Name:______________________________ ID:______________________________

Physics 201

Final Exam

12/2022

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.

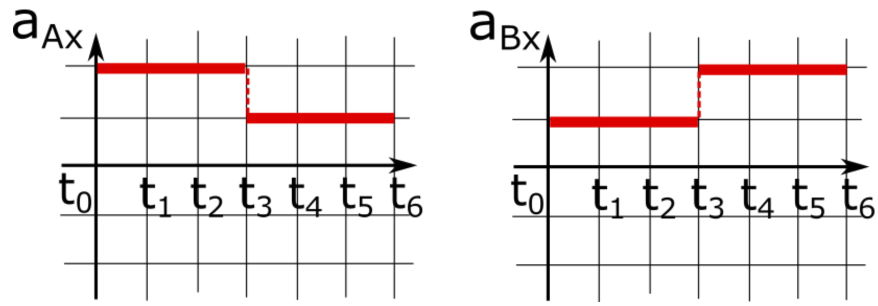
1. (8 points) Use sense-making throughout the exam. When you do, write it down in your solution and denote clearly which kind from the list below. Each instance is worth up to 2 points and you can only receive points once from each kind of sense-making. To receive credit you must put the question number in the appropriate box below of where you've used each one.

Question Number

- *Sign:* Check the **sign** of their quantities makes sense
- *Dimensionality:* Check the **dimensionality** and units of their quantities makes sense
- *Order of Magnitude:* Check the **order of magnitude** of their quantities makes sense
- *Graphical Analysis:* Use a **graph** to see if the behavior of your solution makes sense
- *Proportionality:* Check the behavior of a derived equation makes sense, e.g. **proportional reasoning**
- *Special Cases:* Check the behavior of a derived equation in limiting (**special**) cases makes sense, e.g. as x goes to 90 degrees in sin(x)
- *Self-consistency:* Check derived equations, functions, or values, are **self-consistent**, e.g. check that the slope of a derived position plot matches the values of the given velocity plot
- *Known Values:* Compare given or derived quantities with common well **known values**
- *Related Quantities:* Compare the relative magnitude of two **related quantities**

For questions 2 through 5 **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 **9** correct answers in this section and only the first **9** filled in answers will be graded. There is no partial credit.

2. The acceleration vs time for two velociraptors which both started at rest and are traveling along a straight line are shown below. Raptor **A**'s acceleration vs time plot is on the left, Raptor **B**'s acceleration vs time plot is on the right. Between times $\mathbf{t}_0$ and $\mathbf{t}_6$, which of the following statements *must be* true?

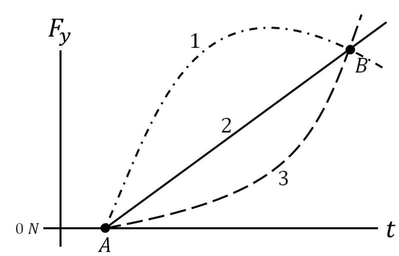


□ (a) $\Delta \mathbf{x_A} < \Delta \mathbf{x_B}$
X (b) $\Delta \mathbf{x_A} > \Delta \mathbf{x_B}$
□ (c) $\Delta \mathbf{x_A} = \Delta \mathbf{x_B}$
□ (d) $\Delta \mathbf{v_A} < \Delta \mathbf{v_B}$
□ (e) $\Delta \mathbf{v_A} > \Delta \mathbf{v_B}$
X (f) $\Delta \mathbf{v_A} = \Delta \mathbf{v_B}$

3. Considering the work-energy model, which of the following statements are true?

X (a) External work is a mechanism to transport energy into or out of a system.
X (b) Internal work is a mechanism to transform energy from one form to another within a system.
□ (c) If the external work is positive, the energy of the system remains the same.
□ (d) If the external work is positive, the energy of the system decreases.
X (e) If the external work is positive, the energy of the system increases.
□ (f) Work is a vector.
X (g) Work is a scalar.

4. Three identical rockets, initially at rest, labeled 1, 2, and 3 in the diagram, are in space far from any other objects. At the same instant, their thrusters turn on, providing a force to each of the rockets in the galactic y-direction. Which of the following statements *must be* true?

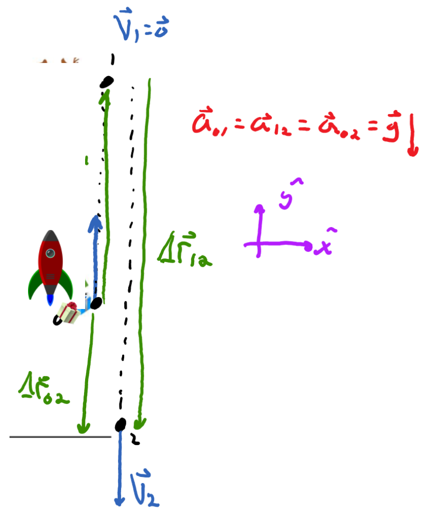


□ (a) Rocket 2 travels at a constant velocity between times A and B.
□ (b) Rocket 2 undergoes constant acceleration between times A and B.
□ (c) Rocket 1 is traveling in the negative y direction at time B.
□ (d) All three rockets have the same displacement during the motion.
X (e) Rocket 1 receives a larger impulse than rocket 3 between times A and B.
X (f) Rocket 1 has more work done on it between times A and B than rocket 3.
□ (g) The work being done on rocket 1 at time B is negative.

5. When a ball is thrown vertically up in the air the initial kinetic energy is converted into gravitational potential energy. If the initial speed is increased to a factor 3/2 times as large, by what factor will the maximum height change?

□ (a) 2/5
□ (b) 5/2
X (c) 9/4
□ (d) 6/4
□ (e) 25/4

6. (10 points) It's 2022, Santa doesn't want to use reindeer anymore, so he built a rocketship to help deliver presents. On a test flight Santa flew vertically upwards at a speed of 11.1 m/s. The moment when Santa reached 10.0 meters above the level ground while flying vertically upwards, a present is released from the rocket. *Ignore air resistance



(a) What is the maximum height above the level ground that the present will reach?

i → f: 0 → 1, y

K	UK
$V_{0y}=11.1\ m/s$	Δy_{01}
$V_{1y}=0$	Δt_{01}
$a_y=-9.8\ m/s^2$	

$$V_{fy}^2 = V_{iy}^2 + 2a_y\Delta y$$

$$0^2=(11.1)^2-2(9.8)\Delta y_{01}$$

$$\Delta y_{01} = 6.27\ m$$

TOTAL HEIGHT = 10 m + Δy_{01}

$$\boxed{\text{TOTAL HEIGHT} = 16.3\ m}$$

(b) What is the total time in the air from the moment the present was released from the rocket to the moment before it hits the level ground?

METHOD 1) 1 STAGE QUADRATIC

i → f: 0 → 2, y

K	UK
$\Delta y_{02}=-10\ m$	
$V_{0y}=11.1\ m/s$	V_{2y}
$a_y=-9.8\ m/s^2$	Δt_{02}

$$\Delta y = V_{iy}\Delta t + \tfrac{1}{2}a_y\Delta t^2$$

$$-10 = 11.1\,\Delta t_{02} - \tfrac{1}{2}(9.8)\Delta t_{02}^2$$

$$-4.9\,\Delta t_{02}^2 + 11.1\,\Delta t_{02} + 10 = 0$$

$$\boxed{\Delta t_{02} = 2.96\ sec}$$ OR $\cancel{-0.690\ SEC}$

METHOD 2) 2 STAGES

STAGE 1

i → f: 0 → 1

$$V_{fy}=V_{iy}+a_y\Delta t$$

$$0 = 11.1 - 9.8\,\Delta t_{01}$$

$$\Delta t_{01} = 1.133\ sec$$

STAGE 2

i → f: 1 → 2, y

K	UK
$\Delta y_{12}=-16.27\ m$	
$V_{1y}=0$	V_{2y}
$a_y=-9.8$	Δt_{12}

$$\Delta y = \cancel{V_{iy}\Delta t} + \tfrac{1}{2}a_y\Delta t^2$$

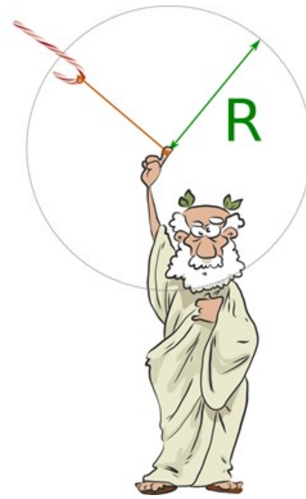
$$-16.27 = -\tfrac{1}{2}(9.8)\Delta t_{12}^2$$

$$\Delta t_{12} = 1.823\ sec$$

$$\Delta t_{02} = \Delta t_{01} + \Delta t_{12}$$

$$\boxed{\Delta t_{02} = 2.96\ sec}$$

~~ Rubric ~~
Part (a) - 5 points
1 pt - Setup: physical representation, known and unknowns
1 pt - Initial velocity of present is the same as Santa
2 pt - Kinematic equation (iii) application
0.5 pts - Total height is delta_y + y_i
0.5 pts - Final answer and units
Part (b) - 5 points
1 pt - Setup: physical representation, knowns and unknowns
1 pt - Final y position
2.5 pts - Kinematic equation (i) application
0.5 pts - Final answer and units



7. (10 points) A 15.0 g candy cane is tied to a 1-m-long string and swung in a vertical circle at constant speed. The candy cane will break if the tension in the string becomes greater then 26 N.
   (a) Where would you expect the candy cane to break first, at the top, bottom, right, or left of the vertical circle? Explain your reasoning.

w/ UCM $V = \text{const}$

so $a_r = \frac{V^2}{R} = \text{constant}$

Thus $\Sigma F_r = \text{const.}$

Then look @ FBD to left ...

F^T is largest @ $\boxed{\text{Bottom}}$ so expect to break there

(b) What is the minimum period (time for one complete revolution) that you can swing the candy cane around and it not break?

FBD @ Bottom

$$\Sigma F_r = m a_r$$

$$F^T - F^g = \frac{mV^2}{R} \qquad V = \frac{2\pi R}{T}$$

$$F^T - mg = \frac{mV^2}{R}$$

$$F^T - mg = \frac{m 4\pi^2 R^2}{T^2 R}$$

$$F^T - mg = \frac{4\pi^2 m R}{T^2}$$

$$T = \sqrt{\frac{4\pi^2 m R}{F^T - mg}}$$

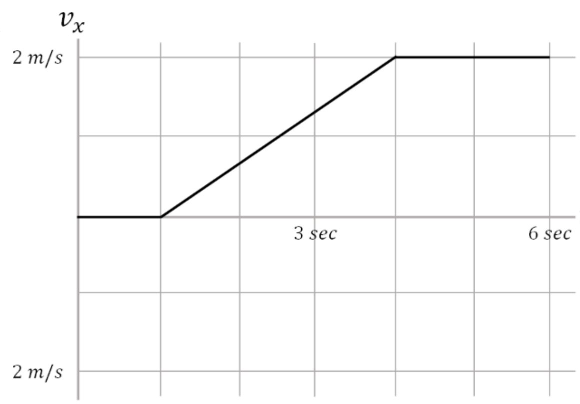
$$= \sqrt{\frac{4\pi^2 \left(\frac{15}{1000}\right)(1)}{26 - \left(\frac{15}{1000}\right)(9.8)}}$$

$$\boxed{T = 0.151 \text{ sec}}$$

~~ Rubric ~~
Part (a) - 3 points
- 2.5 pts - Reasoning
- 0.5 pts - Answer

Part (b) - 7 points
- 1 pt - FBD
- 2 pts - 2nd Law application
- 1 pt - a_r = v^2/R
- 1.5 pt - Speed = circ./T
- 1 pt - Solving for period
- 0.5 pts - Answer and units

8. (10 points) In a topically themed physics experiment, you measure the velocity of a soccer ball as it is sliding across grass for 6 seconds in the x-direction. The graph of this motion is shown here.



(a) The mass of the soccer ball is measured to be 0.45 kg. Fill in the plot of the net force vs time exerted on the soccer ball. Remember to specify the scale on the vertical axis!

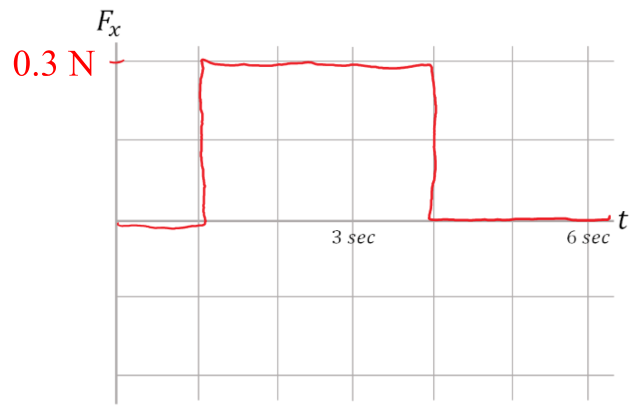
Acceleration is constant => F is constant between 1 and 4 seconds.

$$F_{max} = \frac{m\Delta v}{\Delta t} = \textbf{0.90 N·s / 3 s = 0.30 N}$$

Alternate Solution:

$$a = \frac{\Delta v}{\Delta t}$$

$$f = ma = m\frac{\Delta v}{\Delta t}$$



(b) What is the net impulse exerted on the soccer ball during this time?

Answer: Area under the F(t) curve or…

$$m\Delta v = J$$

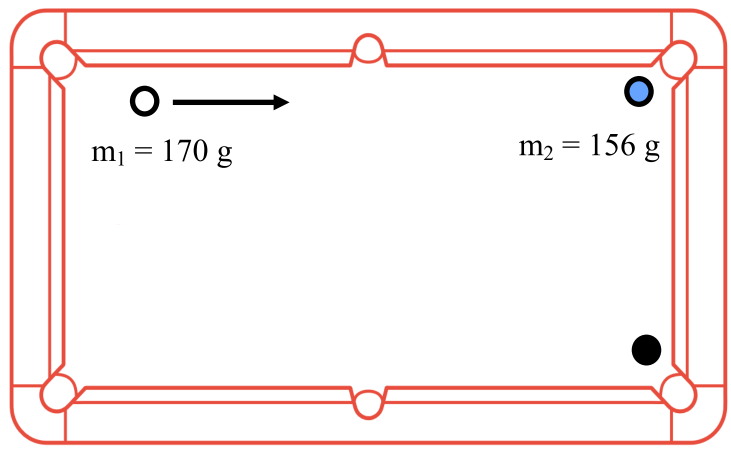
$$J = \textbf{0.90 N·s}$$

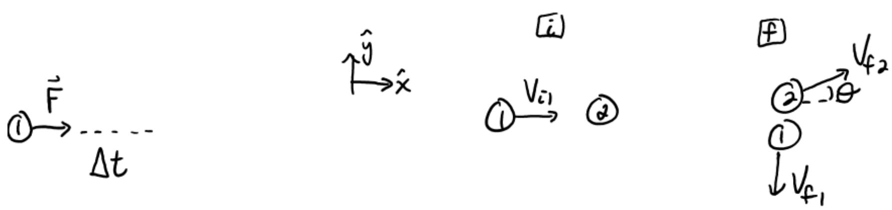
(c) How much net external work was done to the soccer ball during the 6 second interval?

$$W = \Delta KE = \frac{1}{2}m\left(v_f^2 - v_i^2\right) = \textbf{0.90 Joules}$$

~~ Rubric ~~
Part (a) - 4 points
 2 pts - How net force is determined
 2 pts - Answer with scaling on plot
Part (b) - 3 points
 2.5 pts - How impulse is determined
 0.5 pts - Answer with units
Part (c) - 3 points
 2.5 pts - How work is determined
 0.5 pts - Answer with units

9. (10 points) Obi-Wan Kenobi, a Jedi with mysterious powers, is playing billiards. He exerts a force on a cue ball of mass $\mathbf{m_1}$ = 170 g for 1.5 seconds, directly to the right as seen in the figure below. The cue ball then collides with ball two ($\mathbf{m_2}$ = 156 g), moving $\mathbf{m_2}$ at an angle of 40º up and to the right, into the top corner pocket. After the collision the cue ball is redirected straight vertically downward towards the last ball at a speed of 1.5 m/s. It hits the last ball perfectly into the pocket, winning the game. What was the average force Obi-Wan applied to the cue ball for the first 1.5 s? Ignore friction effects.





Stage 1 (Impulse)

$$\Sigma F_x \Delta t = \Delta P_x$$

$$\Sigma F_x \Delta t = m_1 V_{f_x} - m_1 \cancel{V_{ix}}^{\,0} \quad (i)$$

equal to V_{i1} for stage 2

Stage 2 (Collision)

w/ $\Sigma \vec{F}_{ext} \Delta t \approx 0$, $\Sigma \vec{P}_i = \Sigma \vec{P}_f$

$$\boxed{x} \quad m_1 V_{i1x} + m_2 \cancel{V_{i2x}}^{\,0} = m_1 \cancel{V_{f1x}}^{\,0} + m_2 V_{f2x}$$

$$m_1 |\vec{V}_{i1}| = m_2 |\vec{V}_{f2}| \cos\theta \quad (ii)$$

$$\boxed{y} \quad m_1 \cancel{V_{i1y}}^{\,0} + m_2 \cancel{V_{i2y}}^{\,0} = m_1 V_{f1y} + m_2 V_{f2y}$$

$$m_1 |\vec{V}_{f1}| = m_2 |\vec{V}_{f2}| \sin\theta \quad (iii)$$

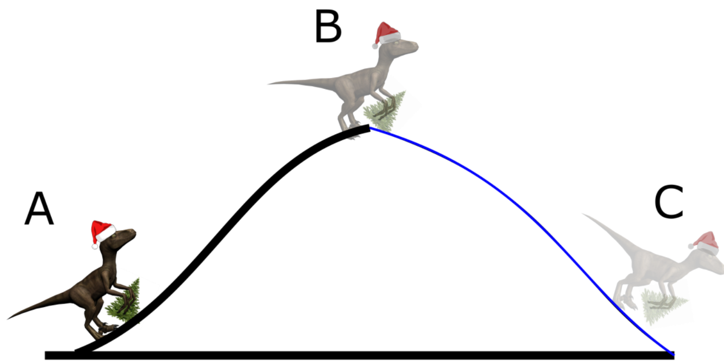
from (iii) $$|\vec{V}_{f2}| = \frac{m_1 |\vec{V}_{f1}|}{m_2 \sin\theta} = 2.543\ m/s$$

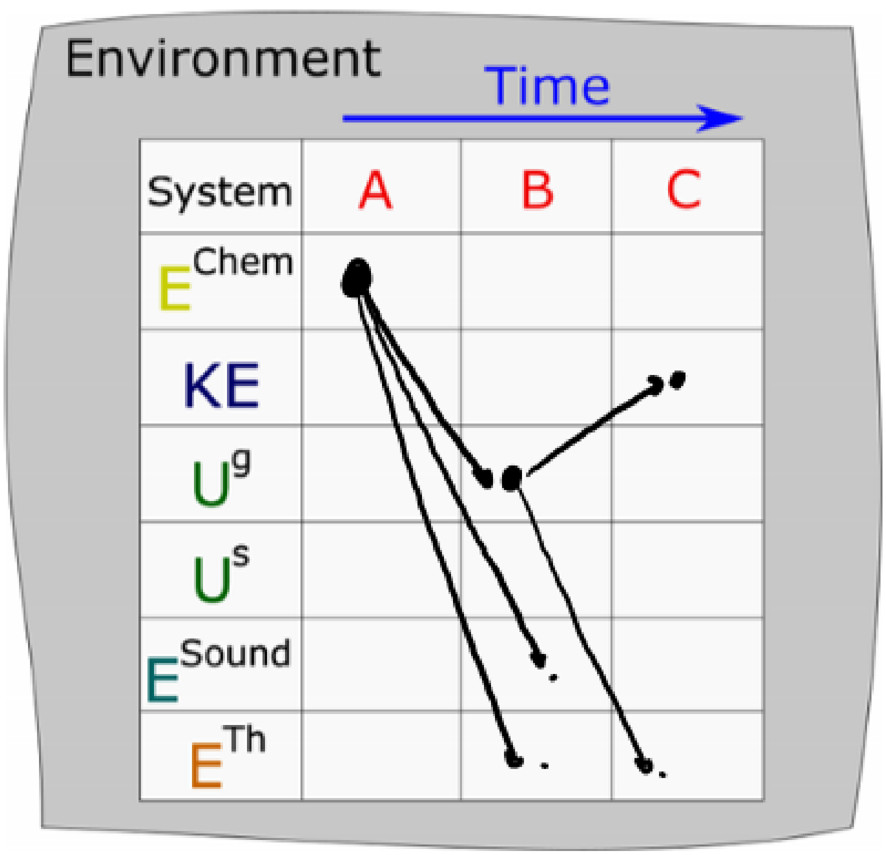
Combine (ii) + (iii) $$|\vec{V}_{i1}| = \frac{|\vec{V}_{f1}|}{\tan\theta} = 1.788\ m/s$$

Plug into (i) $$\Sigma F_x = \frac{m_1 |\vec{V}_{i1}|}{\Delta t} = \frac{m_1 |\vec{V}_{f1}|}{\Delta t \tan\theta} = 0.203\ N$$

Rubric
~~ Stage 1 ~~
1 pt - Identifying impulse (or forces and kinematics)
2 pts - Applying impulse to find stage 1 final velocity
~~ Stage 2 ~~
1 pt - Identifying conservation of momentum
1 pt - Final velocity of ball 2 components
2 pts - Application of COM in 2D
~~ combining ~~
1 pt - final velocity of stage 1 is initial velocity of stage 2
1.5 pt - combining stages algebra
0.5 pts - final answer with units

10. (4 points) A genetically modified velociraptor carrying a Christmas tree is traveling up a hill at a constant velocity from location **A** to location **B** as shown in the image below. When the raptor gets to location **B**, it stops using its muscles and slides down the frictionless right side of the hill increasing in speed from **B** to **C**. Use the provided energy flow diagram to show the energy transformations and transfers if the **system includes the velociraptor, the earth, atmosphere, and the hill**. Be sure that the arrows clearly start and stop in a specific box. 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.

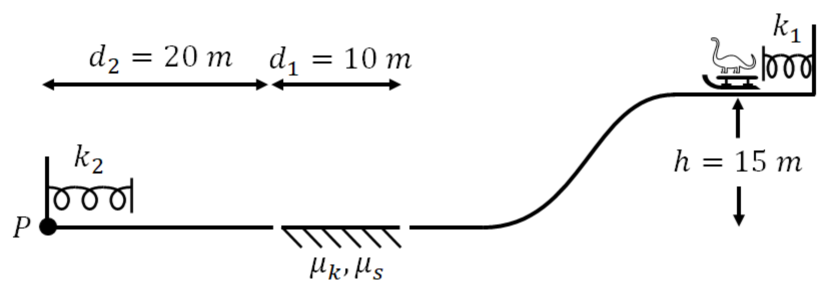




~~ Rubric ~~

1 pts - Energies at A
1.5 pts - Energies at B
1.5 pts - Energies at C

11. (10 points) A sled and a member of the OSU Dinos ultimate "frisbee" team are on top of a 15 -meter-high hill. Together the sled and Dino total 25 kg. They compress a spring of spring constant $\mathbf{k_1}$ = 20,000 N/m by 30 cm from equilibrium. The sled is then released and slides down the frictionless ice-covered hill, across a 10-meter-long patch of rough snow with $\mu_k = 0.20$, $\mu_s = 0.56$. Twenty meters after the rough patch is an ice wall at point P. Attached to the ice wall is a spring of spring constant $\mathbf{k_2}$ = 10,000 N/m. How many times will the sled and Dino pass across the rough patch of snow before coming permanently to rest?



System: m_1 + E + S_1 + surface

$y=0$ $\hat{y}\uparrow$

$$\cancel{KE_i}^0 + U^g_i + U^{S_1}_i + E^{Th}_i + \cancel{\Sigma W_{Ext}}^0 = \cancel{KE_f}^0 + \cancel{U^g_f}^0 + \cancel{U^{S_1}_f}^0 + E^{Th}_f$$

$$U^g_i + U^{S_1}_i = \Delta E^{Th}$$

# of times sled passes over rough patch

$$mgy_i + \tfrac{1}{2}k_1 x_{1i}^2 = -F^{fk} N \Delta r \cos\cancel{\phi}^{-1}$$

$$= \mu_k F^N N d_1$$

F^N, $\vec{F}^{fk}$?, F^g

$\uparrow \hat{y}$ $a_y = 0$

$\Sigma F_y = m\cancel{a_y}^0$

$F^N - F^g = 0$

$F^N = mg$

$$mgh + \tfrac{1}{2}k_1 x_{1i}^2 = N \mu_k m g d_1$$

N = 9.34 times
(9.337)

~~ Rubric ~~
1 pt - Identifying conservation of energy
4 pts - Application of COE
1 pts - Realizing friction takes KE and transfers to thermal energy
2 pts - Work from friction
1.5 pt - N*work from friction and need to solve for N
0.5 pts - Answer