Physics 201, Lecture 8

Today’s Topics

Physics 201, Review 1

Important Notes:
- This review is not designed to be complete on its own. It is not meant to replace your own preparation efforts.
- Exercises used in this review do not form a test problem pool.
- I do not endorse any past exams.
- Please practice more with end of chapter problems.

Chapters Covered

- Chapter 1: Physics and Measurement.
- Chapter 2: Motion in 1-D
  - Sections 2.1-2.7
- Chapter 3: Vectors
  (will largely be tested indirectly via physics problems)
- Chapter 4: Motion in 2-D
  - All Sections

Super Friday Tomorrow
From 10am-5pm, the lab room will be staffed by TAs to answer questions. You are welcome to drop by at any time, regardless of your sections.

About Exam 1

When and where
- Monday Oct 2 5:30-7:00 pm
- Room allocation: Ag Hall 125

Format
- Closed book
- One 8x11 formula sheet allowed, must be self prepared.
  (Absolutely no sample problems, examples, class lectures, HW etc. And no photocopying)
- 20 multiple choice questions.
- Bring a calculator (but no computer). Only basic calculation functionality can be used (see my earlier email for details)
- A B2 pencil is required to do with Scantron

Special needs/ conflicts:
- Should have been settled by now (except for emergency).
- All alternative test sessions are in our lab room, only for approved requests.

Basic Concepts and Quantities

- Measurements
  - Units and Units Conversion
  - Significant figures
  - Scalar and Vector Quantities

Kinematics:
- General quantities: Displacement, Travel distance, Time interval, (average, instantaneous) Velocity/Speed/Acceleration.
- Circular motion specific: radius, circumference, Centripetal acceleration, period, angular velocity, linear velocity
- Kinematical equations
- Relative velocity.

End of chapter "Concepts and Principles" section is a good helper.
Basic Techniques

- Count number of sig. figures.
- Apply addition/subtraction, multiplication/division rules for sig. figures.
- Basic vector operations
- Read x-t, v-t, graphs (1D only).
- Use kinematical equation to convert among x, t, v, a.
- For uniform circular motion, relate \( a_c \) to v, r, \( \omega \).
- For uniform circular motion, calculate T from r and v.
- Decompose a vector quantity (v, a) into x, y projection. (For now, only 2D projection is required.)
- Calculate relative velocity when switching from one reference frame to another.
- Deal with applications such as:
  - Free Fall and Projectile (1D and 2D)
  - Flight time, maximum height, range...
  - Kinematics of Uniform Circular Motion.

A Trivial Conceptual Exercise: Number of Sig. Figures

- What is the number of sig. figures for: 0.0043500?
  A: 3
  B: 5
  C: 8
  D: none of above

Answer: 5. Sig. figures do not include leading zeros.

Reminder: Rules On Significant Figures

- Rule 1: In direct measurement, keep all "sure" digits but only one estimated digit. (estimated digit \( \leftrightarrow \) the least significant figure).
  e.g. 41.2 cm, 23.5 s, ...
- Rule 2: (Definition). Number of sig. figures = number of significant digits not counting leading zeros
  e.g. 41.2 \( \rightarrow \) N of sig. fig. = 3, 0.0032 \( \rightarrow \) N of sig. fig. = 2, 3.20 \( \rightarrow \) N of sig. fig. = 3.
- Rule 3: In additions or subtractions, the least significant figure of the final result can not be more accurate than that of any operands. e.g. 13.8m+2.05m-0.062m (=15.788m) = 15.8m
- Rule 4: In multiplication or division, the N of sig. figures of the final result equals the lowest num. of sig. figures among all operands.
  e.g. 13.8 m x 2.05 m x 0.062 m (=1.75398) = 1.8 m²

Exercise 1: Sig. Figure Rules

- A rectangular wood block is measured 3.20 cm, 75 mm, and 0.1431 m in height (h), width (w), and depth (d), respectively.
  With the sig. fig. rule, what is its side length (s=h+w+d) ?
  a. 2.501 x 10¹ cm
  b. 2.50 x 10¹ cm
  c. 2.5 x 10¹ cm
  d. 3 x 10¹ cm

Solution: see board. Please make sure that the values are converted to the same unit first.
Reminder: Kinematical Quantities to Describe a Motion

Basic Quantities
- **Displacement:** change of position from \( t_1 \to t_2 \)
- **Velocity:** rate of position change.
  - Average: \( \frac{\Delta x}{\Delta t} \)
  - Instantaneous: \( \frac{dx}{dt} \)
- **Acceleration:** rate of velocity change.
  - Average: \( \frac{\Delta v}{\Delta t} \)
  - Instantaneous: \( \frac{dv}{dt} \)

Exercise 2: Average Velocity

- An object moving uniformly around a circle of radius \( r \) has a period \( T \).
  - what is its average velocity over the period \( T \) ?
  - A: 0
  - B: \( 2\pi r/T \)
  - C: \( r/T \)
  - D: Not enough information as the mass of the object is not given.
  - E: None of above

- Average velocity is displacement divided by time interval. And displacement depends only on initial and final positions.
- Conceptual questions like this will make up about 1/3 of the exam.

Exercise 3: Acceleration and Speed

- A particle moving in 1-D has a negative constant acceleration, which of the following statement is true?
  - A: The particle’s velocity must be in negative direction.
  - B: The particle must be speeding up
  - C: The particle must be slowing down.
  - D: None of above is necessarily true.
- In physics, the acceleration is defined per “velocity” while in daily language, the term acceleration is defined per “speed”. Note the difference.

Reminder: Basic Kinematics

- Useful formulas for motion with constant acceleration:
  - \( a(t) = a_0 \)
  - \( v(t) = v_0 + a_0 t \)
  - \( v_{av} = \frac{v_0 + v}{2} \)
  - \( x(t) = x_0 + v_0 t + \frac{1}{2} a_0 t^2 \)
  - \( v(t)^2 = v_0^2 + 2a_0 (x-x_0) \)
- If two dimensional, \( x \) and \( y \) projections are independent of each other
- Free fall and projectile: \( a_x = 0, a_y = -g \) (if up = positive \( y \))
Exercise 4: Use Basic Kinematic Equations

A boat is traveling at 4.0 m/s as it passes the starting line of a race. If the boat accelerates at 1.0 m/s², the distance the boat has traveled after 6.0 seconds is:

- A. 42m
- B. 18m
- C. 26m
- D. 20m
- E. 14m

Questions on basic calculations like this one will make up another 1/3 of the exam.

\[
x(t) = x_0 + v_0 t + \frac{1}{2} a_0 t^2
\]

\[
x(6.0) = 0 + 4 \times 6.0 + \frac{1}{2} \times 1.0 \times 6.0^2 = 42 \text{ m}
\]

Review Exercise: Projectile Motion (Lecture 5)

A projectile is shot at an initial speed \(v_i\) at an angle \(\theta\). After which, it is in motion only under gravitational force. Find position at any time, air time, the range, maximum height.

Step 1: decompose \(v_i\) \(\rightarrow\) \((v_{ix}, v_{iy}) = (v_i \cos \theta, v_i \sin \theta), a_x = 0, a_y = -g\)

- Position at any time (Treat \(x\), and \(y\) separately):
  \[
x(t) = x_0 + v_{ix} t + \frac{1}{2} a_{ix} t^2
\]
  \[
y(t) = y_0 + v_{iy} t + \frac{1}{2} a_{iy} t^2
\]

- Air time (think vertically \(\Delta y = 0\)):
  \[
at t_A, \Delta y = 0 \rightarrow t_A = 2 v_{iy} / g = T_{air}
\]

- Range (Think horizontally):
  \[
  R = v_i \cos \theta, T_{air} = 2 v_i \sin \theta / g
  \]

- Maximum height (think vertically \(v_{iy} = 0\)):
  \[
at A: v_{iy} = 0 \rightarrow t_A = v_{iy} / g (= 1/2 t_A), h = y_A = v_{iy} t_A - \frac{1}{2} g t_A^2 = \frac{1}{2} v_{iy}^2 \sin^2 \theta / g
  \]
  (or use \(R^2 = v_{iy}^2 / 2g\))
Conceptual Exercise: Projectile

- Two balls have trajectories A and B, as shown below. (ignore air friction). Without further information, what can we say about the motions?

a. The launch speed of ball B must be greater than that of ball A.
b. The launch speed of ball A must be greater than that of ball B.
c. Ball A is in the air for a longer time than ball B.
d. Ball B is in the air for a longer time than ball A.
e. None of above can be concluded with given information.

Exercise 5: Projectile

- A projectile is projected on the ground with a velocity of 45.0 m/s at an angle of 60.0 degrees above the horizontal. On its way down, it lands on a rooftop of 4m high. What is the flight time?

  - A. 0.1 s
  - B. 7.9 s
  - C. 2.5 s
  - D. 15.0 s

Solution 1:

\[ v_y = v_0 \sin \theta = 39.0 \text{ m/s} \]

\[ y = y_0 + v_{y0} t - \frac{1}{2} g t^2 \]

Solving quadratic eq. gives \( t = 7.9 \) s

Solution 2:

\[ v_y(t) = v_{y0} - 2g(y - y_0) \]

\[ v_y(t) = -38 \text{ m/s} \]

\[ t = \frac{(v_y(t) - v_{y0})}{-g} = 7.9 \text{ s} \]

Exercise 6: Same Projectile

- A projectile is projected on the ground with a velocity of 45.0 m/s at an angle of 60.0 degrees above the horizontal. On its way down, it lands on a rooftop of 4m high. What is the horizontal distance between the launching and landing points?

  - A. 10 m
  - B. 40 m
  - C. 121 m
  - D. 178 m
  - E. 236 m

Solution:

\[ v_x = v_0 \cos \theta = 22.5 \text{ m/s} \]

\[ x = v_x t = 22.5 \times 7.9 = 178 \text{ m} \]

Additional possible questions: Maximum height? landing velocity? ...

Uniform Circular Motion: Useful Formulas

- \( \omega = \frac{2\pi}{T} \quad \text{(or } T = \frac{2\pi}{\omega} \text{)} \)
- Linear speed \( v = \omega r \)
- Centripetal Acceleration (\( a_c \))
  \[ a_c = r \omega^2 = \frac{v^2}{r} \]

Be familiar to the directional relationship of \( r, v, a_c \).
Exercise 7: Do not forget basic definitions

Figure below shows a particle in uniform circular motion. The radius of the circle is R=3.0m and the period of the motion is T=4.0s. The particle goes counter-clockwise, at time $t_A$, the particle passes point A, and at a later time $t_B = t_A + T/4$, it passes B.

- What is the magnitude of the particle’s average velocity between $t_A$ and $t_B$?
  - a. 4.7 m/s
  - b. 4.2 m/s
  - c. 3.5 m/s
  - d. 6.4 m/s
  - e. none of above is within 5% from the correct answer

Review: Relative Motion

- Conversion between reference frames (Galilean Transformation)

$\vec{v}_{\text{obj \_wrt \_FrameB}} = \vec{v}_{\text{obj \_wrt \_FrameA}} + \vec{v}_{\text{FrameA \_wrt \_FrameB}}$

One example

Same principle but a different configuration

Visualization example: A=bus, B=earth, o=water drops

Exercise 8: Relative Velocity

- If there is no wind, rain drops will fall to earth vertically down. To a passenger in a moving bus, which picture represents the correct vision of rain traces he observes? (Trivial)

- (not so trivial but still doable) If the bus speed is 16 m/s and the speed of rain drops is 9 m/s, to the passengers in the bus, what is the inclination angle the rain drops make with vertical line? (answer 60.6°. Practice after class)

Hint: use relative velocity relationship

Quick Quiz: Relatively Velocity

- Two stones, A and B, are released from rest at a certain height, one after the other. As they are falling down, will the difference in their velocities increase, decrease, stay the same?

Solution:

$\vec{v}_{A \_wrt \_B} = \vec{v}_{A \_wrt \_Earth} - \vec{v}_{B \_wrt \_Earth}$

$\Delta \vec{v}_{A \_wrt \_B} / \Delta t = \Delta \vec{v}_{A \_wrt \_Earth} / \Delta t - \Delta \vec{v}_{B \_wrt \_Earth} / \Delta t = g - g = 0$
Special Consulting Hours

- As announced, there will be a “super Friday” review session tomorrow in our lab room.
  TAs will be there to answer your questions from 10:00am to 5pm.

- In addition, there will still be regular office hours in our consulting room. Check course web for schedule.