Name:______________________________

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Physics 201 | Ecampus

Final Exam

12/07/2021

Collaboration is not allowed. Allowed on your desk are: 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.

For questions 1 through 7 **fill in the square** next to all correct answers. A given problem may have more than one correct answer. Each correctly bubbled answer will receive two points. There are **13** correct answers in this section and only the first **13** filled in answers will be graded. There is no partial credit.

1. The net impulse acting on a boxed shaped present is pointing to the left. Which of the following quantities must also point to the left?
   - ☐ (a) The momentum of the present.
   - **X (b) The net external force on the present.**
   - ☐ (c) The displacement of the present.
   - ☐ (d) The velocity of the present.
   - **X (e) The acceleration of the present.**
   - ☐ (f) The external work on the present.

2. Which of the following quantities are vectors?
   - ☐ (a) Distance.
   - **X (b) Displacement.**
   - ☐ (c) Speed.
   - **X (d) Impulse.**
   - ☐ (e) Work.
   - ☐ (f) Kinetic energy.

3. A rectangular block of wood is on your teacher's kitchen table. The table is flat and the coefficient of both static and dynamic friction are around 0.3. A force is pushing horizontally to the right on the block of wood. Which of the following might be accurate free body diagrams for this situation? (you may assume that arrows which look the same length are the same length and the block may or may not be moving)

   (answers: a, c, f)

4. A spring is initially compressed a distance $\mathbf{x_i}$, such that it has 2.00 J of energy. The spring is then compressed even further to $\mathbf{x_f}$, so that the new spring energy is 8.00 J. By what factor is the initial compression distance changed by?
   - ☐ (a) 1/4
   - ☐ (b) 1/2
   - ☐ (c) 1
   - **X (d) 2**
   - ☐ (e) 4

5. Which of the following statements about an object with constant mass must be true?
   X (a) If the kinetic energy of an object changes, its momentum must also change.
   ☐ (b) If the momentum of an object changes, its kinetic energy must also change.
   ☐ (c) An object traveling in the +x direction has more kinetic energy than an object traveling in the -x direction.
   ☐ (d) Momentum is always conserved for every system.
   ☐ (e) Energy is always conserved for every system.
   X (f) Momentum is **not** always conserved for every system.
   X (g) Energy is **not** always conserved for every system.

6. Consider a car traveling east while slowing down. Which of these options shows the correct direction of the car's velocity and acceleration?
   ☐ (a) velocity - east, acceleration - east
   X (b) velocity - east, acceleration - west
   ☐ (c) velocity - west, acceleration - west
   ☐ (d) velocity - west, acceleration - east

7. The electrostatic force between two identical particles is given by the equation to the right, where **q** is the charge of the particles, **r** is the distance between the two, and **k** is a constant. In S.I. units charge is measured in Coulombs (**C**). Which of the following are the correct S.I. units for the constant **k**?

$$F = k\frac{q^2}{r^2}$$

X (a) $\frac{kg \cdot m^3}{s^2 \cdot C^2}$

☐ (b) $\frac{kg \cdot m \cdot s^2}{C^2}$

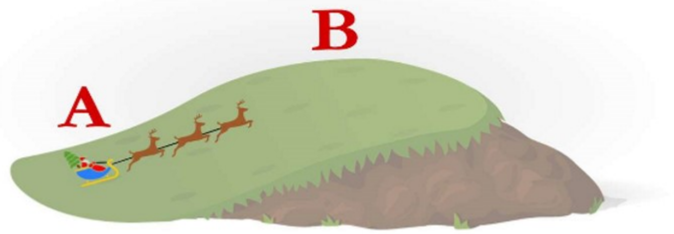
☐ (c) $\frac{kg^2 \cdot m}{s \cdot C^2}$

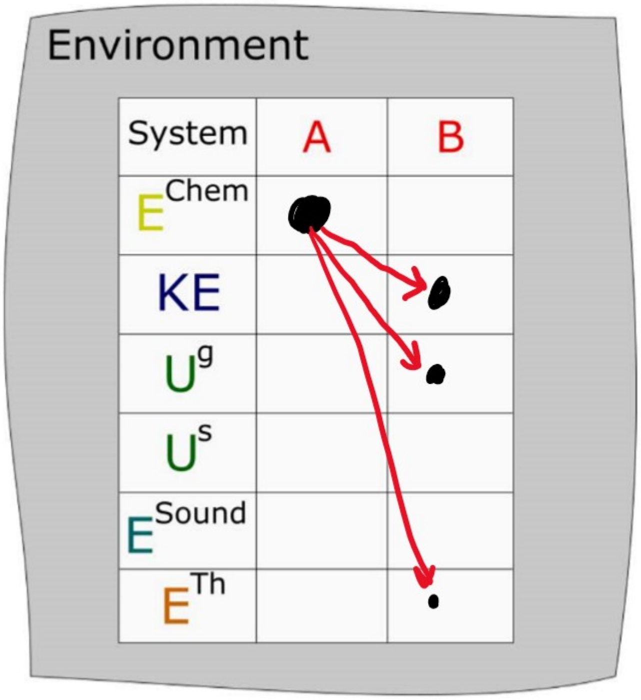
☐ (d) $\frac{kg \cdot C}{s^2 \cdot m^2}$

☐ (e) $\frac{s^2 \cdot m^3}{kg \cdot C}$

8. (4 points) Three non-magical reindeer were watching YouTube when they first saw an add from Santa requesting applications for Reindeer Ground Delivery Service School. All three non-magical reindeer followed the links, applied, and got accepted! On the first day of Reindeer Ground Delivery Service School, Santa had the reindeers start from rest (location **A**) and accelerate up a non-snowy hill as fast as they can. The reindeer were to pull a heavy sleigh to the top of the hill (location **B**) as fast as they can so that their speed at the top could be measured.

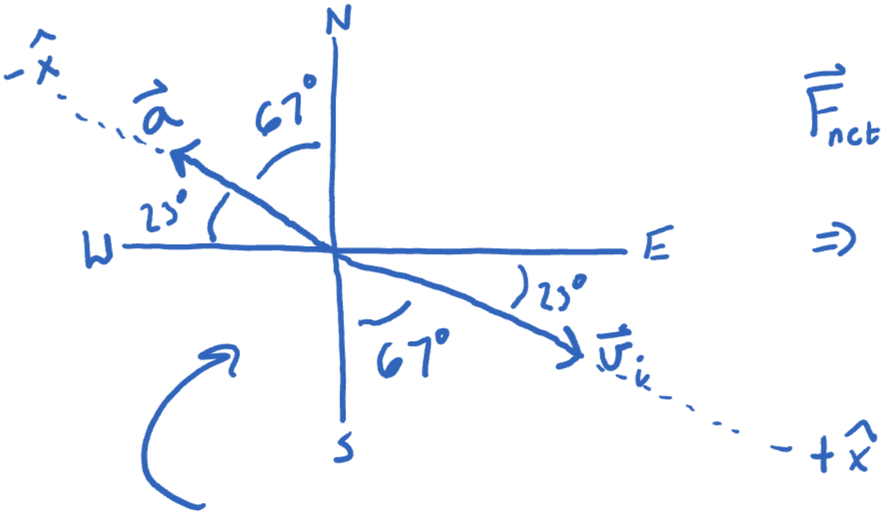
Consider a system consisting of the following: the reindeer, the sleigh, the Earth, and the hill. Use the provided energy flow diagram to show the energy transformations and transfers for the system, OR explain with words the energy transformations and transfers for the system.





Question part	Points	Description
Energy	4 pts	High Level Energy Description: All relevant energy terms are identified at each location with the proper transformations between each location.
Energy	3.5 pt	Mid-High Level Energy Description: Missing or added one key energy term/transformation.
Energy	3.0 pt	Mid Level Energy Description: Missing more than one key energy term/ transformation.
Forces	2.0 pt	Low Level Energy Description: Missing a lot of energy terms/ transformations or identifies quantities that are not energy.
Forces	0 pt	No work or irrelevant physics

9. (7 points) A 2.5 x 10⁶ kg rocket is traveling 256 m/s in a direction 23 degrees South of Galactic East. The rocket's thrusters fire, providing a thrust of 15 x 10⁶ Newtons in a direction 67 degrees West of Galactic North for 12 seconds. How far does the rocket travel during these 12 seconds? (Ignore gravity)



$$\vec{F}_{net} = m\vec{a}$$

$$\Rightarrow \vec{a} = \frac{15 \times 10^6 \text{ N}}{2.5 \times 10^6 \text{ kg}}(-\hat{x})$$

$$= 6 \text{ m/s}^2 (-\hat{x})$$

It's a 1-D problem!

$$\Delta x = v_{ix}\Delta t + \frac{1}{2}a_x \Delta t^2$$

$$\Delta x = (256 \text{ m/s})(12 \text{ s}) + \frac{1}{2}(-6 \text{ m/s}^2)(12 \text{ s})^2$$

$$\Delta x = 2640 \text{ m}$$

3.0	High level kinematics - uses appropriate kinematics to find the distance the rocket traveled during the 12 seconds given an acceleration (hopefully found through a force analysis).
2.0	Mid level kinematics - kinematics concepts are used, but incomplete or incorrect. Picture is hopefully drawn!
1.0	Low level kinematics - kinematic concepts are mentioned

3.0	High level force analysis - uses F_{net} = ma to find the acceleration of the rocket.
2.0	Mid level force analysis - force analysis is incorrect or incomplete
1.0	Low level force analysis - physical concepts related to forces are mentioned

1.0	Partial credit - Good sensemaking
1.0	Partial credit - Picture drawn

1.0	Final answer is found to be 2,640 m (finding <2430, -1032> m is also acceptable)

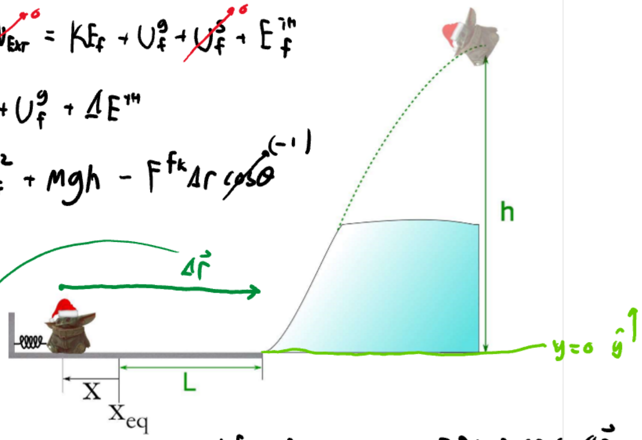
10. (8 points) Captured by remnants of the fallen Galactic Empire, Grogu constructs a spring that will launch him, from rest, up a hill and hopefully high enough to escape the compound walls that hold him captive. Use an energy analysis to construct an equation that would allow you to solve for the spring constant that Grogu would need if he knew all of the other parameters. Your equation should only have the following variables in it: **k, x, L, h, m, g, v**$_f$, and **u**$_k$. SYSTEM | GROGU + EARTH + SPRING + SURFACE

There is kinetic friction while Grogu is being pushed by the spring and for another distance of L after the Grogu leaves the spring. There is negligible friction while Grogu is sliding up the hill.

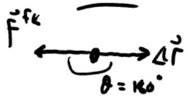
$$\cancel{KE_i}^{0} + \cancel{U_i^g}^{0} + U_i^s + E_i^{Th} + \cancel{W_{Ext}}^{0} = KE_f + U_f^g + \cancel{U_f^s}^{0} + E_f^{Th}$$

$$U_i^s = KE_f + U_f^g + \Delta E^{Th}$$

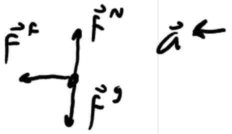
$$\frac{1}{2}kx^2 = \frac{1}{2}mv_f^2 + mgh - F^{fk}\Delta r\,\cancel{\cos\theta}^{(-1)}$$



VEc. oP.



FBD DURING $\Delta\vec{r}$



$$\frac{1}{2}kx^2 = \frac{1}{2}mv_f^2 + mgh + F^{fk}\Delta r$$

$$F^N - mg = m\cancel{a_y}^{0}$$

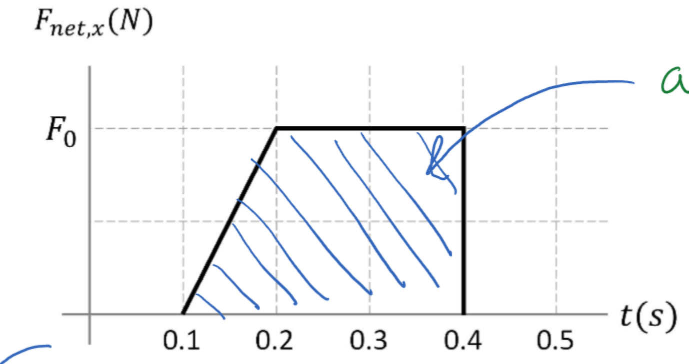
$$F^N = mg$$

$$\frac{1}{2}kx^2 = \frac{1}{2}mv_f^2 + mgh + \mu_k F^N (x+L)$$

$$\boxed{\frac{1}{2}kx^2 = \frac{1}{2}mv_f^2 + mgh + \mu_k mg(x+L)}$$

Question part	Points	Description
Kinetic Energy	0.5 pt	Identifies KE.
Kinetic Energy	0.5 pt	Definition of KE
Gravitational Energy	0.5 pt	Identifies U^G
Gravitational Energy	0.5 pt	Definition of U^G
Spring Energy	0.5 pt	Identifies U^S
Spring Energy	0.5 pt	Definition of U^S
Thermal Energy	0.5 pt	Identifies ΔETH
Thermal Energy	0.5 pt	Definition of ΔETH
Thermal Energy	0.5 pt	Simplifies to ΔETH F^{Fk}Δr cos(theta)
Thermal Energy	0.5 pt	Cos(theta) = -1
Thermal Energy	0.5 pt	Definition of F^{Fk} = uF^N
Thermal Energy	0.5 pt	Shows/explains F^N = mg
Zeros	0.5 pt	Shows/Explains no external work
Zeros	0.5 pt	Initial KE and Ug = 0 (or uses ΔUg), and final Us = 0
Algebra	0.5 pt	Δr = x + L
Algebra	0.5 pt	Correct answer

11. (10 points) Wayne Regretsky, the mediocre hockey player, uses his stick to push a 170 gram hockey puck across the horizontal frictionless ice. The hockey puck then collides with a stationary 156 gram hockey puck. After the collision, both pucks travel in the positive x-direction. The heavier puck has a speed of 5 m/s, while the lighter puck has a speed of 18 m/s. A graph of the force provided to the heavier puck by Wayne's stick is given as a function of time. What is the maximum magnitude of the force, F_0, provided to the heavier puck by Wayne's stick?



$$\text{area} = 0.25\,F_0 \text{ seconds}$$
$$= \Delta p_1$$
$$= m_1 v_{1i} - m_1(0)$$

push ⇒

collision ⇒ momentum conservation!

$$P_{tot,f} = m_1 v_{1f} + m_2 v_{2f} = (0.170\,kg)(5\,m/s) + (0.156\,kg)(18\,m/s) = 3.658\,kg\,m/s$$

$$\underset{\text{after collision}}{P_{tot,f}} = \underset{\text{before collision}}{P_{tot,i}} = m_1 v_{1i} \Rightarrow m_1 v_{1i} = 3.658\,kgm/s$$

$$\left(\text{from area of graph/impulse}\right) \rightarrow m_1 v_{1i} = 0.25\,F_0 \text{ seconds}$$

$$\Rightarrow F_0(0.25\,s) = 3.658\,kg\,m/s$$

$$\Rightarrow \boxed{F_0 = 14.6\,N}$$

2.0	High level graphical interpretation - finds that the impulse is the area under the curve, which is equal to 2.5 F_0 * 0.1 seconds or 0.25 F_0 seconds
1.0	Mid / low level graphical interpretation - uses information from the graph incorrectly or incompletely

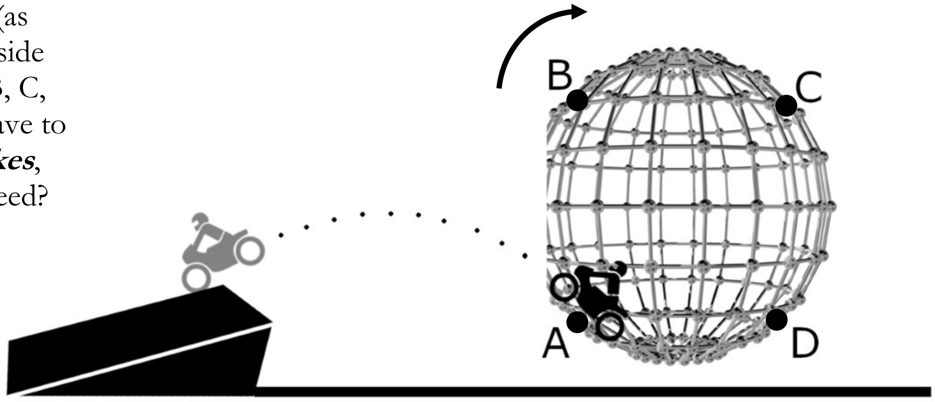
4.0	High level collision physics - conservation of momentum ideas are used to find the speed of the 170 gram puck before the collision. ($m_1 v_{1i} = m_1 v_{1f} + m_2 v_{2f}$) OR finds the final momentum of the system and equate that to the initial momentum of the system
3.0	Mid level collision physics - uses conservation of momentum concepts incorrectly or incompletely (such as assuming the collision is inelastic)
2.0	Low level collision physics - uses relevant physical concepts incompletely or incorrectly (e.g., not applying conservation of momentum, incorrectly assumes kinetic energy is conserved during collision)

3.0	High level impulse momentum analysis - uses impulse and momentum concepts to relate the impulse (F Delta T) from the stick to the m Delta v of the heavy puck.
2.0	Mid level impulse momentum analysis - mentions impulse and momentum concepts but does not make a complete argument or connection.
1.5	Mid/low level impulse momentum analysis - mentions impulse and momentum concepts. Makes an incorrect impulse or momentum argument. Doesn't connect impulse to momentum
1.0	Low level impulse momentum analysis - mentions momentum concepts or tries to use energy / kinematics ideas

1.0	Final answer is F_0 = 14.6 N

12. (14 points) Santa likes to dress up in disguise and perform stunts at shows. In his most recent stunt he rides a motorcycle in a vertical circle ***inside*** of a 6-m-radius spherical cage many rotations before making a daring jump. While in the cage he is able to maintain a constant speed.

(a) Assume Santa is traveling clockwise (as shown in the diagram) around the inside of the cage. Consider the points A, B, C, and D. For each point, does Santa have to give the motorcycle ***gas***, hit the ***brakes***, or ***neither*** to maintain a constant speed?



A: **Gas**

B: **Gas**

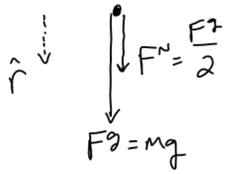
C: **Brake**

D: **Brake**

(b) While in the cage, his speed is such that the normal force at the very top of cage is equal to half the weight of both him and his motorcycle. What is the normal force when he is at the bottom of the cage?

System: Santa + Motorcycle

Top FBD

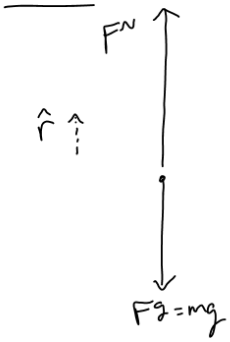


$$\Sigma F_r \Rightarrow F^N + F^g = ma_r$$

$$\frac{\cancel{m}g}{2} + \cancel{m}g = \cancel{m}\frac{v^2}{r}$$

$$\frac{3}{2}g = \frac{v^2}{r} = \text{constant}$$

Bottom FBD



$$\Sigma F_r \Rightarrow F^N - F^g = ma_r$$

$$F^N - mg = m\frac{v^2}{r}$$

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

$$F^N = m\left(\frac{3}{2}g + g\right)$$

$$\boxed{F^N = \frac{5}{2}mg}$$

Rubric

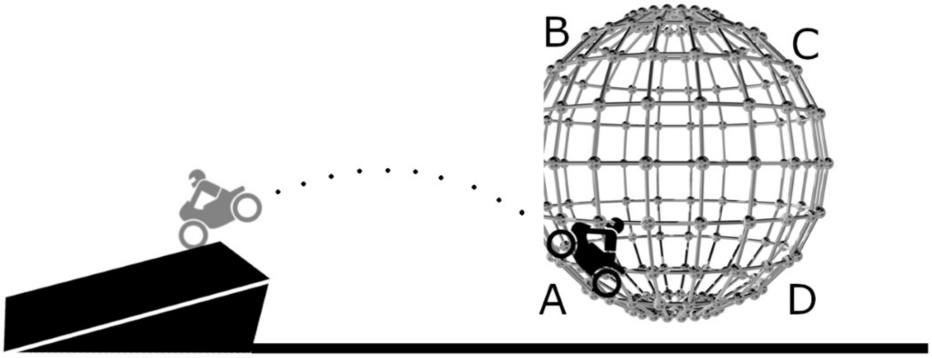
(a) 2 points total
- **0.5 per correct answer**

(b) 6 points total
- **1 pt - FBDs**
- **0.5 pt - 2nd law eq.**
- **0.5 pt - a_r = v^2/r eq.**
- **1.5 pts - application of 2nd law at top**
- **1.5 pts - application of 2nd law at bottom**
- **0.5 pts - connecting top and bottom via speed**
- **0.5 pts - correct answer**

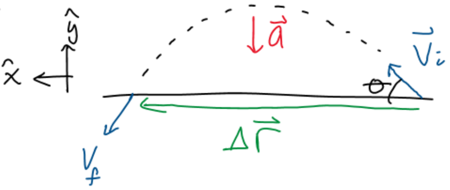
Problem 12 continued…

(c) After many rotations, he jumps the motorcycle out of a hole in the cage at an angle of 45° relative to the horizontal and onto a ramp. The ramp and the hole are at the same height. How far horizontally does he travel when flying through the air?

(d) Use order of magnitude sense making to determine whether your answer to (c) is reasonable or not.



Projectile Motion



Knowns

$a_x = 0$

$\boxed{X}$ $V_{ix} = |\vec{V}_i|\cos\theta$

$V_{fx} = V_{ix}$ b/c $a_x = 0$

Unknowns

Δx

Δt

eq's

(i) $\Delta x = V_i\Delta t + \frac{1}{2}a\Delta t^2$

(ii) $V_f = V_i + a\Delta t$

(iii) $V_f^2 = V_i^2 + 2a\Delta x$

$|\vec{V}_i|$ from (b)

$V_i = \sqrt{\frac{3}{2}gr} = 9.39\,m/s$

$\boxed{y}$ $a_y = -9.8\,m/s^2$

$V_{iy} = |\vec{V}_i|\sin\theta$

$\Delta y = 0$

Δt

V_{fy}

$\boxed{y}$ eq (i)

$$\cancelto{0}{\Delta y} = |\vec{V}_i|\sin\theta\,\cancel{\Delta t} - \frac{g}{2}\Delta t^{\cancel{2}}$$

$$\Delta t = \frac{2|\vec{V}_i|\sin\theta}{g}$$

$\boxed{X}$ eq(i)

$$\Delta x = |\vec{V}_i|\cos\theta\,\Delta t + \frac{1}{2}\cancelto{0}{a_x}\Delta t^2$$

$$\Delta x = \frac{2|\vec{V}_i|^2\cos\theta\sin\theta}{g} = \frac{3gr}{2}$$

$$\boxed{\Delta x = 88.2\,m}$$

Rubric

(c) 5 points total

- **0.5 pt - physical representation**
- **0.5 pt - knowns and unknowns**
- **0.5 pts - velocity component analysis**
- **0.5 pts - using the speed from part (b)**
- **0.5 pts - kinematic equation (i)**
- **2 pts - solving for delta t in y-direction and plugging it into x-direction**
- **0.5 pts - correct answer and units**

(d) 1 point total

My answer (~100 m) is about the length of a sportsball field. That seems about the furthest I would expect. Someone can certainly jump a bike 10 m, and I don't think someone can jump a bike a 1000 meters (1 km), so 100 m is on the order of magnitude that makes it plausible. Plus, it is Santa Claus after all, he's pretty swol.