PHYS 2211 Test 3 - Fall 2019

Please circle your lab section and then clearly print your name & GTID

Day	12-3pm	3-6pm
Monday	W01 W08	W02 W09
Tuesday	W03 W10	W04 W11
Wednesday	W05 W12	W06 W13
Thursday	W07	W14

Name: KEY

GTID:

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Instructions

- Please write with a pen or dark pencil to aid in electronic scanning.
- Read all problems carefully before attempting to solve them.
- Your work must be legible, and the organization must be clear.
- Your solution should be worked out algebraically. Numerical solutions should only be evaluated at the last step. Incorrect solutions that are not solved algebraically will receive an 80 percent deduction.
- You must show all work, including correct vector notation.
- **Correct answers without adequate explanation will be counted wrong.**
- Incorrect work or explanations mixed in with correct work will be counted wrong. Cross out anything you do not want us to grade
- Make explanations correct but brief. You do not need to write a lot of prose.
- Include diagrams!
- **Show what goes into a calculation, not just the final number, e.g.:** $\frac{a \cdot b}{c \cdot d} = \frac{(8\times10^{-3})(5\times10^{6})}{(2\times10^{-5})(4\times10^{4})} = 5\times10^{4}$
- Give standard SI units with your numeric results. Your symbolic answers should not have units.

Unless specifically asked to derive a result, you may start from the formulas given on the formula sheet, including equations corresponding to the fundamental concepts. If a formula you need is not given, you must derive it.

If you cannot do some portion of a problem, invent a symbol for the quantity you can not calculate (explain that you are doing this), and use it to do the rest of the problem.

"In accordance with the Georgia Tech Honor Code,
I have not given or received unauthorized aid on this test."

Sign your name on the line above

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Problem 1 [25 pts]
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Alone again on Thanksgiving you take a small frozen pumpkin out of the freezer and place it in your microwave. The pumpkin has a mass of 2.2 kg and comes out of the freezer at a temperature of −10°C. The heat capacity of the pumpkin is approximately 3.85 $J/K/g$.

A. [5 pts] Assume all of the energy from the microwave flows into the pumpkin as thermal energy. If the oven power is 1600 W (i.e. 1600 J/s), how long does it take before the pumpkin reaches 70 °C?

$$\left.\begin{aligned} Q &= m_p C_p \Delta T = (2200g)(3.85 J/K/g)(70°C - (-10C°)) \\ &= 6.776 \times 10^5 J. \end{aligned}\right\} \text{3 pts}$$

$$P = \frac{Q}{\Delta t} \Rightarrow \Delta t = \frac{Q}{P} = \frac{6.776 \times 10^5 J}{1600 W} = \boxed{423.5 \text{ sec}} \Big\} \text{2 pts}$$

B. [5 pts] In practice, not all of the energy flows into the pumpkin. When you remove the pumpkin from the microwave, you notice that the temperature is only 50 °C. Take the pumpkin and the microwave as your system. Your house transferred energy at a rate of 1600 W of power to the microwave. The microwave (and the air in it) did not change temperature. Calculate the amount of energy lost to the surroundings during the cooking time found in the previous question.

The expected energy input from the microwave is 6.776×10^5 J, but the actual value is

$$\begin{aligned} Q = m_p C_p \Delta T &= (2200g)(3.85 J/K/g)(50°C - (-10°C)) \\ &= 5.082 \times 10^5 J \end{aligned}$$

All or nothing

$$\Rightarrow \boxed{Q_{lost} = 1.694 \times 10^5 J}$$

(-1 Clerical)

C. [10 pts] Using your results from the previous questions, calculate how long you need to microwave your pumpkin to reach a final temperature of 70 °C starting from −10 °C. You can assume that the energy loss to the surroundings you previously determined happens at a constant rate.

$$P_{actual} = \frac{5.082 \times 10^5 \text{ J}}{423.5 \text{ sec}} = 1200 \text{ W}$$

−1 Clerical
−2 Minor
−4 Major
−8 Minimal progress

At this new rate, it takes

$$\Delta t = \frac{Q}{P_{actual}} = \frac{6.776 \times 10^5 \text{ J}}{1200 \text{ W}}$$

$$= \boxed{565 \text{ sec}}$$

D. [5 pts] As your pumpkin is cooking your microwave clock malfunctions and adds an unknown amount of extra time to the microwave. When you take the pumpkin out, you notice that is steaming furiously and measure the temperature to be 90 °C. You take some whipped cream from the refrigerator to help cool the pumpkin down. Whipped cream comes out of the fridge at 10 °C and has a heat capacity of 3.35 $J/K/g$. How many grams of whipped cream should you add to the pumpkin so that the final equilibrium temperature of the pumpkin and whipped cream are a comfortable 60 °C? You can assume the pumpkin and whipped cream are an isolated system.

$$Q_p = m_p c_p (\Delta T_p) = -Q_w = -m_w c_w (\Delta T_w)$$

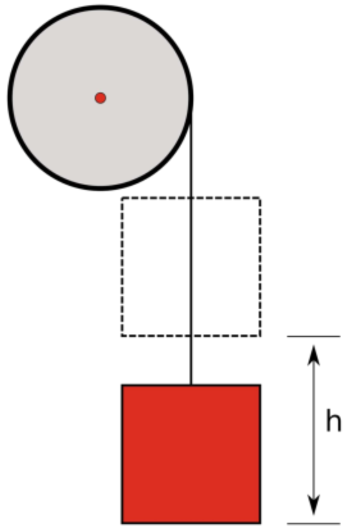
$$\Rightarrow \quad m_w = m_p \frac{c_p \Delta T_p}{c_w \Delta T_w} = -(2.2 \text{ kg}) \frac{(3.85 \text{ J/K/g})(60°\text{C} - 90°\text{C})}{(3.35 \text{ J/K/g})(60°\text{C} - 10°\text{C})}$$

$$\Rightarrow \boxed{m_w = 1.52 \text{ kg}}$$

All or nothing (−1 Clerical)

Problem 2 [25 pts]

A solid wheel of mass m and radius r is attached to an axle and wrapped with rope, from which is hung a block of equal mass (m). The mass of the rope is negligible.



A. [5 pts] At the start of an experiment, the wheel is spinning and the block is falling down with speed v_1. What is the total kinetic energy of the system (consisting of the wheel and the block).

$$\omega = \frac{v}{r}$$

$$K_{total} = K_{trans,block} + K_{rot,wheel} \Big\} + 3 \text{ pts correct energy terms}$$

$$= \frac{1}{2}mv_1^2 + \frac{1}{2}\left(\frac{1}{2}mr^2\right)\frac{v_1^2}{r^2} = \boxed{\frac{3}{4}mv_1^2} \Big\} + 2 \text{ pts for correct final form.}$$

B. [5 pts] After some time, the block drops a distance h. What is the total kinetic energy of the system now?

$$\Delta K = -\Delta U \Rightarrow K_f = K_i + mgh$$

$$\Rightarrow \boxed{K_f = \frac{3}{4}mv_1^2 + mgh}$$

All or nothing

C. [10 pts] What is the angular speed of the wheel after the block has dropped?

From (B), $K_f = \frac{3}{4}mv_1^2 + mgh$. Also,

$$K_f = \frac{1}{2}mv_2^2 + \frac{1}{4}mv_2^2 = \frac{3}{4}m\omega_2^2 r^2$$

$$\Rightarrow \frac{3}{4}\cancel{m}\omega_2^2 r^2 = \frac{3}{4}\cancel{m}v_1^2 + \cancel{m}gh$$

$$\Rightarrow \omega_2^2 = \left(v_1^2 + \frac{4}{3}gh\right)r^2$$

$$\Rightarrow \boxed{\omega_2 = \frac{\sqrt{v_1^2 + \frac{4}{3}gh}}{r}}$$

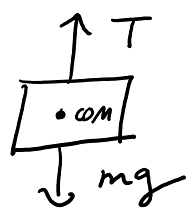
-1 Clerical

-2 Minor

-4 Major

-8 Minimal progress

D. [5 pts] What is the tension in the rope?



Taking the block as the C.O.M. system,

$$\Delta K_{total} = \Delta K_{trans} = (T - mg)(-h).$$ } 3 pts energy principle

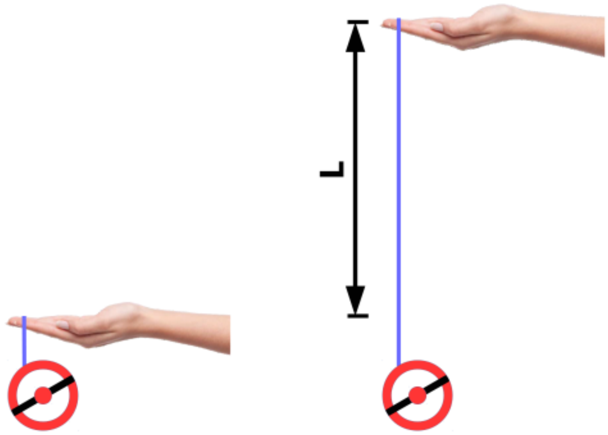
$$\text{Also, } \Delta K_{trans} = \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2 = \frac{1}{2}m\Big(\underbrace{v_1^2 + \frac{4}{3}gh}_{v_2^2 = \omega_2^2 r^2} - v_1^2\Big)$$ } 1 pt for finding v_2 properly

$$\Rightarrow \frac{2}{3}mg\cancel{h} = mg\cancel{h} - T\cancel{h}$$

$$\Rightarrow \boxed{T = \frac{1}{3}mg}$$ } 1 pt for final result

Problem 3 [25 pts]

A physics student is playing with a yo-yo of radius R. The yo-yo is initially held motionless in midair when the student releases the yo-yo and pulls up on the string with a constant unknown force F. Their hand moves up as a length of string L unravels and the yo-yo remains motionless under the force of gravity. The yo-yo has mass m, and the mass of the string can be ignored.



A. [5 pts] Determine the magnitude of the force by the hand F in terms of the known quantities.

$F_{net} = 0$ since the c.o.m. of the yo-yo is motionless

$\Rightarrow \quad F = -F_{grav} = \boxed{mg.}$

All or nothing

B. [20 pts] Calculate the rotational speed ω for the yo-yo after the hand has moved a distance L. You can model the yo-yo as a cylinder of radius R.

$$I_{yoyo} = \frac{1}{2}mR^2$$

$$\Delta E_{sys} = \cancel{\Delta K_{trans}}^{0} + \Delta K_{rot} = K_{rot,f} = \frac{1}{2}\left(\frac{1}{2}mR^2\right)\omega^2.$$

$$W_{ext} = mgL$$

-1 Clerical

-4 Minor

-8 Major

-16 Minimal progress

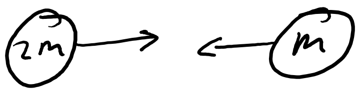
$$\Rightarrow \frac{1}{4}\cancel{m}R^2\omega^2 = \cancel{m}gL$$

$$\Rightarrow \boxed{\omega = \frac{\sqrt{4gL}}{R}}$$

Problem 4 [25 pts]

Two pucks are sliding towards each other along the x-axis on a nearly frictionless surface. The pucks have masses $2m$ and m and equal and opposite momenta given by $\langle p_0, 0, 0\rangle$ and $\langle -p_0, 0, 0\rangle$, respectively.

A. [5 pts] If the pucks collide and stick to each other, what is the velocity vector of the pair after the collision?



$\vec{P}_i = \langle p_0, 0, 0\rangle + \langle -p_0, 0, 0\rangle = \langle 0, 0, 0\rangle.$

Assuming conservation of momentum,

$$\boxed{\vec{P}_f = \langle 0, 0, 0\rangle}$$

All or nothing

B. [5 pts] If the pucks bounce off each other, so that the heavier puck has velocity $\langle v_1, 0, -v_1\rangle$ after the collision, what is the velocity vector of the lighter puck after the collision?

Before the collision, $\vec{P}_i = \langle 0, 0, 0\rangle$.

After the collision $\vec{P}_f = \langle 0, 0, 0\rangle = \vec{P}_{heavy} + \vec{P}_{light}$

$\vec{P}_{light} = -\vec{P}_{heavy} = -2m\langle v_1, 0, -v_1\rangle$

$\Rightarrow \vec{v}_{light} = \dfrac{\vec{P}_{light}}{m} = \boxed{2\langle -v_1, 0, v_1\rangle}$

All or nothing

C. [15 pts] If the pucks undergo a perfectly elastic collision, and the lighter puck ends up going in the $+\hat{z}$ direction, what is the momentum of the heavy puck after the collision?

$\vec{p}_f = \vec{p}_i = \langle 0,0,0 \rangle$. Also, in an elastic collision energy is conserved, so $|\vec{p}_f| = p_o$ for each puck.

Therefore, $\vec{p}_{light,f} = \langle 0, 0, p_o \rangle$

$$\Rightarrow \boxed{\vec{p}_{heavy,f} = -\vec{p}_{light,f} = \langle 0,0,-p_o \rangle}$$

−1 clerical

−3 Minor

−6 Major

−12 Minimal progress