(5)$$
$$v_i = \sqrt{100 + 98} = \sqrt{198}$$
$$\sim 14 \text{ m/s}$$

b) at max h $v_f = 0$

$$\Rightarrow \quad v_f^2 = v_i^2 + 2a(s_f - s_i)$$
$$0 = 198 - 2(9.8)h$$
$$h = \frac{198}{2(9.8)} = \frac{198}{19.6} \sim 10 \text{ m}$$

c) time to travel from zero to h

$$v_f = v_i + at_1$$
$$0 = \sqrt{198} - (9.8)t_1 \qquad t_1 = \frac{\sqrt{198}}{9.8}$$

time to travel from h to chad

$$-10 = 0 - (9.8)t_2 \qquad t_2 = \frac{10}{9.8}$$

$$\text{total time} = \frac{\sqrt{198}}{9.8} + \frac{10}{9.8} \sim 2.5 \text{ sec}$$