Exam-I (Fall '10)

1.) *Multiple Choice* (*18 pts.*)

For each statement below, circle the correct answer (TRUE or FALSE, no reasoning required).

(a) A scalar quantity is characterized by a magnitude and a direction.
TRUE FALSE

(b) If a runner on a circular track completes precisely one lap, his net displacement over this lap is zero.
TRUE FALSE

(c) In projectile motion, the acceleration at the highest point of the trajectory is zero.
TRUE FALSE

(d) A change in velocity, $\vec{v}$, always requires a change in speed, v.
TRUE FALSE

(e) The normal force between an object and a surface is parallel to that surface.
TRUE FALSE

(f) A friction force between an object and a surface is parallel to that surface.
TRUE FALSE

No.	Points
1	HZ
2	RR
3	AP
4	KH
5	YC
6	FZ
Sum	

2.) *Free Fall* *(20 pts.)*

A kid throws a tennis ball straight up (neglect air drag and friction forces), with a launch speed of $12m/s$, and catches it upon return at the original launch point. ($g = 9.8m/s^2$)

(a) What is the *velocity* of the ball when it reaches its maximal height, and when the kid catches it again? (*no calculation necessary!*)

(b) Calculate the maximal height reached by the ball.

(c) Calculate the total flight time of the ball (until the kid catches it again).

(d) Sketch the velocity as a function of time in a $v_y(t)$ plot.

(a) maximal height: $V_y = 0$

return to kid: $V_y = -12 \frac{m}{s}$

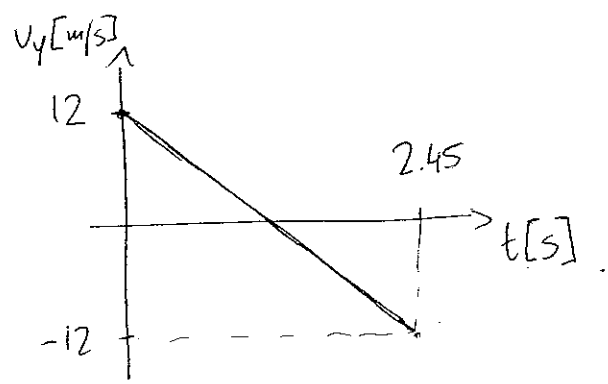
(b) $V_y^2 = V_{oy}^2 - 2gy$ for $y = y_{max}$ one has $V_y = 0$

$\Rightarrow \boxed{y_{max} = \frac{V_{oy}^2}{2g} = 7.35\,m}$

(c) $V_y = V_{oy} - gt$ $V_y = -12\,m/s = -V_{oy}$

$\Rightarrow \boxed{t = \frac{2V_{oy}}{g} = 2.45\,s}$

(d)



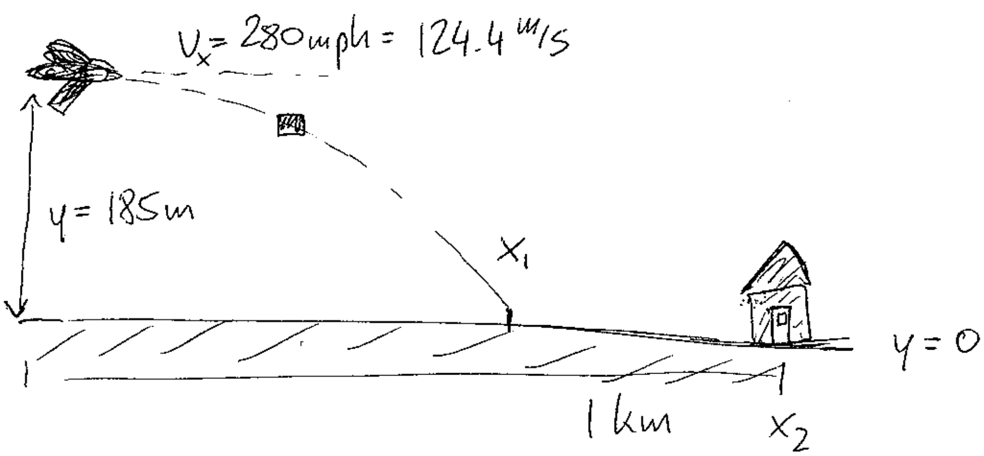
3.) *Projectile Motion* *(18 pts.)*

A supply plane is flying low, just 185m above ground, at a speed of 280mph in horizontal direction. The rescue worker in the plane drops a package of food supply for a snowed-in farm which is on the ground a horizontal distance of 1.0km straight ahead. Neglect any air drag and friction forces. ($1m/s = 2.25mph$)

(a) How long is the package in the air when dropped from rest relative to the plane?

(b) At what horizontal distance from the farm does the package hit the ground?

(c) What is the package's speed when it hits the ground?



(a) Flight time: $y = y_0 - \frac{1}{2} g t^2$ $\quad y = 0$, $y_0 = 185m$

$$\Rightarrow \boxed{t = \sqrt{\frac{2y_0}{g}} = 6.14s}$$

(b) $$\boxed{x_1 = v_{0x} t = 124.4 * 6.14 = 765m}$$

$$\boxed{\Delta x = x_2 - x_1 = 235m}$$

(c) $v_y = -gt = -60.2 \, m/s$

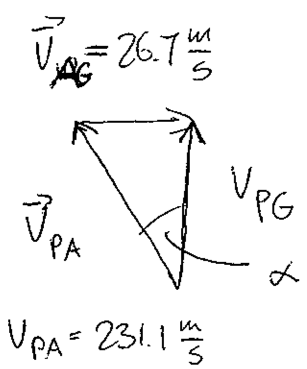
$$\boxed{v = \sqrt{v_{0x}^2 + v_y^2} = 138 \, \frac{m}{s}}$$

4.) *Relative Velocity* (*14 pts.*)

A plane is traveling straight north in still air at its cruising speed of $520mph$, expected to reach its destination in $90min$. Suddenly, it encounters an unexpected strong wind from the west blowing at $60mph$.

(a) By how many degrees relative to north does the captain have to counter-steer to maintain the plane's course straight north? Start by sketching a velocity diagram.

(b) By how many minutes will the arrival at the destination be delayed if the wind keeps blowing steadily?



(a)

$$\sin \alpha = \frac{V_{AG}}{V_{PA}}$$

$$\Rightarrow \boxed{\alpha = \sin^{-1}\left(\frac{V_{AG}}{V_{PA}}\right) = \sin^{-1}\left(\frac{60}{520}\right) = 6.6^\circ}$$

(b) $V_{PG} = V_{PA} \cos \alpha = 516.5 \text{ mph}$

$$\frac{\Delta t_{new}}{\Delta t_{old}} = \frac{V_{PA}}{V_{PG}} \qquad \Delta t_{new} = \Delta t_{old} \frac{V_{PA}}{V_{PG}} = 90.6 \text{ min}$$

$$\Rightarrow \boxed{\text{delay} = 0.6 \text{ min} = 36 \text{ s}}$$

5.) *Newton's Law and Friction* *(15 pts.)*

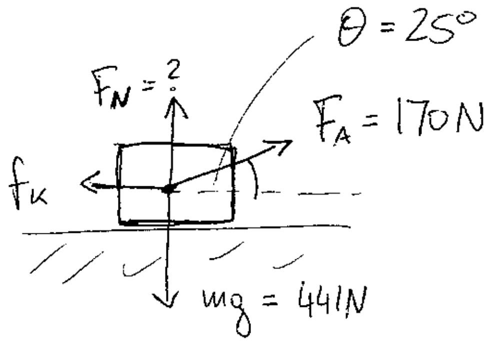
A factory worker is pulling a box (mass $45kg$) which is sliding behind him on a horizontal surface. He is applying a force of $170N$ at an angle of 25° above the horizontal. The kinetic friction coefficient between box and floor surface is $\mu_k = 0.15$.

(a) Draw a free-body diagram of the box including all forces acting on it.

(b) Calculate the normal force on the box.

(c) Calculate the horizontal acceleration of the box.

(a)



(b) Equilibrium in y-direction:

$$0 = \sum_i F_{iy} = F_N - mg + F_A \sin\theta$$

$$\Rightarrow \boxed{F_N = mg - F_A \sin\theta = 369\,N}$$

(c) x-direction:

$$\sum_i F_{ix} = m a_x$$

$$= -f_K + F_A \cos\theta \qquad f_K = \mu_K F_N$$

$$\Rightarrow \boxed{a_x = \frac{1}{m}\left(F_A \cos\theta - \mu_K F_N\right) = 2.19\ m/s^2}$$

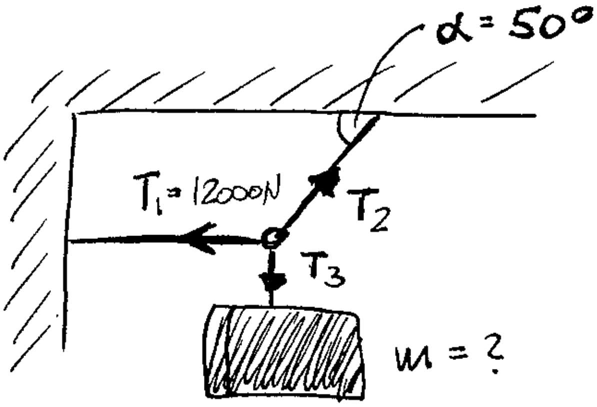
6.) *Equilibrium and Tension* *(15 pts.)*

A heavy cement block is suspended via three steel cables as shown in the diagram below. The left (horizontal) cable is under its maximally allowed tension, $T_1 = 12000N$.

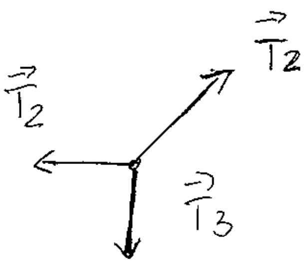
(a) Draw a free-body diagram for the connecting ring (where all 3 cables attach).

(b) Calculate the tension T_2 in the inclined cable 2.

(c) Calculate the mass of the cement block.



(a)



(b) horizontal direction (equilibrium):

$$0 = \sum_i F_{ix} = -T_1 + T_2 \cos\alpha$$

$$\Rightarrow \quad T_2 = \frac{T_1}{\cos\alpha} = 18669\ N$$

(c) vertical direction (equilibrium):

$$0 = \sum_i F_{iy} = -T_3 + T_2 \sin\alpha$$

$$\Rightarrow \quad \boxed{T_3} = T_2 \sin\alpha = \boxed{14301\ N} = mg$$

$$\Rightarrow \quad \boxed{m =} \frac{T_3}{g} = \boxed{1459\ kg}$$