Final exam draft

Tuesday, December 12, 2023 9:11 AM

Name:______________________________

ID:________________________________

Physics 201

Final Exam

12/12/2023

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, a page of scratch paper, writing utensils, and the exam. You will have 110 minutes to complete this exam.

ph201_f23_f

11 answers?

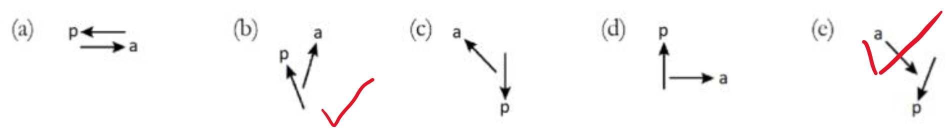
For questions 1 through 6 **fill in the square** next to all correct answers. A given problem may have more than one correct answer. Each correctly bubbled answer will receive two points. There are **??** correct answers in this section and only the first **??** filled in answers will be graded. There is no partial credit.

1. Consider the system contained within the dotted line that includes the glass jar, the bug, and the air inside the jar. In the first scenario the bug is at rest on the bottom of the jar and the scale measuring the normal force acting on the jar reads 5.00. In the 2nd scenario the bug is flying around in the jar, not touching the glass. Which of the following statements are true about the reading on the scale in the 2nd scenario?

   □ (a) If the bug is flying **stationary** (hovering) the reading on the scale will be **less than 5.00**.
   □ (b) If the bug is flying **stationary** (hovering) the reading on the scale will be **5.00**.
   □ (c) If the bug is flying **stationary** (hovering) the reading on the scale will be **more than 5.00**.
   □ (d) If the bug is **accelerating upwards** the reading on the scale will be **less than 5.00**.
   □ (e) If the bug is **accelerating upwards** the reading on the scale will be **5.00**.
   □ (f) If the bug is **accelerating upwards** the reading on the scale will be **more than 5.00**.

2. Shown here are the momentum and acceleration for several different types of motion. In which case (s) is the object speeding up?

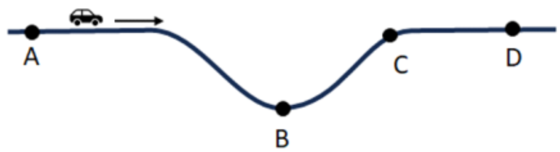
   □ (a)
   □ (b)
   □ (c)
   □ (d)
   □ (e)



3. A **m = 4 kg** bag of presents falls from Santa's sleigh while he is flying horizontally above the city. As it is falling to the ground, which of the following statements are true? Ignore air resistance (drag).

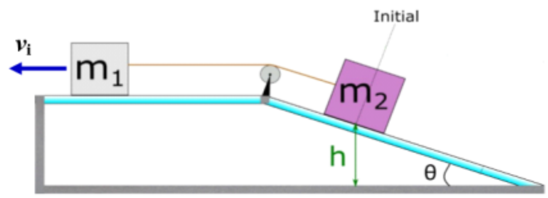
   □ (a) The bag will have a **horizontal** acceleration magnitude **equal to zero**.
   □ (b) The bag will have a **horizontal** acceleration magnitude **greater than zero but less than g**.
   □ (c) The bag will have a **horizontal** acceleration magnitude **equal to g**.
   □ (d) The gravitational force on the bag is 4 N.
   □ (e) The gravitational force on the bag is 9.8 N.
   □ (f) The gravitational force on the bag is 39.2 N.
   □ (g) The bag will have a **vertical** acceleration magnitude **equal to zero**.
   □ (h) The bag will have a **vertical** acceleration magnitude **greater than zero but less than g**.
   □ (i) The bag will have a **vertical** acceleration magnitude **equal to g**.

4. You are driving in a car. At a given instant, you feel that the magnitude of the normal force from your seat is less than what it was when your car was stationary. In which location(s) could you be? (see image)?



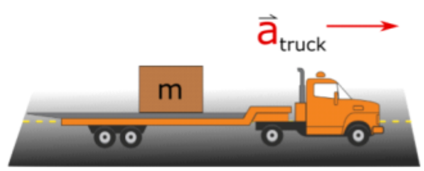
☐ (a) A
☐ (b) B
☐ (c) C
☐ (d) D

5. Two masses are connected via a taught string that goes over an ideal pulley. Mass $\mathbf{m_1}$ is on a horizontal surface, and mass $\mathbf{m_2}$ is on an incline. At the moment shown $\mathbf{m_1}$ is traveling to the left and slowing down. There is negligible friction between the masses and the surfaces. Which of the following statements are correct for the immediate time that follows.



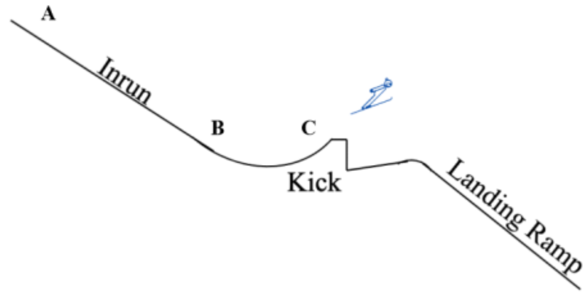
☐ (a) The kinetic energy of $\mathbf{m_1}$ doesn't change but $\mathbf{m_2}$ has gravitational potential energy increasing while it's kinetic energy decreases.
☐ (b) The gravitational potential energy of $\mathbf{m_1}$ and $\mathbf{m_2}$ remains constant as the kinetic energy from $\mathbf{m_1}$ is converted into kinetic energy in $\mathbf{m_2}$.
☐ (c) Gravitational potential energy of both $\mathbf{m_1}$ and $\mathbf{m_2}$ is converted into increasing the kinetic energy of $\mathbf{m_1}$ and $\mathbf{m_2}$.
☐ (d) The kinetic energy of both $\mathbf{m_1}$ and $\mathbf{m_2}$ is converted into increasing the gravitational potential energy of $\mathbf{m_2}$.

6. Consider a truck that is accelerating to the right. The truck is carrying a box that is not sliding relative to the truck. Which of the following statements are true for this situation.



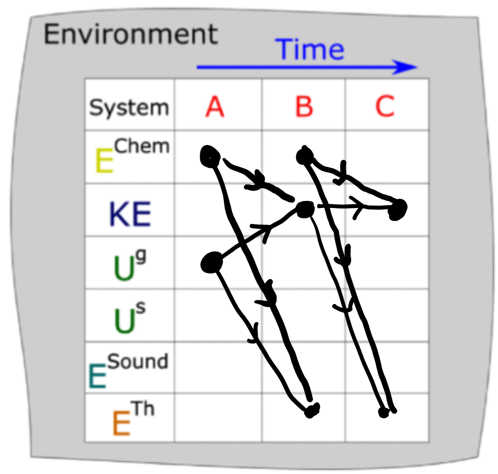
(a) The truck **must** be speeding up to the right.
(b) The truck **could either** be speeding up to the right or slowing down to the left.
(c) The direction of friction acting on the box **must** be to the left.
(d) The direction of friction acting on the box **could either** be to the left or the right.
(e) The direction of friction acting on the box **must** be to the right.

7. (5 points) Consider the ski jump where people start at point **A** and slide down an incline, gaining speed and jumping off the kick at **C**. Point **B** and **C** are at the same height. Do not ignore resistive forces like friction.



(a) Use the provided energy flow diagram to show the energy transformations and transfers if the system includes the skier, the Earth, the atmosphere, and the ski jump hill. Be sure that the arrows clearly start and stop in a specific box. If one of the energies is the same from one point to the next, show the horizontal arrow that indicates it is the same. Do not worry about the size of the dots at the arrow's tail. If there is any external work, be sure to identify which force(s) are responsible for it.

(b) Describe in words the transformations and transfers in energy from point **A** to point **C**.



At point A the skier + Earth system has the greatest amount of gravitational potential energy. As they slide down the incline from point A to B, gravitational PE is transformed into kinetic energy in the skier and some thermal energy through frication and air resistance. From B to C gravitational PE is transformed into kinetic energy again until the bottom of the kick, but then by C, the skier is back to the same height as B and thus the same gravitational PE. Since there is friction I would expect the skiers kinetic energy to be less at C than at B. Skiers are also not completely rigid objects, they have stored chemical PE that fuels their muscles. They will be exerting this energy to maintain form and to push off during the jump. This energy goes into both a little more kinetic energy (maybe because of this the KE is greater at C than B, but it's not from gravitational PE) and also some thermal energy as they increase their temperature through exhaustion. There could be some small amount of sound energy created especially as the skier yells "Ohhh shhhiiii" as they launch off the kick.

Question 7 Rubric

5 pt - Clearly shows and explains the major energy transformations and transfers including: gravitational PE, KE, and E_th. Graders will pull from both the diagram and the words to get a complete picture of understanding of the energies at play in this system. Solutions that clearly explain the energies with words can receive full credit if the diagram is not complete.

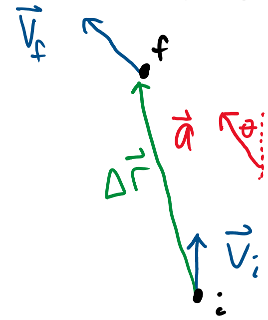
4 pt - Same as 5 pts but some small error.

3 pt - Understands the energies involved but doesn't put how they transfer or transform correctly.

2 pt - Shows some of the energies for some of the points but not how they transfer or transform.

1 pt - mentions potential energy and kinetic energy

8. (10 points) A **10,000 kg** spaceship, far from any gravitational bodies (ignore gravity), is traveling at a constant **1000 km/s** in the positive y-direction. To avoid a potential asteroid the thrusters are turned on to a constant **98,000 N** in a direction **30 degrees** from their initial trajectory, from the positive y-direction towards the negative x-direction.



(a) Will the ship speed up or slow down? Explain.

$\Sigma\vec{F}$ + thus $\vec{a}$ have a component in the same direction as $\vec{V}_i$, thus it should speed up

(b) What is the ship's magnitude of displacement during the first 2 minutes the thrusters are on?

	K	UK
x	V_{ix}, a_x, Δt	Δx, V_{fx}
y	V_{iy}, a_y, Δt	Δy, V_{fy}

$$\Sigma\vec{F} = m\vec{a} \Rightarrow \vec{a} = \frac{1}{m}|\vec{F}^{th}|\langle -\sin\theta, \cos\theta\rangle = \langle -4.9, 8.49\rangle \, m/s^2$$

$$\Delta x = V_{ix}^{\,0}\Delta t + \tfrac{1}{2}a_x\Delta t^2 = -35{,}280 \text{ m}$$

$$\Delta y = V_{iy}\Delta t + \tfrac{1}{2}a_y\Delta t^2 = 181{,}106 \text{ m}$$

$$|\Delta\vec{r}| = \sqrt{\Delta x^2 + \Delta y^2} = 184{,}511 \text{ m}$$

(c) What is the ship's velocity after the first 2 minutes the thrusters are on?

$$V_{fx} = V_{ix}^{\,0} + a_x\Delta t = -588 \text{ m/s}$$

$$V_{fy} = V_{iy} + a_y\Delta t = 2018 \text{ m/s}$$

Question 8 Rubric

Part (a) - 1.5 points
- 0.5 pts - correct answer
- 1 pt - reasoning

Part (b) 6 points
- 0.5 pt - 2nd law equation
- 1 pt - 2nd law application
- 1.5 pt - problem orientation (physical representation, known and unknowns, zeros, FBD)
- 0.5 pt - kinematic equations
- 1.5 pt - application of kinematic equations
- 0.5 pt - magnitude is sqrt of the squares
- 0.5 pt - correct answer and units

Part (c) 2.5 points
- 0.5 pt - kinematic equation
- 1.5 pt - application of kinematic equation
- 0.5 pt - correct answer and units

Question 9 Rubric

1 pt - Conservation of Momentum equation

Part (a) - 1.5 pt total
0.5 pt - correct answer
1 pt - use of proportional reasoning

Part (b) - 3 pts
2 pt - COM application
0.5 pt - mass relationship
0.5 pt - correct answer

Part (c) - 1.5 pt total
0.5 pt - correct answer
1 pt - use of proportional reasoning

Part (d) - 3 pts
1.5 pt - COM application
1 pt - mass relationship
0.5 pt - correct answer

9. (10 points) High energy particles can be created in particle accelerators like the Large Hadron Collider. These high energy particles are not in their natural state and they will sometimes spontaneously decay (split) into many new particles. Consider such a spontaneous decay where a particle of mass **m** and speed **v** is traveling in the positive x-direction. All of the sudden it splits into 3 particles.

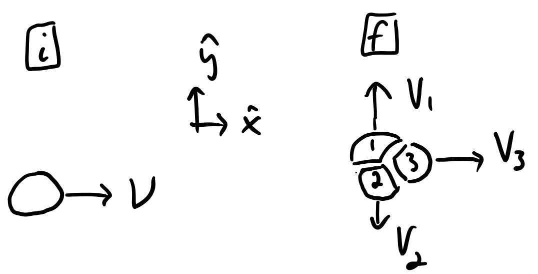
- Particle 1 is traveling in the positive y-direction with speed $\mathbf{v_1}$
- Particle 2 is traveling in the negative y-direction with speed $\mathbf{v_2}$
- Particle 3 is traveling in the positive x-direction with speed $\mathbf{v_3}$
- Particle 2 is twice as massive as particle 1.
- Particle 3 is three times as massive as particle 1.

(a) Do you expect particle 1 to be traveling faster or slower than particle 2? Use proportional reasoning sense-making to determine which should be traveling faster.

(b) Find the ratio $\mathbf{v_1} / \mathbf{v_2}$. You should be able to get a number or a fraction.

(c) Do you expect particle 3 to be traveling faster or slower than the original high energy particle? Use proportional reasoning sense-making to determine whether it should be traveling faster or slower than the original particle's speed **v**.

(d) Find the ratio $\mathbf{v_3} / \mathbf{v}$. You should be able to get a number or a fraction.



w/ $\sum \vec{F}_{ext} = 0$, $\Delta \vec{P} = 0 \Rightarrow \sum \vec{P}_i = \sum \vec{P}_f$

$$m\vec{v} = m_1\vec{v}_1 + m_2\vec{v}_2 + m_3\vec{v}_3$$

(a) [y] $0 = m_1|\vec{v}_1| - m_2|\vec{v}_2| \Rightarrow |\vec{v}_1| = \frac{m_2}{m_1}|\vec{v}_2|$ w/ $m_2 > m_1$, $|\vec{v}_1| > |\vec{v}_2|$

(b) w/ $m_2 = 2m_1$, $|\vec{v}_1| / |\vec{v}_2| = 2$

(c) [x] $m|\vec{v}| = m_3|\vec{v}_3| \Rightarrow |\vec{v}_3| = \frac{m}{m_3}|\vec{v}|$ w/ $m > m_3$, $|\vec{v}_3| > |\vec{v}|$

(d) w/ $m_3 = 3m_1$ + $m_2 = 2m_1$ + $m = m_1 + m_2 + m_3$

$m_3 = \frac{m}{2}$, so $|\vec{v}_3| / |\vec{v}| = 2$

10. (10 points) A cart from your physics lab is rolled along the track at a speed of **0.65 m/s**. The cart collides with a second, identical, cart. Both carts have a mass of **0.32 kg**. The two carts stick together and travel at an unknown speed $\mathbf{v_f}$ after the collision.

(a) What is the magnitude of $\mathbf{v_f}$?

$p_{ix} = p_{fx}$

$m_1 v_{1i} = (m_1 + m_2) v_f$

$m_1 v_{1i} = 2 m_1 v_f$

$v_f = \frac{v_i}{2} = 0.325\ m/s$

(b) What is the initial kinetic energy of the system?

$KE_i = \frac{1}{2} m v_{1i}^2 = \frac{1}{2}(0.32\ kg)(0.65\ m/s)^2 = 0.0676\ J$

$67.6\ mJ$

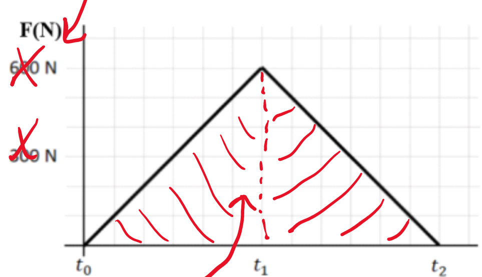
(c) How much kinetic energy is converted to thermal energy during the collision?

$KE_f = \frac{1}{2}(0.32)(0.325\ m/s)^2 = 0.0169$

$-\Delta KE = +0.0507\ J = \Delta E^{th}$

$0 \rightarrow t_2 = $ collision

(d) A graph of the magnitude of the force as a function of time felt by the first cart during the collision is shown. How long did the collision last?



6 N

$J = \Delta p$

$\Delta p_1 = m_1(v_f - v_i) = (0.32)(0.325 - 0.65)$

$= -0.104\ kg\,m/s$

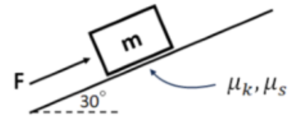
$\text{area} = \frac{1}{2}(b)(h) + \frac{1}{2}(b)(h)$

$= 2 \times \frac{1}{2}(t_1)(6N)$

$\Rightarrow |\Delta p| = |\text{area}| \Rightarrow 0.104 = t_1(6N) \Rightarrow t_1 = 0.017\ s$

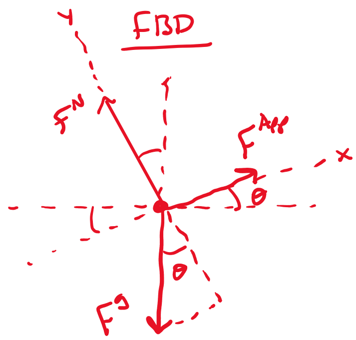
$t_2 = 2t_1 = 0.034\ s = 34\ ms$

11. (8 points) A box of mass **m = 10 kg** is placed at rest on a ramp which makes an angle of **30 degrees** with the horizontal. The coefficients of friction between the ramp and box are **μ_k = 0.15** and **μ_s = 0.35**. A force of **20 N** (70N) is then applied to the box, parallel to the ramp as shown.



(a) Does the box move? Show that the box does or does not move.

FBD



Y

$|F^N| - |F^g_y| = m a_y^{\,0}$

$|F^N| = |F^g_y| = mg\cos\theta$

$= 84.87$ N

$\Rightarrow |f^{f,s}_{max}| = \mu_s |F^N| = 29.7$ N

x

$|F^A| - |F^g_x| = m a_x$

$F^A - mg\sin\theta = m a_x$

F^A 49N

$49\,N < F^A < 78.7\,N$

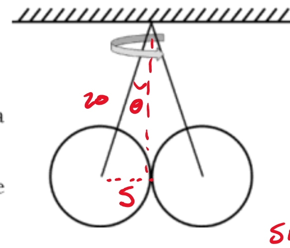
(c) What is the magnitude of frictional force acting on the box?

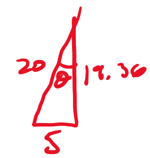
$f^{f,s} = F^A - mg\sin\theta = 70 - 49 = 21\,N$

Speed = 0? ✓

at a speed less than (b) → ✗

12. (10 points) Two identical spheres, each of mass 3 kg and radius 0.05 m, are hung from their centers with 0.2 m long strings. The strings are fixed to the same spot on a platform above the two spheres. The platform, strings and spheres all begin to rotate with a very slowly increasing rate of rotation.



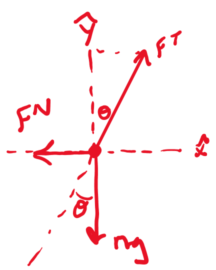


$\sin\theta = \frac{5}{20} = \frac{1}{4}$

$\theta = 14.48°$

(a) Draw a free body diagram for the left sphere. Each force should be labeled, in an appropriate direction, and scaled (reasonably) to the size of the other forces.

FBD



y

$F^T\cos\theta - mg = 0$

$F^T = \frac{mg}{\cos\theta}$

$= 30.36$

x

$-|F^N| + |F^T|\sin\theta = m\frac{v^2}{r}$

$0 + \frac{mg}{\cos\theta}\sin\theta = m\frac{v^2}{r}$

$\sqrt{gr\tan\theta} = v$

$v = 1.898$ m/s

(b) As the apparatus spins faster, the two sphere's will lose contact with each other. At what (linear) speed are the balls travelling when this happens? Hint: what happens to the normal force between the spheres when they lose contact?

$\Delta t = \frac{2\pi(0.05)}{1.898}$

rpm = 362 rpm

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