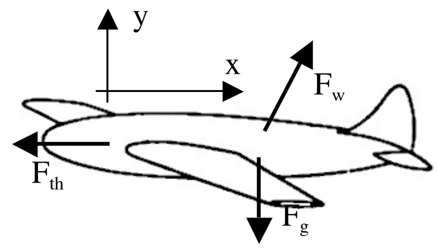
Name:_______________________________________

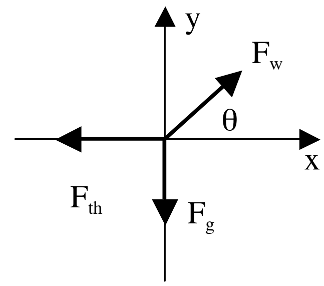
Solve the following problems in the space provided. Use the back of the page if needed. Each problem is worth 20 points. You must show your work in a logical fashion starting with the correctly applied physical principles. The equations you need are on the equation sheet. Your score will be maximized if your work is easy to follow because partial credit will be awarded.

1. The 4000kg plane shown at the right feels a horizontal forward force (called the "thrust") created by the engines of 9000N. Find the magnitude and direction of the force on the wings assuming the plane is moving with a constant velocity.



Using the free body diagram at the right and applying Newton's Second Law,

$$\Sigma F_x = ma_x \Rightarrow F_w \cos\theta - F_{th} = 0 \Rightarrow F_{th} = F_w \cos\theta$$
$$\Sigma F_y = ma_y \Rightarrow F_w \sin\theta - F_g = 0 \Rightarrow F_g = F_L \sin\theta$$



Dividing the y-equation by the x-equation,

$$\frac{F_w \sin\theta}{F_w \cos\theta} = \frac{F_g}{F_{th}} \Rightarrow \tan\theta = \frac{mg}{F_{th}} \Rightarrow \theta = \arctan\left(\frac{mg}{F_{th}}\right)$$

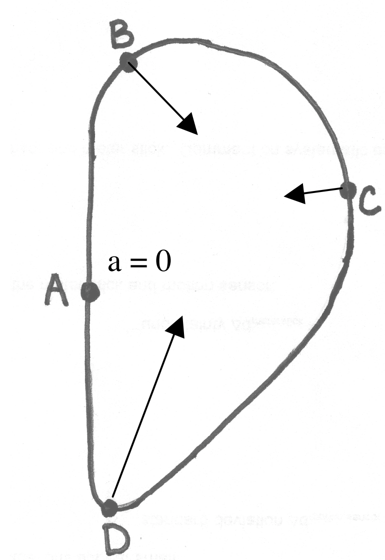
$$\theta = \arctan\left(\frac{(4000)(9.80)}{9000}\right) \Rightarrow \boxed{\theta = 77.1^\circ}.$$

Solving the x-equation for the lift,

$$F_w = \frac{F_{th}}{\cos\theta} = \frac{9000}{\cos 77.1^\circ} \Rightarrow \boxed{F_w = 40.2kN}.$$

The force on the wings is 40.2kN directed at 77.1° above horizontal.

2. A racecar goes completely around the racetrack shown at the right moving at a constant speed of 200km/h the entire way. Indicate in the diagram the direction of the acceleration at each of the labeled points and rank the accelerations from largest to smallest. Explain your thinking.



Since the speed of the car is constant there will be no tangential acceleration. The centripetal acceleration is given by,

$$a_c = \frac{v^2}{r}.$$

Since v is constant, the acceleration will be the largest when the radius of the turn is the smallest. Where the track is straight, the radius is infinite and the centripetal acceleration is zero. So the ranking will be,

$$\boxed{D>B>C>A=0}.$$

3. Charles "Gabby" Street was a catcher for the Washington Senators from 1909 to 1911. He reputedly caught a 145g baseball dropped from the top of the Washington Monument which is 152m tall. Modern wind tunnel measurements suggest that the maximum speed of a dropped baseball should be about 42.7m/s. Find (a)the work done by gravity on the falling ball, (b)the net work done on the ball during its fall and (c)the work done by air resistance during the fall.

(a)Using the definition of work and the fact that the force of gravity is constant and in the direction of motion of the ball,

$$W \equiv \int \vec{F} \bullet d\vec{s} \Rightarrow W_g = F_g y = mgy = (0.145)(9.80)(152) \Rightarrow \boxed{W_g = 216J}.$$

(b)According to the Work-Energy Theorem,

$$W_{net} = \Delta K = \tfrac{1}{2}mv^2 - \tfrac{1}{2}mv_o^2 = \tfrac{1}{2}(0.145)(42.7)^2 - 0 \Rightarrow \boxed{W_{net} = 132J}.$$

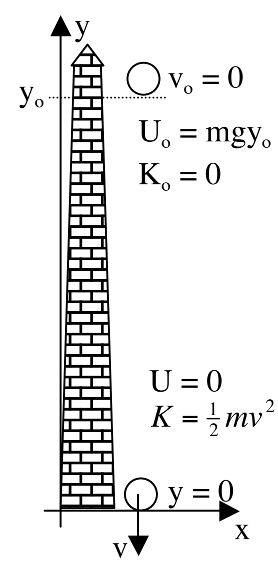
(c)The total work done is the sum of the work done by each force. In this case,

$$W_{net} = W_g + W_{air} \Rightarrow W_{air} = W_{net} - W_g = 132 - 216 \Rightarrow \boxed{W_{air} = -83.8J}.$$

Note that the answer is negative because air resistance acts opposite the motion.

4. Use energy methods to find the speed that the baseball in problem 3 would have struck the ground if there were no air resistance.

Applying the Law of Conservation of Energy and ignoring air resistance,



$$\Delta K + \Delta U = 0 \Rightarrow (K - K_o) + (U - U_o) = 0 \Rightarrow K - U_o = 0 \Rightarrow K = U_o$$

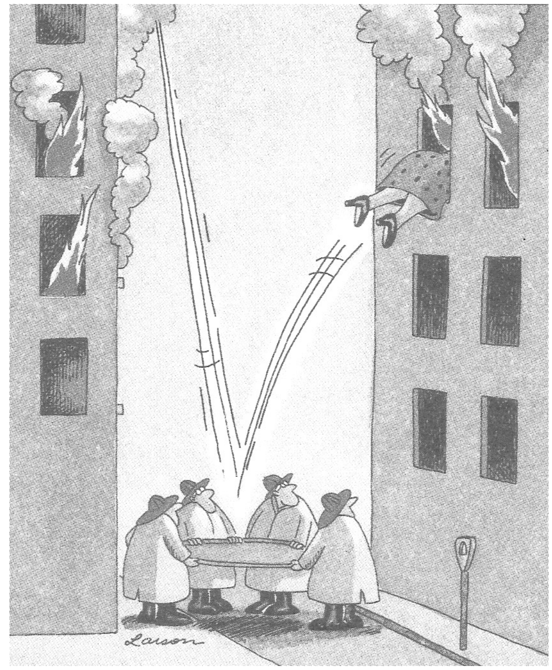
Using the kinetic and potential energies,

$$\tfrac{1}{2}mv^2 = mgy_o \Rightarrow v = \sqrt{2gy_o}$$

Plugging in the numbers,

$$v = \sqrt{2(9.80)(152)} \Rightarrow \boxed{v = 54.6m/s}.$$

5. The 52.0kg woman pictured at the right falls into the safety net and stretches it 0.500m. The net springs back and he flies through the third story window 9.00m above the net at a speed of 13.0m/s. Find (a)the height of the window she fell from and (b)the effective spring constant of the safety net.



(a)Initially, as the woman begins to fall,

$$K_o = 0 \text{ and } U_o = mgy_o.$$

As the woman goes through the window shown,

$$K = \tfrac{1}{2}mv^2 \text{ and } U = mgy.$$

Applying the Law of Conservation of Energy,

$$\Delta K + \Delta U = 0 \Rightarrow (K - K_o) + (U - U_o) = 0 \Rightarrow K + U - U_o = 0.$$

Putting in the expressions above,

$$\tfrac{1}{2}mv^2 + mgy - mgy_o = 0 \Rightarrow y_o = y + \frac{v^2}{2g}.$$

Putting in the numbers,

$$y_o = 9.00 + \frac{(13.0)^2}{2(9.80)} \Rightarrow \boxed{y_o = 17.6m}.$$

(b)At the instant the woman is at the bottom of the net, her kinetic energy is zero. Keeping in mind that she has fallen an additional 0.500m, her potential energy at this point is,

$$U = \tfrac{1}{2}kx^2 - mgx.$$

Applying the Law of Conservation of Energy,

$$\Delta K + \Delta U = 0 \Rightarrow (K - K_o) + (U - U_o) = 0 \Rightarrow (0 - 0) + (\tfrac{1}{2}kx^2 - mgx - mgy_o) = 0.$$

Soling for the spring constant,

$$k = \frac{2mg(x + y_o)}{x^2} = \frac{2(52.0)(9.80)(0.500 + 17.6)}{(0.500)^2} \Rightarrow \boxed{k = 73.8kN/m}.$$