CCNY PHYS 20300 - Spring 2025
Midterm Exam 1
Mar 10, 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. Report answers in SI units 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.

fill in like this: (A) (B) ● (D) (E)

not like this: (A) (B) (C) (D) (E)

$$a^2 + b^2 = c^2 \neq (a+b)^2$$

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

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

$$x = x_0 + v_0 t + \frac{1}{2} a t^2$$

$$v^2 = v_0^2 + 2a\Delta x$$

$$F_G = G\frac{m_1 m_2}{r^2}$$

Physical Constants	Value	Units
Mass of the Earth (M_E)	5.97×10^{24}	kg
Radius of the Earth (R_E)	6,353	km
Gravitational Constant (G)	6.67×10^{-11}	$m^3\ kg^{-1}\ s^{-2}$

1. Order of Magnitude

Make an estimate for how many heartbeats an average human will have in a lifetime.

$\sim 60\ \frac{\text{bpm}}{} \times \frac{60\ \text{m}}{1\ \text{hr}} \times \frac{24\ \text{hr}}{1\ \text{day}} \times \frac{365.25\ \text{day}}{1\ \text{year}} \times \frac{77.5\ \text{years}}{1\ \text{lifetime}} = 2.4 \times 10^9$ beats

2. Lost in a field

A rover delivering supplies begins its mission by traveling 4 km to the East of its starting position. It reaches the 4km point after 8 minutes and then it heads in the South West direction proceeding at the same speed for another 6 minutes. Then it stops to unload the supplies.

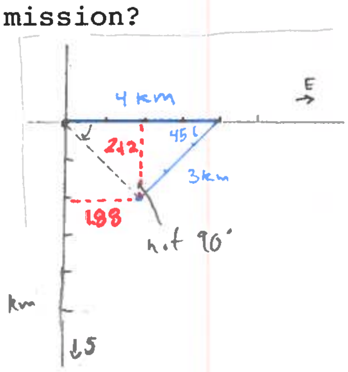
a. How many total kilometers did the rover travel during this mission?

$v = \frac{1}{2}\frac{\text{km}}{\text{min}}$

$a = 4\text{km}$

$b = 6\ \text{min} \times \frac{1}{2}\frac{\text{km}}{\text{min}} = 3\ \text{km}$

total distance $= 4\ \text{km} + 3\ \text{km} = 7\ \text{km}$



b. How far from the origin is it located after the mission?

$y = \sin(45°) \times 3 = 2.121$

$x = 4 - \cos(45°)3 = 1.879$

$2.121^2 = 4.499$

$1.879^2 = 3.53$

$\rightarrow 2.834$ km

c. What was the rover's average velocity during the entire trip? (include magnitude and direction)

$\frac{2.83\ \text{km}}{14\ \text{min}} = 0.202\ \frac{\text{km}}{\text{m}}$ at 48° South of East

$\left(\tan^{-1}\left(\frac{2.12}{1.88}\right) = 48.4°\right)$

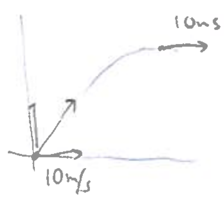
d. The rover is powered with a ketchup engine. It uses 2 kg of ketchup per kilometer. How much ketchup should it have in the tank to make this entire trip?

$2\frac{\text{kg}}{\text{km}} \times 7\text{km} = 14$ kg of ketchup

3. Launch Time

A particle is launched from the ground with a velocity that has an x component equal to 10 m/s and a y component that is unknown at launch time.

a. What will the speed of the particle be when it reaches its maximum height?



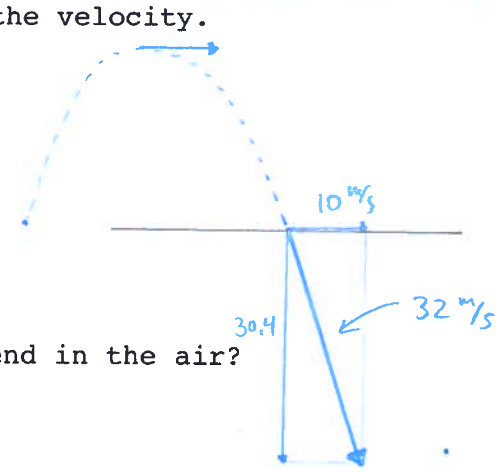
all velocity is horizontal, so

$V_{at\ h_{max}} = 10$ m/s

b. When it hits the ground, its speed is 32 m/s. Use this information to figure out the initial y component of the velocity.

$10^2 + v_y^2 = 32^2$

$v_y = \sqrt{32^2 - 10^2} \Rightarrow v_y = 30.38$ m/s



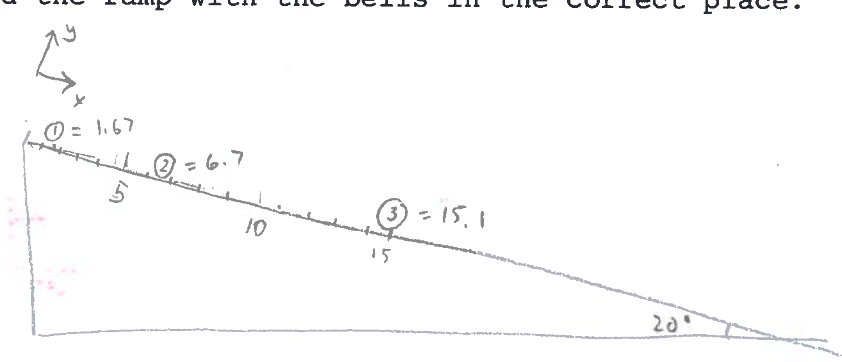
c. How much time did the projectile spend in the air?

$0 = 0 + v_o \cancel{t} - \frac{1}{2} 9.8\, t^{\cancel{2}}$

$\frac{2 v_{oy}}{9.8} = t = 6.2$ s

4. Ding ... Ding ... Ding...

A ramp is set up so that a ball can roll down it. The angle of the ramp (w.r.t the horizontal level) is 20 degrees. The ball is released at t = 0, and as the ball rolls down, it very gently hits three little bells that are carefully positioned along the path. Your job is to figure out where to put the three bells so that they ring exactly at t = 1 second, 2 seconds, and 3 seconds. The answer to this problem should be a drawing of the ramp with the location of the bells clearly indicated, so that someone could take your drawing and use it to actually build the ramp with the bells in the correct place.



how far after 1 seconds?

$x_1 = \frac{1}{2} 9.8 \sin(20)\, t^2$

$= \frac{1}{2}(3.35)(1^2)$

$= 1.676$ meters

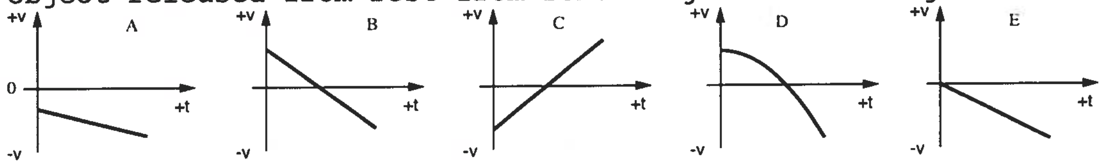
$x_2 = \frac{1}{2}(3.35)(2^2)$

$= 6.7$ meters

$x_3 = \frac{1}{2}(3.35)(3^2)$

$= 15.075$

5. Which of the four plots portrays the velocity as a function of time for an object released from rest from some height above the ground?



6. A bottle of soda is thrown straight up into the air at t = 0 s. When the bottle is at the highest point of its motion, its acceleration vector is

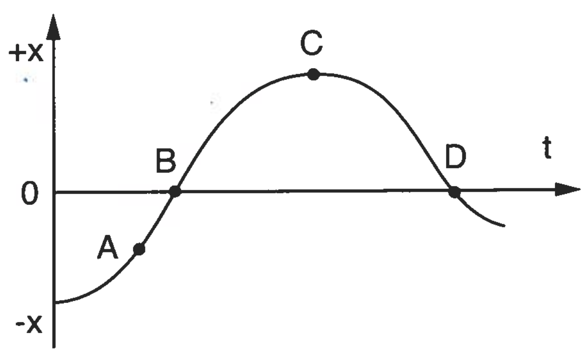
a. is directed downwards.

b. is directed upwards.

c. changes direction from upwards to downwards.

d. Is equal to the magnitude of the velocity vector at that instant, divided by the time.

e. is zero.



The following 2 questions relate to this position vs. time graph for an object in motion.

7. At what point(s) is the object at rest? (Answer E if never)

8. At which of the four times does the object have the largest negative velocity?

9. How far away from the surface of the earth should you go if you want the acceleration due to gravity to be about 1 m/s^2?

a. 1.4 km

b. 14 km

c. 140 km

d. 1,400 km

e. 14,000 km

10. You're in an elevator holding a sandwich in your outstretched palm - the elevator might be moving but it's hard to say. One of the forces present in this system is the force of gravity pulling down on the sandwich. Newton's third law requires another equal and opposite force to be present. This force is:

a. The force of gravity acting on your hand.

b. The force of the sandwich pulling up on the earth.

c. The force of the sandwich pushing down on your hand.

d. The force of your hand pushing up on the sandwich.

11. You are being pulled up towards the ceiling at a constant velocity, v_0, by a rope attached to your belt. Your belt breaks. Ruh-roh! Which of the following will be closest to your velocity immediately after the belt breaks?

a. $+v_0$

b. 0

c. $-v_0$

d. -9.8 m/s

Multiple Choice Answers

Enter your answers in these boxes.

5. A B C D E
6. A B C D E
7. A B C D E
8. A B C D E
9. A B C D E
10 A B C D E
11 A B C D E

12. Graphical Exercise

At time t_0, an small craft is released from rest from a height h. It begins to fall towards the earth. At time t_1, it turns on its engines to start slowing down. The rockets are programmed to apply a constant acceleration to the rocket opposite to gravity so that at t_2, it reaches the ground with almost 0 speed, preventing a nasty collision upon landing.
Sketch plots of the objects position, velocity, and acceleration values that would capture the essential features of this entire event, from t_0 to t_2 on the three coordinates below. Make sure all 3 graphs use the same time axes scaling as indicated by the ticks.