Name:________________ ID:________________ Lab (day/time)____________

Physics 201

Midterm Exam 2

11/8/2017

Collaboration is not allowed. Allowed on your desk are: up to ten 8.5 x 11 inch doubled sided sheets of notes that are bound together, non-communicating/graphing scientific calculator, 1 page of scratch paper, writing utensils, and the exam. You will have 80 minutes to complete this exam.

1. (5 points) Imagine sitting in the back seat of a car, looking forward as your friend drives in a straight line. Suddenly he turns the car sharply to the left, and you slide (no seatbelt) to the right-side door, feeling pressed against it through the remainder of the turn. From your perspective it felt like there was a force to the outside of the turn, radially outward. Was there a force radially outward? If so, which one? What are all the forces that acted on you during the turn?

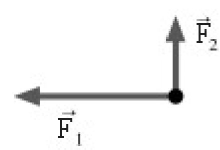
No, there was no force acting on you radially outward. What appears to be an outward force is really your inertia traveling straight forward and the car moving out from under you to the left. This leaves you on the right side with the door pushing you to the left so that you stay in the car. This apparent force is an effect of you being in the rotating reference frame and is sometimes referred to as a centrifugal force. It is not a real force but a feature of your rotating reference frame. The real forces that do act on you are gravity, normal force from the seat, friction from the seat, and a normal force from the door.

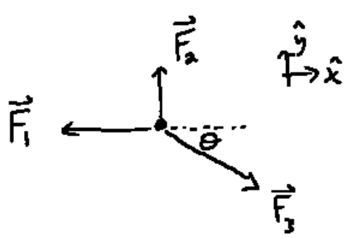
Rubric

+1 pt – No radially outward force

+ 4pt – forces that do act on you

2. (3 points) The figure shows two forces that are acting on an object. The magnitude of $\mathbf{F_1}$ is 6.0 N and the magnitude of $\mathbf{F_2}$ is 2.7 N. What would be the magnitude and direction of a third force that would put the object into equilibrium?





$\Sigma F_x \Rightarrow \quad F_{3x} - |\vec{F}_1| = m\cancel{a_x}^{0}$

$F_{3x} = 6.0N$

$\Sigma F_y \Rightarrow \quad F_2 + F_{3y} = m\cancel{a_y}^{0}$

$F_{3y} = -2.7N$

So $|\vec{F}_3| = \sqrt{F_{3x}^2 + F_{3y}^2} = \underline{6.58N}$, $\tan\theta = \frac{|F_{3y}|}{|F_{3x}|} \Rightarrow \theta = \underline{24.2°}$

Rubric

-2 pts - ΣF_x + ΣF_y

+ 1pt - answer, mag + dir.

For questions 3 through 7 circle all correct answers, a given problem may have more than one correct answer. Each correctly circled answer will receive two points. There are **7** correct answers in this section and only the first **7** circled answers will be graded. There is no partial credit.

3. The net force on an object is in the northern direction. Which of the following quantities also *necessarily* point north?

[T] (a) acceleration
[F] (b) change in position
[F] (c) force of acceleration
[F] (d) centripetal force
[T] (e) change in velocity

4. An object is undergoing uniform circular motion. Which of the following statements are *necessarily* true regarding this situation?

[F] (a) There must be at least one force that points directly towards the center of the circle.
[F] (b) The velocity of the object is a constant.
[F] (c) The acceleration of the object is a constant.
[T] (d) The summation of all the forces acting on the object points radially inward.
[T] (e) The object maintains a constant speed.

5. A large unidentified flying object (UFO) climbs with a constant velocity of 175 m/s at an angle of 32° with respect to the horizontal. Which of the following statements are true concerning the magnitude of the *net force* on the UFO?

[F] (a) It is equal to the weight of the UFO.
[F] (b) It is equal to the magnitude of the force of air resistance.
[F] (c) It is less than the weight of the UFO but greater than zero.
[F] (d) It is equal to the component of the weight of the UFO in the direction of motion.
[T] (e) It is zero.

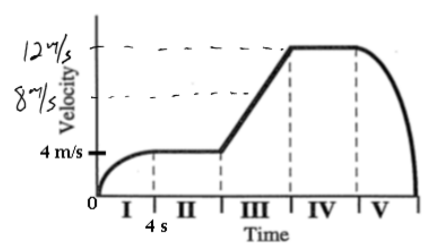
6. A person who normally weighs 200 pounds is standing on a scale inside an elevator. The elevator is moving upwards with a constant speed of 7 m/s when it begins to slow down at a rate of 5 m/s^2. Before the elevator begins to slow down, the reading of the scale is __________, and while the elevator is slowing down, the reading of the scale is _________.

[T] (a) 200 pounds, less than 200 pounds
[F] (b) 200 pounds, greater than 200 pounds
[F] (c) greater than 200 pounds, less than 200 pounds
[F] (d) greater than 200 pounds, 200 pounds
[F] (e) less than 200 pounds, greater than 200 pounds

7. For something falling from rest, when air resistance *isn't* negligible, which of the following would you expect?

[F] (a) The instantaneous acceleration of the object would be zero at the start of the fall but then increase until it equaled *g*.
[F] (b) The magnitude of the initial acceleration would actually be greater than *g* but would then decrease as the object falls.
[F] (c) The instantaneous acceleration for the object might be less than *g*, but the average acceleration throughout the fall would still be approximately 1 *g*.
[T] (d) The instantaneous acceleration of the object at any point during the fall would depend on how fast the object is falling at that point.
[F] (e) The acceleration downward at any point would still be a constant value, but would be something less than *g*.

8. (5 points) A 3 kg drone is traveling in a straight line. Its velocity as a function of time, separated into 5 equal time intervals, is plotted in the figure. Estimate the average net force acting on the drone for each of the 5 time intervals. Explain your reasoning.



$$\Sigma \vec{F} = m\vec{a} = m\frac{\Delta \vec{V}}{\Delta t}$$ slope of $V(t)$

(I) $(3\,kg)\left(\frac{4\,m/s}{4\,s}\right) = \underline{3\,N}$ (II) $\Delta V = 0$ so $\underline{\Sigma \vec{F} = 0}$

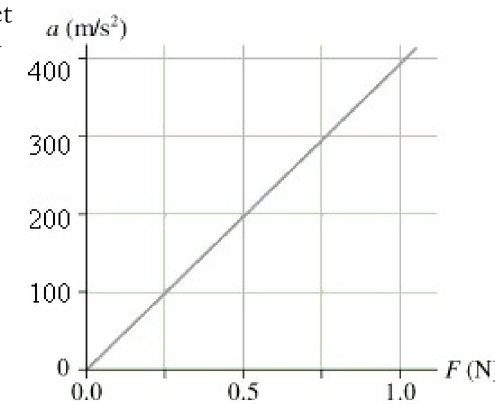
(III) $(3\,kg)\left(\frac{8\,m/s}{4\,s}\right) = \underline{6\,N}$ (IV) $\Delta V = 0$ so $\underline{\Sigma \vec{F} = 0}$ (V) $(3\,kg)\left(\frac{-12\,m/s}{4\,s}\right) = \underline{-9\,N}$

Rubric

2.5 pts - reasoning

2.5 pts - answers

9. (3 points) The figure shows an object's acceleration-versus-net force graph. What is the object's mass in grams? Explain how you determined this value.



10

$\Sigma F = ma \Rightarrow a = \frac{1}{m}\Sigma F$ linear function w/ slope $\frac{1}{m}$

Slope of $a(F) = 400\,kg^{-1}$

So $m = \frac{1}{400}\,kg = 0.0025\,kg$

$= \underline{2.5\,g}$

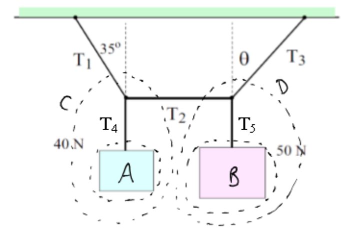
Rubric

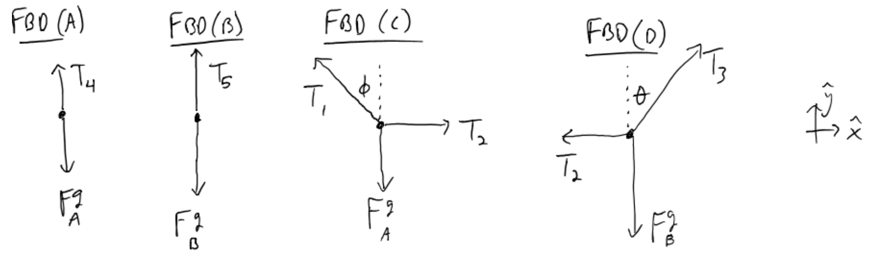
1.5 pts - reasoning

1 pt - Interpreting plot

0.5 pts - answer + units

10. (12 points) Two blocks, weighing 40 N and 50 N respectively, are hung with the help of 5 light strings, as shown in the figure. The entire apparatus is placed in an elevator. (a) If the elevator is moving downward at a constant speed of 3 m/s, determine the tension in each string. (b) If the elevator then suddenly starts to slow down at a rate of 1.5 m/s², what is the new tension in each strings?





Constraints
$\vec{a}_A = \vec{a}_B = \vec{a}_C = \vec{a}_D \equiv \vec{a}$

Part (a), $a = 0$

using $\phi = 35°$
Part (b), $a = +1.5\,m/s^2$

A $\Sigma F_y \Rightarrow T_4 - F^g_A = M_A a \Rightarrow T_4 = F^g_A = 40N \Rightarrow T_4 = M_A a + F^g_A = 46.12\,N$

B $\Sigma F_y \Rightarrow T_5 - F^g_B = M_B a \Rightarrow T_5 = F^g_B = 50N \Rightarrow T_5 = M_B a + F^g_B = 57.65\,N$

C $\Sigma F_y \Rightarrow T_1 \cos\phi - F^g_A = M_A a \Rightarrow T_1 = \frac{F^g_A}{\cos\phi} = 48.8N \Rightarrow T_1 = \frac{1}{\cos\phi}(M_A a + F^g_A) = 56.305\,N$

$\Sigma F_x \Rightarrow T_2 - T_1 \sin\phi = M_A a \Rightarrow T_2 = T_1 \sin\phi = 28.0N \Rightarrow T_2 = M_A a + T_1 \sin\phi = 38.42\,N$

D $\Sigma F_y \Rightarrow T_3 \cos\theta - F^g_B = M_B a \Rightarrow T_3 = \frac{F^g_B}{\cos\theta}$ so $T_3 = 57.3\,N \Rightarrow T_3 = \frac{1}{\cos\theta}(M_B a + F^g_B)$

$\Sigma F_x \Rightarrow T_3 \sin\theta - T_2 = M_B a \Rightarrow \frac{F^g_B}{\cos\theta}\sin\theta = T_2 \Rightarrow \tan\theta = \frac{T_2}{F^g_B} \Rightarrow \theta = 29.25° \Rightarrow \frac{1}{\cos\theta}(M_B a + F^g_B)\sin\theta = T_2 + M_B a$

$\tan\theta = \frac{T_2 + M_B a}{(M_B a + F^g_B)} \Rightarrow \theta = 38.63°$

Notice if $g \to g + a$ that is a 15.3% increase + all of the tensions Increased by 15.3%.
This is like being in equilibrium on a planet w/ $g = 9.8\,m/s^2 + a$

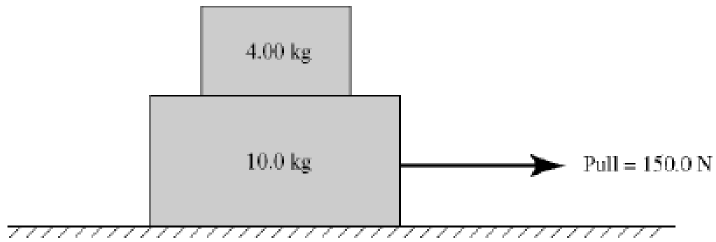
if $\phi = 35°$ w/ $a \neq 0$
+ $\theta = 29.25°$
then $T_3 = \frac{M_B a + F^g_B}{\cos\theta} = 66.1\,N$

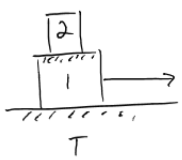
if $\phi = 35°$ + $\theta = 38.63°$
$T_3 = 73.8\,N$

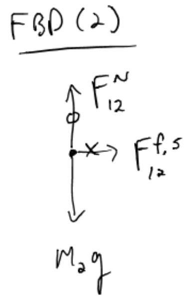
In reality w/ $M_A \neq M_B$ both angles change w/ $a \neq 0$

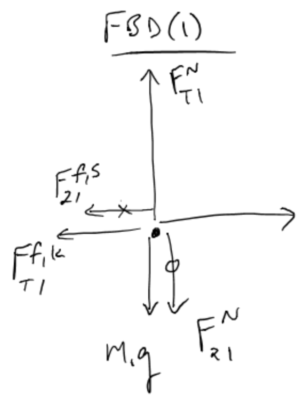
Rubric
+2pts - FBD's
(a) +2pts - T_4 + T_5 answers
+4pts - ΣF_x + ΣF_y for C + D
+1pts - T_1 + T_2 answers
+1.5pts - Algebra to find θ + T_3
+0.5pt - T_3 answer
(b) +1pt - attempting $a \neq 0$

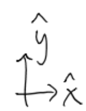
11. (12 points) A 4.00-kg box sits atop a 10.0-kg box on a horizontal table. The coefficient of kinetic friction between the two boxes and between the lower box and the table is 0.600, while the coefficient of static friction between these same surfaces is 0.800. Starting from rest, a horizontal 150 N pull is applied to the right on the lower box. The boxes proceed to move together without slipping. (a) What is the friction force, magnitude and direction, on the UPPER box? (b) What is the maximum pulling force that can be applied and not have the upper box slip relative to the bottom box?

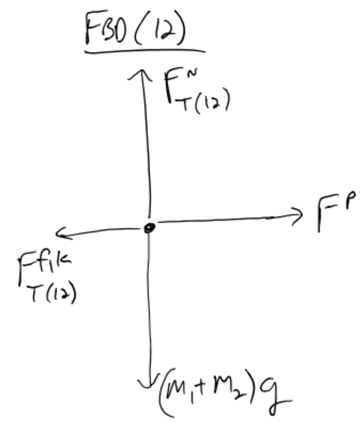












Constraints

$$\vec{a}_1 = \vec{a}_2 = \vec{a}_{12} \equiv \vec{a}$$

12 $\sum F_y \Rightarrow F^N_{T(12)} - (m_1+m_2)g = (m_1+m_2)\cancel{a_y}^{\,0} \Rightarrow F^N_{T(12)} = (m_1+m_2)g$

$\sum F_x \Rightarrow F^P - \underbrace{\mu_k (m_1+m_2)g}_{F^{f,k}_{T(12)}} = (m_1+m_2)\,a_x \Rightarrow a_x = \dfrac{F^P - \mu_k(m_1+m_2)g}{m_1+m_2}$

2 $\sum F_y \Rightarrow F^N_{12} - m_2 g = m_2 \cancel{a_y}^{\,0} \Rightarrow F^N_{12} = m_2 g$

(a) w/ $F^P = 150\text{N}$

$\sum F_x \Rightarrow F^{f,s}_{12} = m_2 a_x \Rightarrow$ (i) $F^{f,s}_{12} = \dfrac{m_2}{(m_1+m_2)}\left(F^P - \mu_k(m_1+m_2)g\right) = 19.3\,N,\ +\hat{x}$ direction

(b) for max pull $F^{f,s}_{12} \rightarrow F^{f,s}_{max} = \mu_s F^N_{12} = \mu_s (m_2 g)$

(i) $\mu_s(m_2 g) = \dfrac{m_2}{(m_1+m_2)}\left(F^P_{max} - \mu_k(m_1+m_2)g\right) \Rightarrow F^P_{max} = 192\,N$

Rubric

+3pts - FBD's

+1pt - constraints

+1pt - $F^{f,k} = \mu_k F^N$

+4pts - 2nd Law from FBD's

+1pt - Algebra

+0.5pt - answer (a)

+1pt - $F^{f,s} \rightarrow F^{f,s}_{max}$

+0.5pts - answer (b)

extra space if needed

Scores:

Problems

1	2	3-7	8	9	10	11

Exam Total