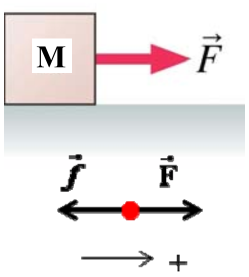
Physics 2211K
Test # 2
October 14, 2010

"I have neither given nor received help on this exam." **TEST VERSION 1**

In order to evaluate your progress in this course, I must see how you arrive at your answers. THEREFORE, YOU MUST SHOW YOUR WORK IN ORDER TO RECEIVE CREDIT FOR A QUESTION. Always circle your answer and show the units. ***{Unless otherwise instructed, use g = 10 m/s² for all questions.}***

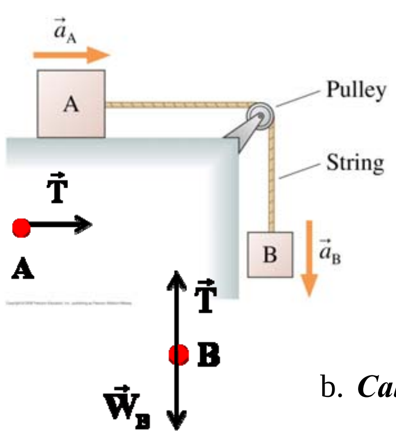
1. In the sketch below, the applied force ***F = 60 N*** causes the object of ***M = 20 kg*** to slide with constant speed (***v = 5 m/s***) on the horizontal surface with friction. Calculate the coefficient of kinetic friction μ_k. ***(10 pts)***



$$F_{net} = ma = F - f = F - \mu n = F - \mu mg$$
$$\text{constant speed} \Rightarrow a = 0 \;\&\; F_{net} = 0$$
$$\therefore f = F = \mu mg, \text{ and}$$
$$\mu = \frac{F}{mg} = \frac{60\text{ N}}{200\text{ N}} = 0.3$$

2. In the system below, mass ***A = 12 kg***, mass ***B = 8 kg***, the horizontal surface is frictionless, and the string is massless.

   a. ***Calculate the acceleration of the objects; (10 pts)***



$$m_A a = T$$
$$m_B a = W_B - T = m_B g - T = m_B g - m_A a$$
$$a = \frac{m_B g}{m_A + m_B} = \frac{80\text{N}}{20\text{kg}} = 4\text{ m/s}^2$$

   b. ***Calculate the tension in the string. (10 pts)***

$$T = m_A a = (12\text{ kg})(4\text{ m/s}^2) = 48\text{ N}$$

3. A ***1500 kg*** car traveling at ***20 m/s*** (approx. 50 mi/hr) approaches an unbanked (circular) curve with radius ***125 m***. If the coefficient of static friction between the car's tires and the road is μ_s ***= 0.5,*** can the car go around the curve without sliding? ***(Show calculations to support your yes / no answer!!!) (10 pts)***

To travel around the curve, the car needs

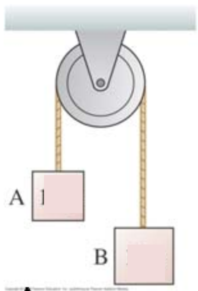
$$F_c = \frac{mv^2}{r} = (1500\text{ kg})\left(\frac{400\text{ m}^2/\text{s}^2}{125\text{ m}}\right) = 4800\text{ N}$$

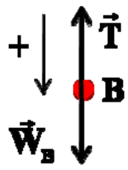
Maximum $f_s = \mu_s n = \mu_s mg = (0.5)(1500\text{ kg})(10\text{ m/s}^2) = 7500\text{ N}$

$\therefore f_s$ **can provide more than the necessary force since 7500 N > 4800 N.**

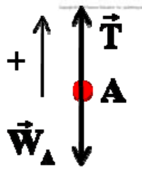
The answer is YES.

4. In the pulley arrangement below, mass ***A = 6 kg***, mass ***B = 10 kg***, and they are connected by a massless string.
   a. Calculate the ***acceleration of each; (10 pts)***





$$m_A a = T - m_A g$$
$$m_B a = m_B g - T$$
$$a = \frac{(m_B - m_A)g}{(m_A + m_B)} = \frac{(4\,kg)(10\,m/s^2)}{(16\,kg)} = 2.5\,m/s^2$$



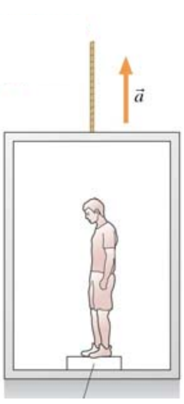
   b. Calculate ***the tension in the string***. ***(10 pts)***

$$T = m_A a + m_A g = (6\,kg)(12.5\,m/s^2) = 75\,N$$

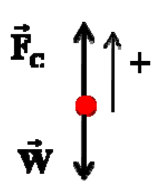
5. Newton's law of gravitation states that $F_G = G\frac{m_1 m_2}{r^2}$. If the gravitational acceleration at the surface of the earth is $\boldsymbol{g = 9.8\ m/s^2}$ ***(***$\boldsymbol{R_E = 6.37 \times 10^6\ m;\ M_E = 5.98 \times 10^{24}\ kg}$***)***, what is the acceleration at an altitude above the surface equal to R_E ***(***$2 \times R_E$ ***from the center of the earth)***? (Think about it---do you really need to know the values of R_E ***and*** M_E?) ***(10 pts)***

$$\text{Reasoning: As } r \to 2r,\ F_G \to \frac{F_G}{4};\ \text{so } mg \to \frac{mg}{4}\ \&\ g \to \frac{9.8\,m/s^2}{4} = 2.45\,m/s^2$$
$$\text{Formally, @ the surface of the earth, } mg = G\frac{mM_E}{R_E^2} = m\left(G\frac{M_E}{R_E^2}\right)$$
$$\text{so } \left(G\frac{M_E}{R_E^2}\right) = 9.8\,m/s^2 \text{ and } \left[G\frac{M_E}{(2R_E)^2}\right] = \frac{9.8\,m/s^2}{4} = 2.45\,m/s^2$$

6. As sketched below, the ***90 kg person*** is in an elevator accelerating upwards at $\boldsymbol{2.5\ m/s^2}$.



   a. ***How much is the force of contact between his feet and the floor of the elevator***? ***(10 pts)***

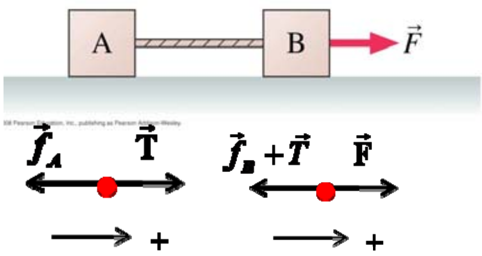


$$F_{net} = ma = F_c - mg \Rightarrow F_c = ma + mg = m(a+g)$$
$$Up \Rightarrow a > 0$$
$$F_c = (90\,kg)(12.5\,m/s^2) = 1125\,N$$

   b. ***Calculate the force of contact for the case of the elevator accelerating downwards at*** $\boldsymbol{2.5\ m/s^2}$***. (10 pts)***

$$F_{net} = ma = F_c - mg \Rightarrow F_c = ma + mg = m(a+g)$$
$$Down \Rightarrow a < 0$$
$$F_c = (90\,kg)(7.5\,m/s^2) = 675\,N$$

7. In the system below, mass ***A = 6 kg***, mass ***B = 8 kg***, and the string is ***massless***. The ***coefficient of friction*** between *A* and the horizontal surface is $\mu_{kA} = 0.2$, that for ***B*** is $\mu_{kB} = 0.4$, ***F = 80 N directed as shown***, and the objects are sliding to the right.



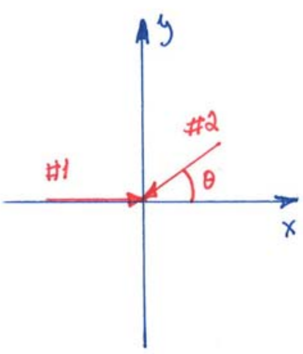
a. ***Calculate their acceleration; (10 pts)***

$$m_A a = T - f_A \Rightarrow f_A = \mu_A m_A g = (0.2)(6\text{ kg})(10\text{ m/s}^2) = 12\text{ N}$$
$$m_B a = F - T - f_B \Rightarrow f_B = \mu_B m_B g = (0.4)(8\text{ kg})(10\text{ m/s}^2) = 32\text{ N}$$
$$a = \frac{(F - f_A - f_B)}{(m_A + m_B)} = \frac{(80 - 12 - 32)\text{ N}}{(6+8)\text{ kg}} = 2.57\text{ m/s}^2$$

b. ***Calculate the tension in the string. (10 pts)***

$$T = m_A a + f_A = (6\text{ kg})(2.57\text{ m/s}^2) + 12\text{ N} = 27.43\text{ N}$$

8. As sketched below, Georgia State's ***90 kg*** running back ***(#1)*** runs at ***8 m/s*** across the line of scrimmage. The other team's ***100 kg*** linebacker ***(#2)***, running at ***6 m/s*** (***θ= 30° as shown)*** tackles the running back and holds on so they both move together afterwards. ***Calculate the magnitude and direction of their velocity immediately after the impact. (10 pts)***

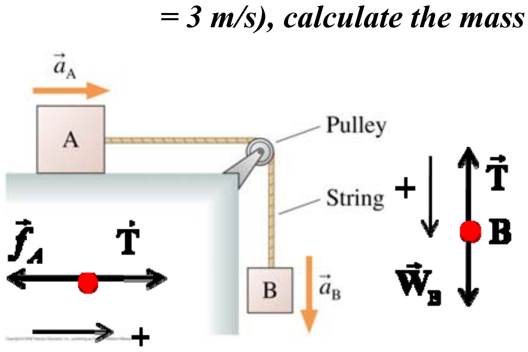


For collisions, momentum is conserved immediately before and after contact so $\vec{p}_{iT} = \vec{p}_{fT}$.

Momentum is a vector, so this becomes (note the direction of #2!!!):

$$x: \quad (p_{1x} + p_{2x})_i = (p_{1x} + p_{2x})_f \Rightarrow (90\text{ kg})(8\text{ m/s}) - (100\text{ kg})(6\text{ m/s})\cos 30° = (190\text{ kg})v_{fx}$$
$$v_{fx} = \frac{(720 - 519.6)\text{ kgm/s}}{190\text{ kg}} = 1.05\text{ m/s}$$
$$y: \quad (p_{1y} + p_{2y})_i = (p_{1y} + p_{2y})_f \Rightarrow 0 - (100\text{ kg})(6\text{ m/s})\sin 30° = (190\text{ kg})v_{fy}$$
$$v_{fy} = \frac{(-300)\text{ kgm/s}}{190\text{ kg}} = -1.58\text{ m/s}$$
$$\vec{v}_f = (1.05\hat{i} - 1.58\hat{j})\text{ m/s, or } 1.88\text{ m/s @ } -56.4°$$

9. In the system below, mass ***A = 8 kg***, the friction between it and the horizontal surface is characterized by $\mu_k = 0.5$ and the string is ***massless***. ***If the masses move at constant speed (v = 3 m/s), calculate the mass of B. (10 pts)***



$$m_A a = T - f_A$$
$$m_B a = T - W_B$$

Constant speed $\Rightarrow a = 0$, **so**

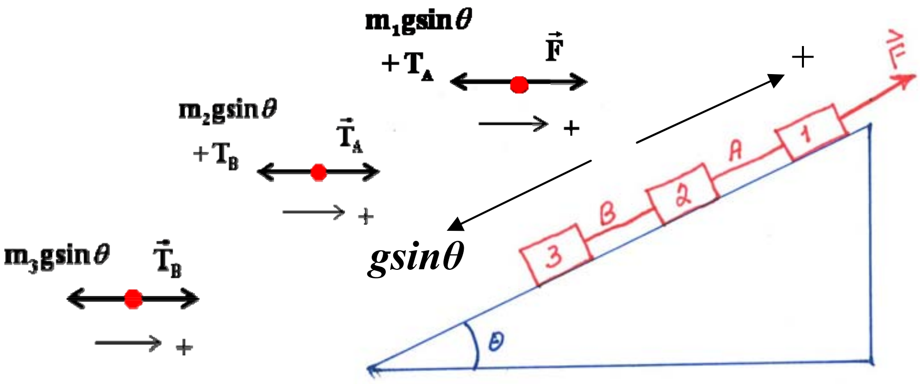
$T = f_A$, **and**

$T = W_B$, **so** $f_A = W_B$, **and**

$$m_B = \frac{f_A}{g} = \frac{\mu_A m_A g}{g} = \mu_A m_A = (0.5)(8\text{ kg}) = 4\text{ kg}$$

Extra credit. You may earn up to 10 additional points for success with this problem. ***Do not attempt it until you have done your best on the rest of the exam.***

10. In the system sketched below, the three masses slide upwards on the frictionless incline and are connected ***by massless strings A and B***. ***Mass 1 = 2 kg, mass 2 = 8 kg, mass 3 = 4 kg, θ = 30°, and the tension in string A = 100 N up the incline.*** **(Use g= 10 m/s²)**



Basic relations :
$m_1 a = F - T_A - m_1 g\sin\theta$
$m_2 a = T_A - T_B - m_2 g\sin\theta$
$m_3 a = T_B - m_3 g\sin\theta$

a. What is the ***acceleration*** of the objects?

Because T_A is the given force, note that *a* can be obtained from the m_2 and m_3 relations :

$$\left.\begin{aligned} m_2 a &= T_A - T_B - m_2 g\sin\theta \\ m_3 a &= T_B - m_3 g\sin\theta \end{aligned}\right\} \quad a = \frac{T_A - m_2 g\sin\theta - m_3 g\sin\theta}{(m_2 + m_3)} = 3.33\ \text{m/s}^2$$

b. How much is the ***applied force F***?

With the solution for *a*, then *F* can be obtained from the m_1 relation :

$$m_1 a = F - T_A - m_1 g\sin\theta \Rightarrow F = m_1 a + T_A + m_1 g\sin\theta$$

so, F = 116.67 N