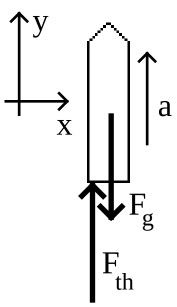
Name:____

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 which are on the last page. Your score will be maximized if your work is easy to follow because partial credit will be awarded.

1. The initial mass of a rocket is $1.50x10^4$kg and the initial acceleration is $5.00m/s^2$ upward. (a)Find the weight of the rocket and (b)find the upward force on the rocket exerted by the exhaust gases from the engine. (c)If this upward force is the "action" force acting on the rocket, find the size of the "reaction" force. (d)Name the object that the reaction force acts on.



(a)Using the mass/weight rule, $F_g = mg = (1.50x10^4)(9.80)$ $\boxed{F_g = 1.47x10^5 N}$.

(b)Applying Newton's Second Law,

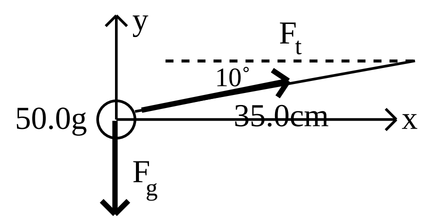
$$\Sigma F = ma \quad F_{th} - F_g = ma \quad F_{th} = ma + F_g$$

$$F_{th} = (1.50x10^4)(5.00) + 1.47x10^5 \quad \boxed{F_{th} = 2.22x10^5 N}.$$

(c)According to Newton's Third Law the sizes of the action and reaction are always equal so, $\boxed{F = 2.22x10^5 N}$.

(d) According to Newton's Third Law, if the gas exerts a force on the rocket, the rocket must exert an equal force back on the gas.

2. A 50.0g ball is twirled overhead at the end of a 35.0cm string. The string makes a 10.0˚ angle with the horizontal. (a)Draw the forces that act on the ball is the sketch at the right. (b)Find the speed of the ball and (c)the number of revolutions per minute.



(b)Applying Newton's Second Law,

$$\Sigma F_x = ma_x \quad F_t\cos 10^\circ = ma_c \text{ and } \Sigma F_y = ma_y \quad F_t\sin 10^\circ - F_g = 0 \quad F_t\sin 10^\circ = F_g\,.$$

Using the mass/weight rule and the centripetal acceleration,

$$F_t\cos 10^\circ = m\frac{v^2}{r} \text{ and } F_t\sin 10^\circ = mg\,.$$

Dividing the vertical equation by the horizontal equation,

$$\frac{F_t\sin 10^\circ}{F_t\cos 10^\circ} = \frac{mgr}{mv^2} \quad \tan 10^\circ = \frac{gr}{v^2}\,.$$

Noting that $r = \ell\cos 10^\circ$ and solving for the speed,

$$\tan 10^\circ = \frac{g\ell\cos 10^\circ}{v^2} \quad v = \sqrt{\frac{g\ell\cos 10^\circ}{\tan 10^\circ}} = \sqrt{\frac{(9.80)(0.350)\cos 10^\circ}{\tan 10^\circ}} \quad \boxed{v = 4.38\text{m/s}}.$$

(b)Using the definition of speed,

$$v \equiv \frac{\Delta x}{\Delta t} = \frac{2\pi r}{T} = 2\pi r f \quad f = \frac{v}{2\pi r} = \frac{v}{2\pi\ell\cos 10^\circ} = \frac{4.38}{2\pi(0.350)\cos 10^\circ}$$

$$\boxed{f = \left(2.02\tfrac{\text{rev}}{\text{s}}\right)\left(\tfrac{60\text{s}}{\text{min}}\right) = 121\text{rpm}}.$$

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 gravitational force is constant,

$$W \equiv \int \vec{F}\cdot d\vec{s} \quad W_g = F_g h = mgh = (0.145)(9.80)(152) \quad \boxed{W_g = 216\text{J}}.$$

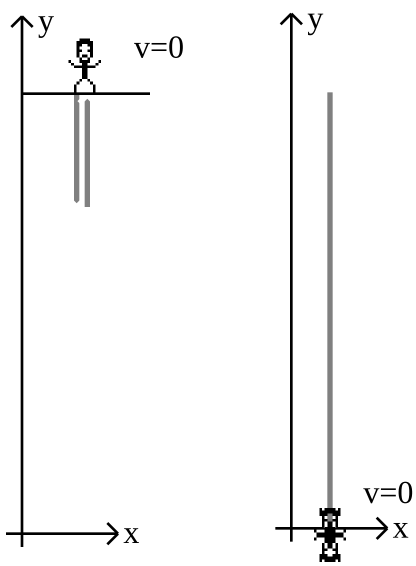
(b)Using the Work-Energy Theorem and the definition of kinetic energy,

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

(c)The net work must also equal the work done by gravity plus the work done by air resistance,

$$W_{net} = W_g + W_{air} \quad W_{air} = W_{net} - W_g = 132 - 216 \quad \boxed{W_{air} = -84.0\text{J}}.$$

4. A 60.0kg bungee jumper steps off a 55.0m high bridge. The unstretched length of the cord is 30.0m and it stretches an additional 20.0m when the jumper is at the lowest point. Find the spring constant of the cord assuming air resistance is negligible and the cord is massless.



$U_o = mgy$ $\quad U = \frac{1}{2}kx^2$

$K_o = 0$ $\quad K = 0$

Using the Law of Conservation of Energy,

$\Delta K + \Delta U = 0$.

The kinetic energy is zero at the top and the bottom. The potential energy has changed from gravitational to spring.

$(0 - 0) + (\frac{1}{2}kx^2 - mgy) = 0 \qquad \frac{1}{2}kx^2 = mgy$

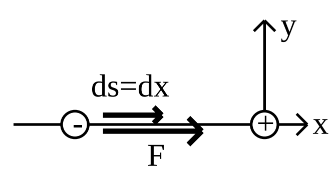
Solving for the spring constant,

$$k = \frac{2mgy}{x^2} = \frac{2(60.0)(9.80)(50.0)}{(20.0)^2} \qquad \boxed{k = 147\text{N/m}}.$$

5. The force of electrical attraction between a proton and an electron in a hydrogen atom is given by $F = \frac{a}{x^2}$ where a=2.30x10^{-28}N·m^2 and x is the distance between them. Find the work done by the electric force if the electron is initially 200x10^{-12}m away and moves toward the proton until it is 50.0x10^{-12}m away. Explain physically (not mathematically) why your answer should be positive.

Using the definition of work and the fact that the force is in the direction of motion,

$$W \equiv \int \vec{F} \cdot d\vec{s} = \int_{x_o}^{x} \left(\frac{a}{x^2}\right)(dx).$$



Doing the integration,

$$W = -\frac{a}{x} + \frac{a}{x_o} = -\frac{2.30\text{x}10^{-28}}{-50.0\text{x}10^{-12}} + \frac{2.30\text{x}10^{-28}}{-200\text{x}10^{-12}} \qquad \boxed{W = 3.45\text{x}10^{-18}\text{J}}.$$

The work done must be positive because the force acts in the direction of the motion of the electron.