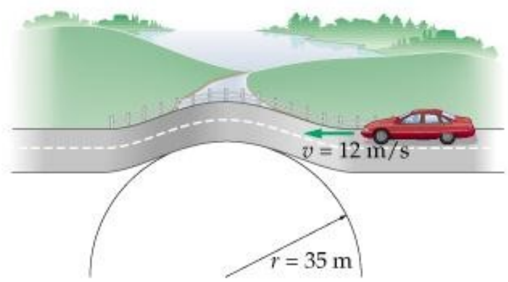
Name:________________ ID:________________ Lab (day/time)____________

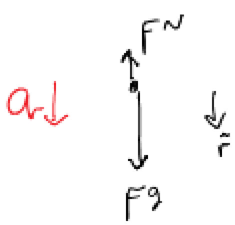
Physics 201
Final Exam
7/14/2016

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 110 minutes to complete this exam.

1. (8 points) While driving your car at a constant 12 m/s speed you drive over a circular bump, as shown in the figure. Find the apparent weight of a 72-kg person in your car as you pass over the top of the bump.



FBD (top)



$$\Sigma F_r \Rightarrow F^g - F^N = m a_r$$

$$w/\ a_r = \frac{v^2}{r}, \quad F^N = F^g - m\frac{v^2}{r}$$

$$F^N = m\left(g - \frac{v^2}{r}\right) = 409\ N$$

Rubric

2pt - FBD
2pt - $\frac{v^2}{r}$ eq
2pt - Writing 2nd Law at all
3pt - " " " correctly
1pt - Answer w/ unit

For questions 2 through 8 circle all correct answers, a given problem may have more than one correct answer. Each correctly circled answer will receive two points. There are **10** correct answers in this section and only the first **10** circled answers will be graded. There is no partial credit.

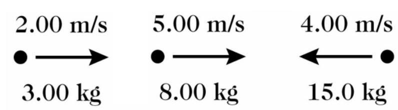
2. In a system where zero non-conservative work is being done on the system, which of the following statements are *necessarily* true?

[F] (a) If the kinetic energy is decreasing than so is the total mechanical energy.
[F] (b) If the potential energy is decreasing than so is the total mechanical energy.
[F] (c) If the kinetic energy is decreasing then so is the potential energy.
[F] (d) If the potential energy is decreasing than so is the kinetic energy.
[T] (e) The total mechanical energy is constant.
[T] (e) If the kinetic energy is increasing than the potential energy is decreasing.

3. The force of friction

[F] (a) is always in the opposite direction of the motion of an object.
[F] (b) is always in the same direction of motion of an object.
[T] (c) can be either in the same or opposite direction of motion of an object.
[F] (d) always slows an object down.
[T] (e) can speed an object up.

4. Three particles are moving as shown in the diagram. After some time they all collide and stick together. What will be the final momentum of the group after the collision? Take the positive direction to be towards the right.



[F] (a) +106 kg m/s
[F] (b) -106 kg m/s
[F] (c) +14 kg m/s
[T] (d) -14 kg m/s
[F] (e) 0 kg m/s

5. A person drops one rock from rest and it falls 100 meters down a cliff before hitting the ground. The person then throws an identical rock horizontally. The amount of kinetic energy gained by the rock dropped from rest is _____ that of the second rock, and the magnitude of the final speed of the rock dropped from rest is _____ that of the second rock.

[F] (a) equal to, greater than
[F] (b) greater than, greater than
[F] (c) less than, less than
[T] (d) equal to, less than

6. Which of the following situations are *not possible*?

[P] (a) A body has zero velocity and non-zero acceleration.
[P] (b) A body travels with a northward velocity and a northward acceleration.
[P] (c) A body travels with a northward velocity and a southward acceleration.
[NP] (d) A body travels with a constant velocity and a time-varying acceleration.
[P] (e) A body travels with a constant acceleration and a time-varying velocity.

7. A man stands on a scale in a moving elevator and notices that the scale reading is 20% larger than when he weighs himself in his bathroom. Which of the following statements can *not* be true?

[T] (a) The tension in the elevator's supporting cable must exceed the weight of the elevator and its contents.

[T] (b) The elevator could be moving upward with increasing speed.

[T] (c) The elevator could be moving downward with decreasing speed.

[F] (d) The elevator could be moving upward at constant speed.

8. A Pokemon in your hand is being raised up at a constant velocity. Which of the following statements are *false* regarding this situation?

[F] (a) The normal force on the Pokemon must be larger than the gravitational force.

[T] (b) The impulse acting on the Pokemon is zero.

[T] (c) The Pokemon travels through constant distances over equal time intervals.

[T] (d) The normal force does positive work on the Pokemon.

[F] (e) The kinetic energy of the Pokemon increases from one second to the next.

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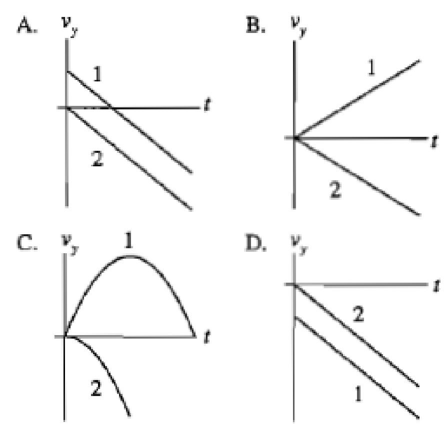
9. (4 points) Ball 1 is thrown straight up in the air and, at the same instant, ball 2 is released from rest and allowed to fall. Which velocity graph represents the motion of the two balls - explain your reasoning.

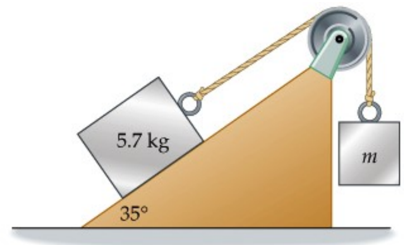


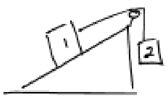
A - The slope of the velocity plot is acceleration and an object in free-fall is undergoing constant acceleration, thus the slop of the plot must be constant (eliminates C). The acceleration is also the same (eliminates B). Finally the first ball is through upward with a positive acceleration, so it must start above zero velocity.

Rubric

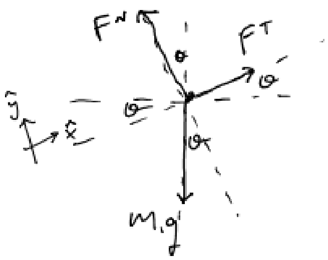
2 pts - answer
2 pts - reasoning

10. (10 points) Two boxes are connected via a light string across a pulley. All surfaces are frictionless. If the hanging mass **m** is equal to 7.0 kg, what is the magnitude and direction of the acceleration of the 5.7 kg mass? *Hint*: draw a separate FBD for each mass and identify the constraints connecting them.

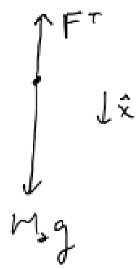




FBD (1)



FBD(2)



Constraints

$F_1^T = F_2^T \equiv F^T$

$\vec{a}_1 = \vec{a}_2$ w/ Cord. system shown

$\boxed{1}$ $\sum F_x \Rightarrow \quad F^T - m_1 g \sin\theta = m_1 a_x$

$\boxed{2}$ $\sum F_x \Rightarrow \quad m_2 g - F^T = m_2 a_x$

2 eq's
2 unknowns

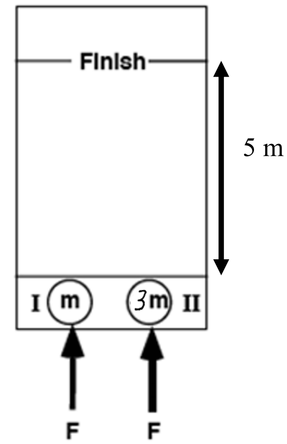
$$m_2(g - a_x) - m_1 g \sin\theta = m_1 a_x \Rightarrow a_x = \frac{m_2 g - m_1 g \sin\theta}{m_1 + m_2} = 2.88\ m/s^2$$

up incline

Rubric

1.5 pts - FBD (1)
1 pt - FBD (2)
2 pts - Constraints
2 pts - $\sum F_1$
2 pts - $\sum F_2$
1 pt - Algebra
0.5 pt - answer w/ units + direction

11. (10 points) A 2-kg-puck of (mass **m**) is pushed by a constant 12-N-force (**F**) on a frictionless table. A second puck, three times as massive, is also pushed by an equivalent force. (a) Upon reaching the finish line, which puck will have the greater momentum? Explain. (b) What will be the kinetic energy of the puck with the greater momentum at the finish line? (c) For the puck that has the smaller momentum at the finish line, how much longer (in seconds), past the finish line, would the force have to be applied to end up with the same momentum as other puck had at the finish line?



$\boxed{10}$

a) $\Sigma F_{ext} = ma \Rightarrow$ w/ $\Delta x = \frac{1}{2} a \Delta t^2 \Rightarrow$ if $a \downarrow$, $\Delta t \uparrow$

Constant

$m_2 > m_1$ so $a_1 > a_2$

$+ \ \Delta t_1 < \Delta t_2$

Impulse Momentum

$\Delta P = \Sigma F_{ext} \Delta t \Rightarrow P_f \propto \Delta t \rightarrow P_{f2} > P_{f1}$

b) $\cancel{K_i}^{\,0} + \cancel{U_i} + \Sigma W = K_f + \cancel{U_f}$ $\qquad$ * $W_1 = W_2$ so $K_{f_1} = K_{f_2}$

$F \Delta x \cancel{\cos\theta}^{\,1} = K_f = 60\ J$

c) from (a) $\quad \Delta t^2 = \frac{2 \Delta x \, m}{F}$, to finish line $\Delta t_2 = 2.24 s$, $\Delta t_1 = 1.29 s$

w/ same force, 1 needs applied same time as 2 to acquire same momentum

.... so $\Delta t_2 - \Delta t_1 = 0.945 s$ longer

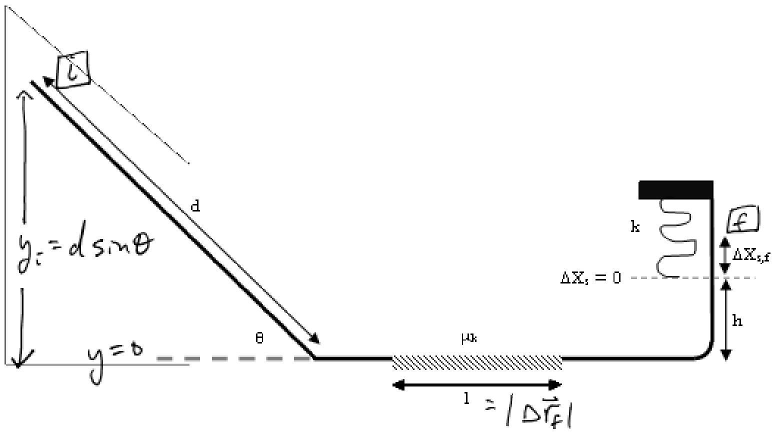
Rubric

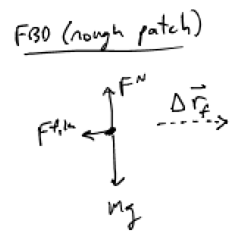
(a) 2pts - Impulse Momentum
1.5pts - $\Delta t_1 < \Delta t_2$
0.5 - Answer

(b) 2pts - Cons. of Energy
1.5pts - $W = F \Delta x$
0.5pts - Answer + units

(c) 2pts

12. (10 points) An object of mass **m**, starting from rest slides a distance **d**, down a frictionless incline that makes an angle **θ** with respect to the horizontal. Then the object slides across a horizontal surface that is also frictionless except for a patch of length **l** that has a coefficient of kinetic friction between the surface and the object of μ_k. After the horizontal surface the object is redirected up a frictionless vertical section a distance **h** to a relaxed massless spring of constant **k**. The object then continues higher, compressing the spring by an amount $\Delta X_{s,f}$. Apply an energy analysis from the initial state at the top of the ramp to the final state, where the spring is compressed. Your expression should only include the variables **m**, **d**, **θ**, **l**, μ_k, **h**, **k**, $\Delta x_{s,f}$, and the gravitational constant **g**. *Hint*: you do not have to solve anything, just apply conservation of energy properly.
Extra Credit: Solve your expression for the compression of the spring in terms of the variables **m**, **d**, **θ**, **l**, μ_k, **h**, **k**, and the gravitational constant **g**.





w/ $\Sigma F_y = 0$, $F^N = mg$

↳ $F^{f,k} = \mu_k mg$

$$\Sigma E_i + \Sigma W_{nc} = \Sigma E_f \Rightarrow \cancel{K_i}^{0} + U_i^g + \cancel{U_i^s}^{0} + W^F = \cancel{K_f}^{0} + U_f^g + U_f^s$$

So, $$mgy_i + |\vec{F}^{f,k}||\Delta\vec{r}_f|\cancel{\cos\theta_f}^{-1} = mg(h+\Delta X_{s,f}) + \tfrac{1}{2}k\,\Delta X_{s,f}^2$$

(a) $$mgd\sin\theta - \mu_k mgl = mg(h+\Delta X_{s,f}) + \tfrac{1}{2}k\,\Delta X_{s,f}^2$$, quadratic for $\Delta X_{s,f}$

e.c. Rearrange $$\underbrace{\tfrac{1}{2}k}_{A}\,\Delta X_{s,f}^2 + \underbrace{mg}_{B}\,\Delta X_{s,f} + \underbrace{(mgh + \mu_k mgl - mgd\sin\theta)}_{C} = 0$$, form $Ax^2+Bx+C=0$

So $$\Delta X_{s,f} = \frac{-mg \pm \sqrt{(mg)^2 - 4(\tfrac{1}{2}k)(mgh + \mu_k mgl - mgd\sin\theta)}}{2(\tfrac{1}{2}k)}$$

Rubric

1pts - con. of E attempt

1.5pt - $K_i = K_f = U_i^s = 0$

1pt - $U^g = mgy$

1pt - $U^s = \frac{1}{2}k\Delta x^2$

1.5pt - $W = F\Delta r\cos\theta$

1.5pt - $F^f = \mu_k mg$

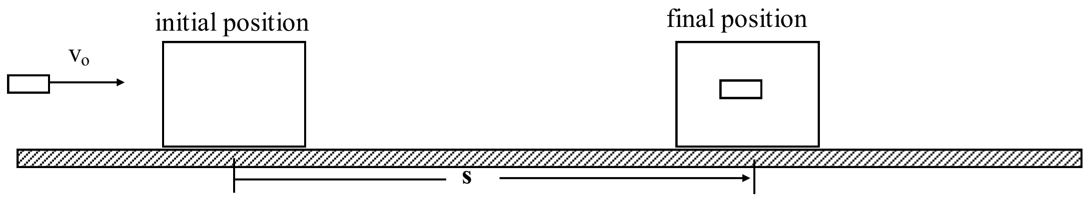
1pt - $y_i = d\sin\theta$

1pt - $U_f^g = mg(h + \Delta X_{s,f})$

0.5pt - final Expression

e.c. 3pts

13. (10 points) A bullet of mass $\mathbf{m_1}$ is fired at a speed $\mathbf{v_o}$ into a wooden block of mass $\mathbf{M_2}$. The bullet instantaneously comes to rest in the block. The block with the embedded bullet slides along a horizontal surface with a coefficient of kinetic friction $\boldsymbol{\mu}$.



Which one of the following expressions determines how far the block slides before it comes to rest (the magnitude of displacement **s** in the figure)? Show your work for full credit.

a.	b.	c.	d.	e.
$\dfrac{m_1 v_o^2}{M_2 \mu g}$	$\left(\dfrac{m_1}{m_1+M_2}\right)^2 \sqrt{\dfrac{v_o^2}{2\mu g}}$	$\left(\dfrac{m_1}{m_1+M_2}\right)\dfrac{v_o^2}{\mu g}$	$\dfrac{v_o^2}{\mu g}$	$\left(\dfrac{m_1}{m_1+M_2}\right)^2 \dfrac{v_o^2}{2\mu g}$

Stage 1: Perfectly Inelastic Collision

w/ $\vec{J} \approx 0$, $\Sigma \vec{P}_i = \Sigma \vec{P}_f$, $\boxed{1D}$ $m_1 v_0 + M_2 \cancel{v_{2i}}^{\,0} = (m_1+m_2)V_f$

$$V_f = \frac{m_1 V_0}{m_1+m_2} \quad (i)$$

Stage 2: sliding to rest

$$\Sigma E_i + W_{nc} = \Sigma E_f \Rightarrow \frac{1}{2}(m_1+m_2)V_i^2 + \underbrace{\vec{F}^{fk}\cdot\Delta\vec{r}}_{-\mu_k(m_1+m_2)gs} = \frac{1}{2}(m_1+m_2)\cancel{V_f^2}^{\,0}$$

So $\frac{1}{2}\cancel{(m_1+m_2)}V_i^2 = \mu_k \cancel{(m_1+m_2)} g s$ (ii)

Combine (i) + (ii)

$$\frac{1}{2}\left(\frac{m_1 V_0}{m_1+m_2}\right)^2 = \mu_k g s \Rightarrow s = \left(\frac{m_1}{m_1+M_2}\right)^2 \frac{V_0^2}{2\mu_k g} \quad \boxed{e}$$

Rubric

collision { 2.5pts - Apply Con. of Mom.
1.5pts - " " " " correctly

sliding { 2.5pts - Apply Con. of Energy (or kin. + mech)
1.5pts - " " " " correctly

1pt - Algebra

1pt - Answer

Scores:

Problems

1	2-8	9	10	11	12	13

Exam Total
