Phys121/S12/Hassam/Final/May 14

Name: ____________________________

Signature: __________________________

TA Name: __________________________

Seat Number: __________________________

1. Closed Book. Only 2 sheets of paper (double sided) allowed

2. Put final answers into the boxes provided. **SHOW ALL WORK.**

3. Express all your answers using two significant figures, if needed.

4. Use reverse sides for scratch work.

5. After you finish the exam, write and sign the Honor Pledge in the box below:
   “I pledge on my honor that I have not given or received any unauthorized assistance on this exam”

   \[
   g = 9.8 \text{ m/s}^2 \quad G = 6.67300 \times 10^{-11} \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-2}
   \]

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<tr>
<th>Problem</th>
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TRUE/FALSE

T F When two railroad cars collide and couple together, the sum of their momenta is the same before and after the collision.

MULTIPLE CHOICE

M1
A person is pushing horizontally on a box with a constant force, causing it to slide across the not-smooth floor with a constant speed. If the person suddenly stops pushing on the box, the box will
(a) Immediately come to a stop.
(b) Continue moving at a constant speed for a while, then gradually slow down to a stop.
(c) Immediately change to a slower but constant speed.
(d) Immediately begin slowing down and eventually stop.

M2
As seen from above, a car rounds the curved path shown in the figure at a constant speed. Which vector best represents the net force acting on the car?
(circle one)

M3
The number of atoms in a container of ideal gas is increased by a factor of 5 while the temperature is held constant. Which statement is true?

1. The pressure decreases by a factor of 10
2. The pressure decreases by a factor of 5.
3. The pressure stays the same.
4. The pressure increases by a factor of 5.
5. The pressure increases by a factor of 10.

M4
The figure below shows block A sitting on top of block B. A constant force \( F \) is exerted on block B, causing block B to accelerate to the right. Block A rides on block B without slipping. Which statement is true?

(a) block B exerts a friction force on block A, directed to the left.
(b) block B exerts a friction force on block A, directed to the right.
(c) block B does not exert a friction force on block A.
Problem 1

The two blocks in the figure are at rest on frictionless surfaces. What must be the mass of the right block in order that the two blocks remain stationary?

\[ m \sin \theta = 10 \sin \theta \]

\[ T = 10 \sin 23 \]

\[ T = mg \sin \theta \]

Problem 2

The 100 kg block and the 50 kg block in the figure are released from rest in gravity.

(a) what is the acceleration of the 100 kg block?

\[ a = 3.3 \ m/s^2 \]

(b) what is the tension in the string?

\[ T = 653 \ N \]

\[ T - mg = ma \]

\[ 100g - T = 100a \]

\[ (100 - m)g = (100 + m)a \]

\[ a = \frac{1}{3} g \]

\[ 50g = \frac{1}{3} \times 150a \]

\[ T = 100(g - a) = 100 \times \frac{2}{3} g \]
Problem 3

1. You mass is $m$ Kg and you live on Earth. You step into an elevator which then accelerates up at 9.8 m/s$^2$; that is, the acceleration up is “one g”. What is the fraction (apparent weight)/(your weight)? To answer this, you must show a complete FBD. Note that your “weight” is the same thing as $mg$, and “apparent weight” is the same thing as the normal force on your feet.

\[
\text{(apparent weight)/(your weight) = } 2
\]

\[
F_N - mg = ma
\]

\[
F_N = mg + ma
\]

\[
\frac{F_N}{mg} = 1 + \frac{a}{g} = 2
\]

\[\begin{aligned}
\text{Earth} & \\
\end{aligned}\]

2. Newton figured out a general formula for gravitational forces, namely $F = GMm/r^2$. He realized therefore that there must be a relationship between the gravitational acceleration $g$ and the quantities $\{G, M, \text{ and } R\}$ where $M$ is the Earth mass and $R$ is the Earth radius. What is this relationship? So, under what circumstances should you NOT use the formula “gravitational force = mg”? (one sentence only)

<table>
<thead>
<tr>
<th>Relationship between $g, G, M, R$</th>
<th>One sentence:</th>
</tr>
</thead>
<tbody>
<tr>
<td>$g = GM / R^2$</td>
<td>When you are very far from Earth surface</td>
</tr>
</tbody>
</table>

\[
mg = GMm / R^2
\]

3. The elevator in Part 1 goes up really high. Suppose your elevator is so high up that its distance from the center of the Earth is 3 times Earth radius $R$. What is the fraction (apparent weight)/(your weight) if you are still accelerating up at $g$ m/s$^2$. (All “weight” definitions are still the same.) In finding this fraction, you must use the relationship from part 2 to eliminate $G$ and $M$, so your final answer should be a number.

\[
\text{(apparent weight)/(your weight) = } 1 + \frac{a}{g} = 1 + \frac{3g}{g} = 4
\]

\[\begin{aligned}
\text{Earth} & \\
\end{aligned}\]

* "your weight" here was meant to be $m \times (9.8)$.
Credit was given for other interpretations & partial credit especially for correct FBD's and associated eqns.
Problem 4

In collisions between two objects, momentum is always conserved. If the collision is *elastic*, kinetic energy is also conserved.

An object of mass \( m_1 = 1 \) kg is moving to the right at speed 1 m/s. It makes an *elastic* collision with a stationary object of mass \( m_2 \) kg. After the collision, both \( m_1 \) and \( m_2 \) are moving, separately, as follows: mass \( m_1 \) is seen to be moving in the left direction, at speed 1/2 m/s; mass \( m_2 \) is seen to be moving to the right, at speed \( V \) m/s.

Find the mass \( m_2 \) and its speed \( V \). For partial credit, state your steps clearly.

\[
\begin{align*}
\text{momentum:} & \quad l \times l = -l \times \frac{l}{2} + m_2 V \\
\text{energy:} & \quad \frac{1}{2} l (l) = \frac{1}{2} \left( \frac{l}{2} \right) (V_1)^2 + \frac{1}{2} m_2 V^2 \\
\text{substituting} & \quad V = \frac{3/4}{3/2} = \frac{V_2}{2} \\
& \quad m_2 \left( \frac{l}{2} \right) = \frac{3}{2} \quad \Rightarrow \quad m_2 = 3
\end{align*}
\]
Problem 5

A 50 gm ball is fired horizontally with initial speed 30 m/s toward a 100 gm ball that is hanging motionless in gravity from a 1.0 m-long string anchored to a pivot (see pics). The balls undergo a head-on collision and stick together. The hit is so hard that the (50+100)g combo swings completely around the pivot in a circle.

(a) What is the speed of the combo immediately after the hit?
(b) If you took a snapshot of the combo mass at the very top of the circle, what would be its speed? (Assume there is no air resistance or any type of friction in this system.)
(c) What is the tension in the string at the top of the circle?

\[
\begin{align*}
(a) \quad & 50 \times 30 = (50+100) \times V \\
& 30 = 3 \times V \quad V = 10 \\

(b) \quad & \text{Energy} = \text{Cons} \quad \frac{1}{2} (150) V^2 = (500)g \ h + \frac{1}{2} (150) V_{\text{top}}^2 \\
& V^2 = 2gh + V_{\text{top}}^2 \quad , \ h = 2 \quad V^2 = 10 \\
& V_{\text{top}}^2 = 100 - 4g \\
& \boxed{V_{\text{top}} = \sqrt{100-4g}} \\

(c) \quad & T + mg = m V_{\text{top}}^2 / r \\
& T + mg = m (100-4g) \\
& T = 100m - 4mg - mg \quad (T = 100-5g)m
\end{align*}
\]
Problem 6

Refrigerators have a thermodynamic limit on their COP, given by \( \text{COP} < \frac{T_c}{T_h - T_c} \), where \( T_c(\text{K}) \) is the temperature of the fridge, \( T_h(\text{K}) \) is the environment temperature, and COP is defined as \( \text{COP} = \frac{\text{heat extracted from fridge}}{\text{input work}} \).

A fridge is in an environment which is at 127 degrees C, and we desire to operate the fridge at 27 degrees C. You are provided with a motor. The system is optimized to give a COP equal to \( \frac{1}{3} \) of the maximum COP limit. You find that the heat extracted from the fridge per cycle is 60 J. Find

1. the heat in Joules exhausted to the environment per cycle
   \[ Q_h = 127 + 273 = 400 \]
   \[ \text{Heat exhausted per cycle} = 120 \text{ J} \]

2. the energy per cycle that must be supplied by the motor
   \[ 72 + 273 = 300 \]
   \[ \text{Motor energy/cycle} = 60 \text{ J} \]
   \[ \text{COP} = \frac{60}{W} \]
   \[ \text{COP}_{\text{max}} = \frac{300}{120} = 3 \]
   \[ \frac{1}{3} \text{COP}_{\text{max}} = 1 \]
   \[ W = 60 \]
   \[ Q_h = 60 + 60 = 120 \]
Problem 7

Marianne really likes coffee, but on summer days she doesn't want to drink a hot beverage. She is served 200 g of coffee at 87°C in a well-insulated container. She adds 100 g of ice at 0°C. She waits until the ice melts and all the resulting drink has come to a final temperature. What is the final temperature of her coffee?

\[ T_{\text{final}} = 31^\circ C \]

Specific heat of water = 4190 J/(Kg-K)
Specific heat of ice = 2090 J/(Kg-K)
Latent heat of freezing for water = 3.33 x 10^5 J/Kg

\[ \text{Coffee} \rightarrow \text{Ice + Ice + Water Warmup} \]

\[ M_{\text{water}} (87 - T_f) = L_f M_{\text{ice}} + M_{\text{ice}} C_w T_f \]

\[ \frac{M_{\text{water}}}{M_{\text{ice}}} (87 - T_f) = \frac{L_f}{C_w} + T_f \]

\[ \frac{L_f}{C_w} = 3.33 \times 10^5 \div 4190 = 77.5 \]

\[ \Phi F = \frac{L_f}{C_w} + 3T_f \]

\[ T_f = \frac{174 \Phi F / C_w}{3} = 31 \]

\[ \text{Coffee} \rightarrow \text{Ice + Water Warmup} \]