	Physics 240: Worksheet 06	Name ___________________

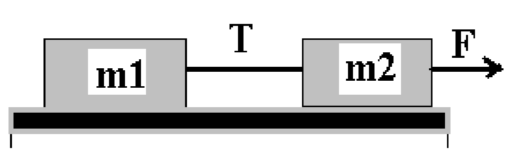
(1) A bicycle has a mass of 10.5 kg and the rider has a mass of 82 kg. Suppose that the rider is able to peddle hard enough so that a net horizontal force of 8 N accelerates the system. Find the acceleration.

(2) An arrow starts from rest and leaves a bow with a speed of 30.0 m/s. If the average force exerted on the arrow by the bow were doubled, ***all else remaining the same (except the time the arrow is in contact with the bow)***, with what speed would the arrow leave the bow? What if instead, the distance through which the force was applied also doubled? Again, the time that the force was applied would change.

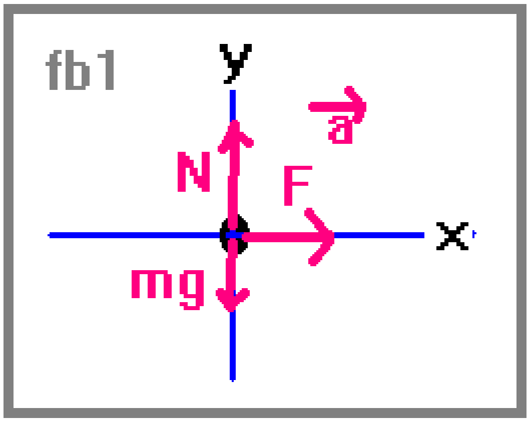
(3) A high diver of mass 70.0 kg jumps off a board 10.0 m above the water. If his downward motion is stopped 2.00 s after he enters the water, what average upward force did the water exert on him?

(4) A mass M is lying on a frictionless table and is acted upon by two forces, F_1 and F_2. For this problem, F_2 is bigger than F_1. Find the normal force and the acceleration of the system. If M=10kg, F_1=3N and F_2=4N, provide numerical answers together with the correct units.

(5) Consider the system shown. Find the tension and acceleration of this system if there is no friction between the blocks and the table. If m1=m2=1 kg, provide numerical values for these quantities with F=1 N.



(1) A bicycle has a mass of 10.5 kg and the rider has a mass of 82 kg. Suppose that the rider is able to peddle hard enough so that a net horizontal force of 8 N (exerted by the road, actually) accelerates the system. Find the acceleration.



Apply Newton's laws to the free body diagram shown to the left.

$$\sum \vec{F} = m\vec{a} \Rightarrow \begin{matrix} F = ma_x \\ N - mg = 0 \end{matrix} \Rightarrow \begin{matrix} a = \frac{F}{m} \\ N = mg \end{matrix}$$

Providing numerical answers gives:

$$a = \frac{8N}{(82+10.5)kg} = \frac{8}{92.5} = 0.086\frac{m}{s^2}$$

Also we can find the normal force:
$N = (92.5)g = 906.5N$.

(2) An arrow starts from rest and leaves a bow with a speed of 30.0 m/s. If the average force exerted on the arrow by the bow were doubled, ***all else remaining the same*** ***(except the time the arrow is in contact with the bow)***, with what speed would the arrow leave the bow? What if instead, the distance through which the force was applied also doubled? Again, the time that the force was applied would change.

Since F is doubled, the acceleration is doubled:

$$\vec{F}_1 = m\vec{a}_1 : \vec{F}_2 = m\vec{a}_2 : \vec{F}_2 = 2\vec{F}_1 \Rightarrow \vec{a}_2 = 2\vec{a}_1$$

If the arrow is in contact with the bow through the same distance (but not necessarily the same time) then:

$$v^2 = v_0^2 + 2a\Delta x \Rightarrow \begin{matrix} v_1^2 = v_{1,0}^2 + 2a_1\Delta x \Rightarrow v_1^2 = 2a_1\Delta x \\ v_2^2 = v_{2,0}^2 + 2a_2\Delta x \Rightarrow v_2^2 = 2a_2\Delta x \end{matrix} \Rightarrow \frac{v_1^2}{v_2^2} = \frac{a_1}{a_2} = \frac{a_1}{2a_1} = \frac{1}{2}$$

$$\therefore v_2^2 = 2v_1^2 \Rightarrow v_2 = \sqrt{2}v_1$$

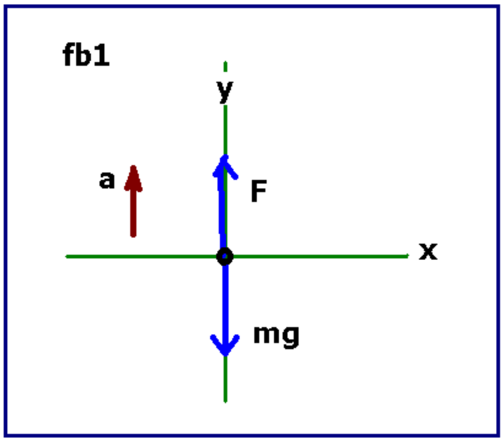
So if in the first case the velocity was 30 m/s, then in the second case the velocity would be 42.4 m/s.

If the force and Δx were both doubled, then:

$$v^2 = v_0^2 + 2a\Delta x \Rightarrow \begin{matrix} v_1^2 = v_{1,0}^2 + 2a_1\Delta x_1 \Rightarrow v_1^2 = 2a_1\Delta x_1 \\ v_2^2 = v_{2,0}^2 + 2a_2\Delta x_2 \Rightarrow v_2^2 = 2a_2\Delta x_2 \end{matrix} \Rightarrow \frac{v_1^2}{v_2^2} = \frac{a_1\Delta x_1}{a_2\Delta x_2} = \frac{a_1\Delta x_1}{(2a_1)(2\Delta x_1)} = \frac{1}{4}$$

$$\therefore v_2^2 = 4v_1^2 \Rightarrow v_2 = 2v_1$$

(3) A high diver of mass 70.0 kg jumps off a board 10.0 m above the water. If the downward motion is stopped 2.00 s after entering the water, what average upward force did the water exert on the diver?

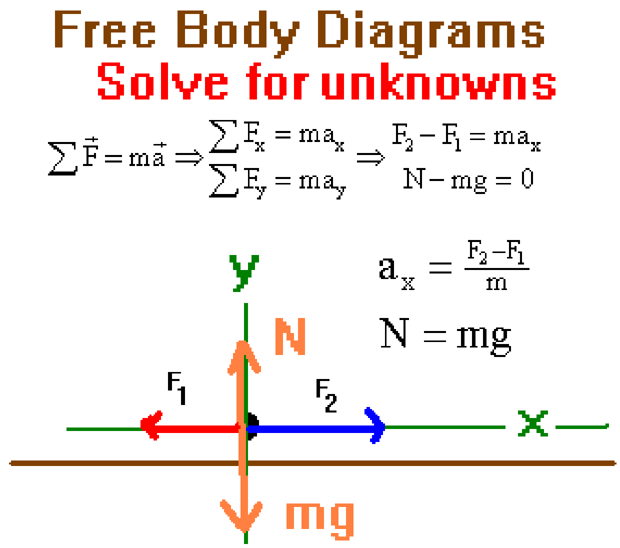


Again, $F = m\frac{\Delta v}{\Delta t}$. Here, however, we are not immediately given the initial velocity. Let's assume that the height above the water is 10.0 m. Then, if the diver has an initial velocity of zero upon leaving the board, we can find the velocity immediately upon entering the water:

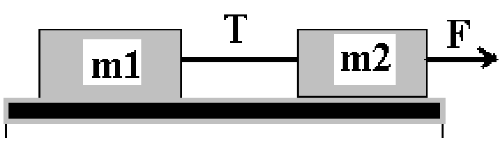
$$v^2 = v_o^2 - 2g(\Delta y) \Rightarrow v = \pm\sqrt{2g\Delta y} = \sqrt{2(9.8)(10)} = \pm 14 m/s.$$

The physical solution here is negative. We can now use this to find the average force exerted: $F = m\frac{\Delta v}{\Delta t} = 70\frac{14}{2} = 490N$

(4) A mass M is lying on a frictionless table and is acted upon by two forces, F_1 and F_2. For this problem, F_2 is bigger than F_1. Find the normal force and the acceleration of the system. If M=10kg, F_1=3N and F_2=4N, provide numerical answers together with the correct units.



I have provided on the web page an animated gif showing the steps needed to achieve this answer. In this particular problem, $a=1/10=0.1 m/s^2$ and N=10(9.8)=98N.



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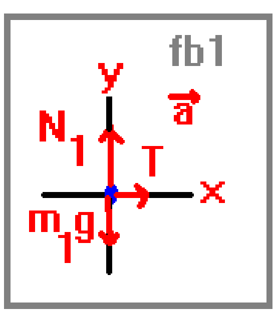

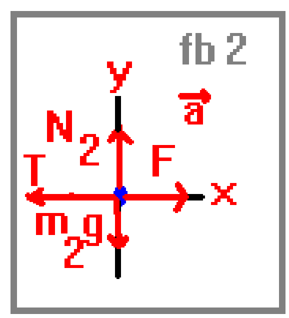

$$\sum \vec{F} = m_1\vec{a}$$
$$T = m_1 a$$
$$N_1 - m_1 g = 0$$

$$\sum \vec{F} = m_2 a$$
$$F - T = m_2 a$$
$$N_2 - m_2 g = 0$$

Solve for T, we find

$$F - m_1 a = m_2 a \Rightarrow a = \frac{F}{m_2 + m_1} \Rightarrow T = \frac{m_1}{m_1 + m_2} F .$$

With $m_1=m_2=1$kg and F=1 N, we find $a=1/2 \text{ m/s}^2$ and T=1/2 N.