CCNY PHYS 20300 - Spring 2025
Midterm Exam 2
April 9th, 2025

Name Solutions

Instructions:

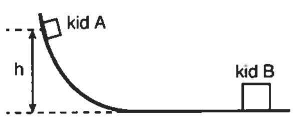
Short Answer problems: (3 pts/part) Show your work on the test for the short answer problems. You must show your work to get credit for the short answer problems. Each problem is worth the same amount. Include the SI units in your answers unless otherwise indicated. When doing the problems, the more steps you justify, the more likely you are to receive full credit, in other words, please show your work. Show *how you know*, not just *that you know*.

Multiple Choice: (2 pts each) Pick the best answer from the options available. You do not need to show any work for the multiple choice problems, however, you must fill in the circle for your final choice **or else no credit will be given.** Please do not lightly fill in several circles hoping that the vagueness of your selection can be used as a means of claiming points later (yes, people have done this). If your answers are not obviously indicated they may be marked incorrect.

Graphical Exercise: (3 pts per graph) Sketch plots that show the relations between quantities on the two axes. Make your lines clear: if it's supposed to be a linear dependence, make the line clearly straight. If it's supposed to be quadratic, or something else non-linear, make the curves obvious.

1. **Kid A and Kid B**

A kid slides down a frictionless slide starting from a height of h meters. At the bottom is another kid, who has twice the mass of the sliding kid. Kid A collides with Kid B, and they continue sliding stuck together.



a. What is the speed of both kids after the collision? (Express the speed v as an simplified equation in terms of the variables g and h only)

kid A falls a distance h

from cons. of Energy

$\frac{1}{2}m_A v^2 = m_A g h$ (Energy @ bottom = Energy @ top) => thus the speed of kid A at the bottom is

$\frac{1}{2}m_A v^2 = m_A g h$

$m_A v^2 = 2 m_A g h$

$v = \sqrt{2gh}$

then kid A collides with kid B!

from conservation of momentum:

$m_A v_i = (m_A + m_B) v_f$; but $v_i = \sqrt{2gh}$

so: $m_A\sqrt{2gh} = (m_A + m_B) v_f$; also $m_B = 2m_A$ (kid B is twice as massive)

$m_A\sqrt{2gh} = (m_A + 2m_A) v_f$ => solve for v_f

$v_f = \frac{1}{3}\sqrt{2gh} = \frac{\sqrt{2}}{3}\sqrt{gh}$

2. Fun with a Microwave

Inside most microwave ovens is a rotating platform (which normally ensures that all parts of the food are heated evenly). However, we can use it for a physics experiment!

a. If the platform goes around 15 times per minute at a constant rate, how many seconds does it take to go around once?

time to go around once $= \frac{60 \text{ seconds}}{15 \text{ times}} = 4$ seconds $=$ Period $= T$

b. If you put a ice cube at the edge of the platform, 20 cm from the center, what is the speed of the ice cube?

$r = 20$ cm $= 0.2$ m

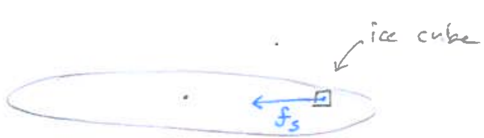
circumference $= 2\pi r$ → thus $v = \frac{2\pi r}{T} = \frac{2\pi(.2)}{4} \approx \frac{\pi}{10}$

$= 0.314$ m/s

c. What is the centripetal acceleration of the ice cube?

$a_c = \frac{v^2}{r} = 0.493 \text{ m/s}^2$

d. As the ice cube heats up, some of it melts, making the platform very slippery. If it gets too slippery, the ice cube will slide off the rotating platform. Determine the minimum coefficient of static friction that will keep the ice cube in place on the platform as it rotates 15 times per minute.



$f_s^{MAX} = \mu_s mg$

the largest force static friction can create

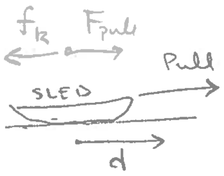
thus

$\mu_s mg \geq ma_c = m\frac{v^2}{r}$

$\therefore \mu_s \geq \frac{a_c}{g} = \frac{0.493 \text{ m/s}^2}{9.8 \text{ m/s}^2} = 0.050$

3. I get groceries with my sled in the winter sometimes. On the walk home, it has a mass of about 12 kilograms, (that's both the sled and the food). The kinetic friction between the cart and the ground is $\mu_k = 0.3$, and the static friction between the cart and the ground is $\mu_s = 0.4$.

a. How much work do I do against friction on my 2 kilometer walk home, assuming I pull the sled at a constant velocity, and the rope is at an angle parallel to the ground?



$\theta = 0$

$W = F \times d \times \cos(\theta)$

$= f_k \times d \times (1)$

$= \mu_k mg \times d \times 1$

$= 0.3 \times 12 \times 9.8 \times 2{,}000 = 70{,}560\ J$

$\Sigma F = -f_k + F_{pull} = 0$ (constant velocity)

$\therefore F_{pull} = f_k = \mu_k mg$

b. If the cart gets stuck and stops, how much force does it take for me to overcome friction and get it moving again?

$f_s^{MAX} = \mu_s mg$

$= .4 \times 12 \times 9.8$

$= 47\ N$

4. Goes Boom

A mass of 10 kg is moving to the right at 5 m/s. All of a sudden, it explodes into two pieces. Piece 1 continues to the right at 8 m/s while piece 2 is sent to the left at another velocity. If piece 1 is 5 times more massive than piece 2, what is the speed of piece 2 after the explosion?

conservation of momentum

before = after

$10\ kg \times 5\ m/s = m_1 \times 8\ m/s - m_2 V_{2f}\ m/s$ .... (1)

also $m_1 = 5 \times m_2$ & $m_1 + m_2 = 10$

$\therefore m_1 = 10 - m_2$

$= 10 - \frac{m_1}{5}$

$m_1 + \frac{m_1}{5} = 10$

$m_1\left(\frac{6}{5}\right) = 10$

$m_1 = \frac{50}{6} = 8.33$

$m_2 = \frac{10}{6} = 1.67$

$m_1 + m_2 = 10$ ✓

solve (1) for V_{2f} and use the two mass values:

$\vec{V}_{2f} = -10\ m/s$ or speed $= 10\ m/s$

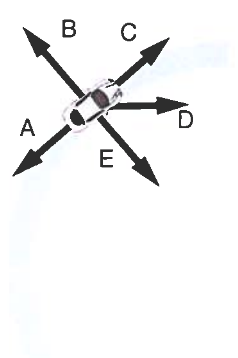
$10 \times 5 = m_1 8 + m_2 V$

$56 = \frac{56}{6} \times 8 + \frac{50}{6}\frac{1}{5} V$

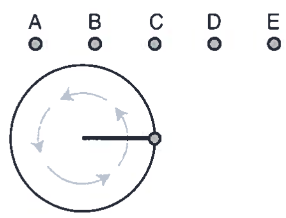
$1 - \frac{8}{6} = + \frac{1}{30} V$

$V = \frac{-2}{6} \times 30 = -\frac{1}{3} \times 30$

$V = -10$



5. A car drives at a constant speed around the curved path as shown. Which vector best describes the net force acting on the car? Answer F if there is zero net force on the car.



6. A ball is being swing around in a circle as shown, via a rope from the center of the circle. (you're looking down on this situation from above) If the rope breaks when the ball is exactly at the position shown, where among the 5 points listed will the ball most likely be after a short time?

7. A car drives over a hill that is basically shaped like part of a circle. It doesn't loose contact with the ground as it does so. At the moment when the car is at the top of the hill, how does the normal force acting on the car compare to its weight?

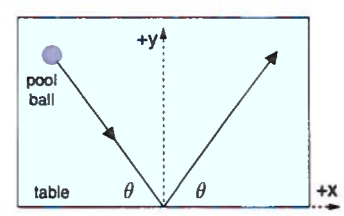
a. The normal force is greater than its weight.

b. The normal force is less than its weight.

c. The normal force is equal to its weight.

d. Can't say because it depends on the ratio between the mass of the car and the radius of the hill, which we don't know.

8. The pool ball below bounces elastically with the edge of the table as shown. In which direction is the $\Delta\vec{p}$ vector pointing?



a. +x

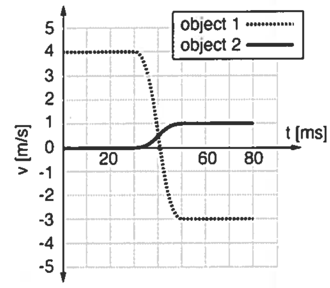
b. -x

c. +y

d. -y

e. an angle θ above the x axis

9. Shown is a graph of the velocities of a one dimensional collision between two objects. What can you imply from this graph?



a. This collision violates the conservation of momentum.

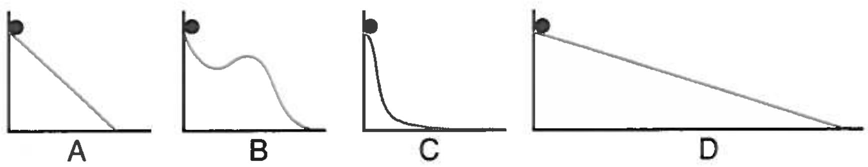
b. The masses of the two objects are nearly identical.

c. The masses of the two objects are different by about a factor of two.

d. The masses of the two objects are different by about a factor of five.

e. The masses of the two objects are different by about a factor of seven.

10. Four identical balls are let fall from the same height, but down four different ramps, shown below. Which ranking best describes the speeds of the balls when they reach the bottom?



a. $v_A > v_B > v_C > v_D$

b. $v_C > v_B > v_A > v_D$

c. $v_A = v_B = v_C = v_D$

d. $v_C = v_B > v_A = v_D$

11. Considering the same ramps as the previous question: which ball will take the longest amount of time to reach the bottom?

a. A

b. B

c. C

d. D

e. They will all take the same time

f. Can't say for sure without more information.

Multiple Choice Answers

Enter your answers in these boxes.

5. (A) (B) (C) (D) ● (F)
6. (A) (B) ● (D) (E)
7. (A) ● (C) (D)
8. (A) (B) ● (D) (E)
9. (A) (B) (C) (D) ●
10 (A) (B) ● (D)
11 (A) (B) (C) (D) (E) ●

12. Graphical Exercise

At time $t = 0$, a mass is launched with an initial vertical velocity straight up (i.e. no horizontal velocity) near the surface of the earth where we can assume the force of gravity is constant and there is negligible air resistance. Its position vs time graph is shown in the top right panel, and we see how it reaches the maximum height at time t_0. Complete the rest of the graphs: p momentum of the mass, PE its potential energy, KE its kinetic energy, and E its total mechanical energy. Make your graphs qualitative, but clear. I.e. if it's supposed to be a straight line, make it straight. If it's supposed to be a parabola, make it obviously a parabola.