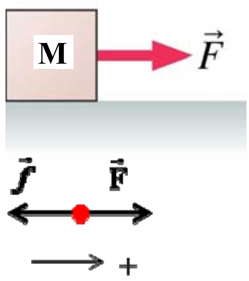
# Physics 2211K
# Test # 2
# October 14, 2010

***"I have neither given nor received help on this exam."*** **<u>TEST VERSION 2</u>**

**In order to evaluate your progress in this course, I must see how you arrive at your answers. <u>THEREFORE, YOU MUST SHOW YOUR WORK IN ORDER TO RECEIVE CREDIT FOR A QUESTION</u>. Always circle your answer and show the units.** ***{Unless otherwise instructed, use $g = 10\ m/s^2$ for all questions.}***

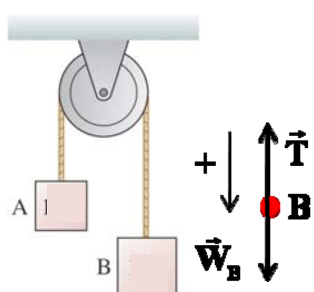
1. In the sketch below, the applied force ***F = 80 N*** causes the object of ***M = 20 kg*** to slide with constant speed (***v = 5 m/s***) on the horizontal surface with friction. Calculate the coefficient of kinetic friction $\mu_k$. ***(10 pts)***

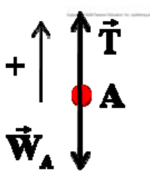



$$F_{net} = ma = F - f = F - \mu n = F - \mu mg$$
$$\text{constant speed} \Rightarrow a = 0\ \&\ F_{net} = 0$$
$$\therefore f = F = \mu mg,\ \text{and}$$
$$\mu = \frac{F}{mg} = \frac{80\ N}{200\ N} = 0.4$$

2. In the pulley arrangement below, mass ***A = 3 kg***, mass ***B = 8 kg***, and they are connected by a massless string.

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




$$m_A a = T - m_A g$$
$$m_B a = m_B g - T$$
$$a = \frac{(m_B - m_A)g}{(m_A + m_B)} = \frac{(5\ kg)(10\ m/s^2)}{(11\ kg)} = 4.54\ m/s^2$$

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

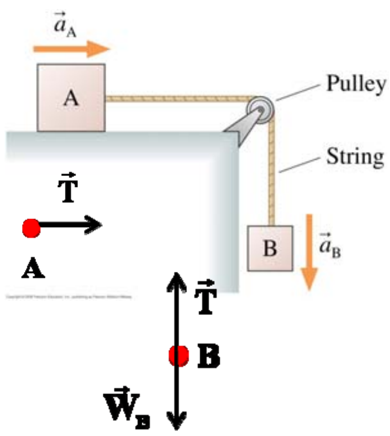
$$T = m_A a + m_A g = (6\ kg)(14.54\ m/s^2) = 43.6\ N$$

3. 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 ***g = 9.8 m/s² ($R_E = 6.37 \times 10^6$ m; $M_E = 5.98 \times 10^{24}$ kg)***, what is the acceleration at an altitude above the surface equal to ***$R_E$ (2×$R_E$ 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)***

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

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

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




$$m_A a = T$$
$$m_B a = W_B - T = m_B g - T = m_B g - m_A a$$
$$a = \frac{m_B g}{m_A + m_B} = \frac{20\text{N}}{10\text{kg}} = 2\ \text{m/s}^2$$

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

$$T = m_A a = (8\ \text{kg})(2\ \text{m/s}^2) = 16\ \text{N}$$

***5.*** 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 $\mu_k = 0.5$, 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**

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

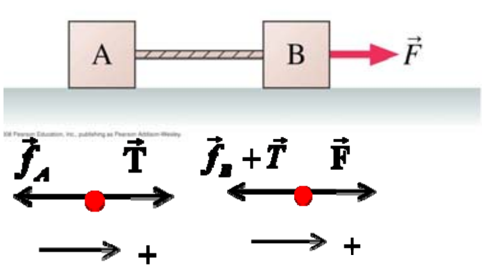
**Maximum** $f_s = \mu_s n = \mu_s mg = (0.5)(1500\ \text{kg})(10\ \text{m/s}^2) = 7500\ \text{N}$

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

**The answer is YES.**

6. In the system below, mass ***A = 8 kg***, mass ***B = 6 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 = 70 N directed as shown***, and the objects are sliding to the right.

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

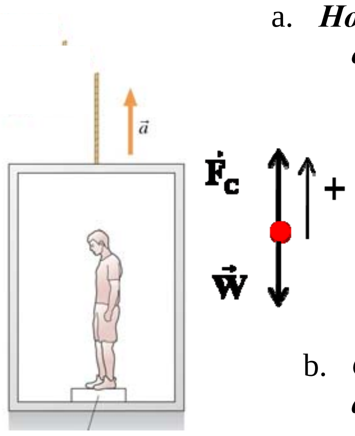



$$m_A a = T - f_A \Rightarrow f_A = \mu_A m_A g = (0.2)(8\ \text{kg})(10\ \text{m/s}^2) = 16\ \text{N}$$
$$m_B a = F - T - f_B \Rightarrow f_B = \mu_B m_B g = (0.4)(6\ \text{kg})(10\ \text{m/s}^2) = 24\ \text{N}$$
$$a = \frac{(F - f_A - f_B)}{(m_A + m_B)} = \frac{(70 - 16 - 24)\text{N}}{(8+6)\text{kg}} = 2.14\ \text{m/s}^2$$

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

$$T = m_A a + f_A = (8\ \text{kg})(2.14\ \text{m/s}^2) + 16\ \text{N} = 33.1\ \text{N}$$

7. As sketched below, the ***80 kg person*** is in an elevator accelerating upwards at ***2.5 m/s²***.



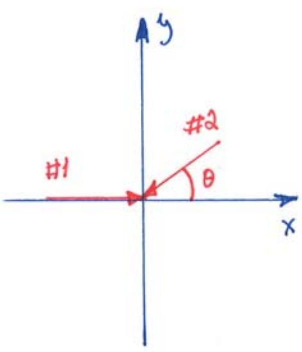

a. ***How much is the force of contact between his feet and the floor of the elevator***? ***(10 pts)***

$$\mathbf{F_{net} = ma = F_c - mg \Rightarrow F_c = ma + mg = m(a+g)}$$
$$\mathbf{Up \Rightarrow a > 0}$$
$$\mathbf{F_c = (80\ kg)(12.5\ m/s^2) = 1000\ N}$$

b. ***Calculate the force of contact for the case of the elevator accelerating downwards at 2.5 m/s². (10 pts)***

$$\mathbf{F_{net} = ma = F_c - mg \Rightarrow F_c = ma + mg = m(a+g)}$$
$$\mathbf{Down \Rightarrow a < 0}$$
$$\mathbf{F_c = (80\ kg)(7.5\ m/s^2) = 600\ N}$$

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)***

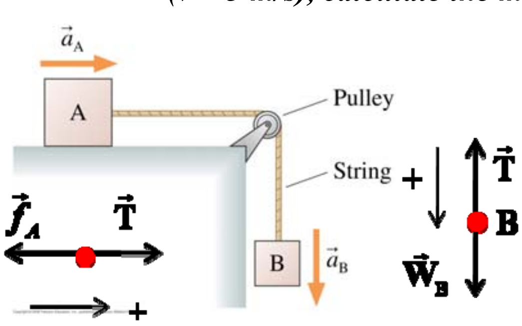



**For collisions, momentum is conserved immediately before and after contact so** $\vec{p}_{iT} = \vec{p}_{fT}$.

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

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

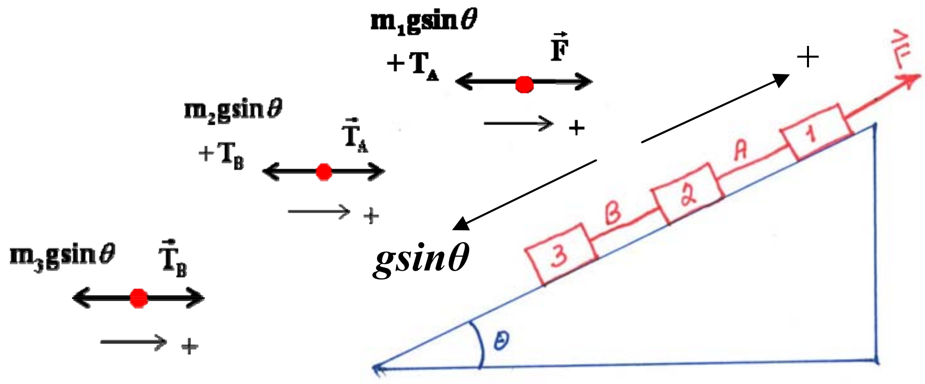
9. In the system below, mass ***A = 8 kg***, the friction between it and the horizontal surface is characterized by ***μ<sub></sub>***$\mu_k = 0.4$, and the string is ***massless***. ***If the masses move at constant speed (v = 3 m/s), calculate the mass of B. (10 pts)***




$$\mathbf{m_A a = T - f_A}$$
$$\mathbf{m_B a = T - W_B}$$
**Constant speed** $\Rightarrow$ $\mathbf{a = 0}$, **so**
$\mathbf{T = f_A}$, **and**
$\mathbf{T = W_B}$, **so** $\mathbf{f_A = W_B}$, **and**
$$\mathbf{m_B = \frac{f_A}{g} = \frac{\mu_A m_A g}{g} = \mu_A m_A = (0.4)(8\ kg) = 3.2\ kg}$$

**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 = 4 kg, mass 2 = 2 kg, mass 3 = 8 kg, θ=30°, and the tension in string A = 80 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:**

$$\left.\begin{array}{l} m_2 a = T_A - T_B - m_2 g\sin\theta \\ m_3 a = T_B - m_3 g\sin\theta \end{array}\right\} \quad a = \frac{T_A - m_2 g\sin\theta - m_3 g\sin\theta}{(m_2 + m_3)} = 3.0\ \text{m/s}^2$$

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, $F = 116.7$ N**