STUDY GUIDE
Physics for Poets – Midterm 1
Tuesday, Oct. 7 – 2:30-3:45, SW 007
(vers.1) http://hep.physics.indiana.edu/~hgevans/c105/exams/m1_guide.pdf

MATERIAL COVERED
● Topics: Motion, Momentum, Force
● Problem Sets 1,2
● Format: 5 multi-part Questions
  - Multiple Choice ~10%
  - Short Answer ~60%
  - Physical Reasoning ~30%

● Questions will be based on material covered in:
  - Lectures
  - Problems Sets
  - Material not touched upon in the lectures or the homework will not appear on the exam, however, you will be expected to apply concepts you have learned to new problems.

● Content
  - Exam questions will be very similar to those given in the problem sets.
  - Questions about historical context will deal mainly with the development of concepts, rather than the sequence of events. Emphasis will be placed on:
    ▶ experiments and their interpretation
    ▶ ideas that changed the way physicists thought
  - Physical reasoning questions will ask you to apply the concepts you’ve learned in class to understand phenomena qualitatively
    ▶ for example, predicting the general shape of a cannonball’s trajectory in the presence of air resistance compared to that with no air resistance
    ▶ any calculations will involve only simple arithmetic

● The exam will be closed book and you will not be allowed to use notes.
  - I will supply a formula sheet with the exam (see end of this guide)
  - You do not need a calculator
GENERAL ADVICE

- Studying for the Exam
  - Do all the homework problems and understand the solutions.
  - Review your lecture notes – see more information on the Lectures web page.
  - Use the texts if you have difficulty understanding some aspect of the lectures or problems. Remember, exam questions will be based on the lectures and problem sets, not on the text.

- Exam-Taking Strategies
  - Before beginning the exam read over all the problems.
  - Before doing a problem read it carefully so you don’t miss anything.
  - Start with the easiest problem.
  - If you get stuck – don’t waste time. Go on to another problem.
  - Write legibly. If the grader can’t read your solution he/she can’t grade it.
  - Try not to be too verbose in the Short Answer questions. A few sentences should be sufficient.
  - Describe your logic in the Physical Reasoning problems. Never just state the answer
  - Draw detailed pictures - this can indicate to the grader that you understand the concept of the problem even if you don’t get the details right.

- Partial Credit
  - Partial credit will be given on the Short Answer and Reasoning questions, but not on the Multiple Choice section.
  - You are much more likely to get partial credit if your answer follows clear and logical steps.
    - Do not scribble down ideas/equations all over the page at random and expect the grader to guess at your thought processes.
    - Do draw diagrams whenever possible and label them clearly with relevant information such as forces, trajectories, etc.
KEY CONCEPTS

VECTORS AND GEOMETRY

- Understand the difference between a vector and a scalar (number)
  - Vector = magnitude and direction (at least two numbers)
  - Scalar = just a magnitude
- Understand the concept of independent directions
  - horizontal – vertical ; x – y ; NS – EW
- Understand conceptually (no calculations) how to break a vector up into its x,y components and how to find the magnitude and direction of the vector from these components
- Don’t worry about doing any calculations using more than 2 dimensions

MOTION

- Aristotle’s theory
  - Basic ideas
    - horizontal and vertical motion are different
      - vertical motion comes from objects seeking their natural place
      - horizontal motion is only possible if someone causes it
    - the heavens are a perfect place
      - therefore stars and planets move in perfect trajectories (circles)
  - Motivation
    - why things move, not how
  - Strengths and weaknesses (see Homework 1, Problem 1)
    - strength: a reasonably self-consistent answer to the question of why things move that was mainly consistent with observation
    - weakness: made very few real predictions
    - weakness: predicted that objects should fall with different speeds
- Conceptual differences between Galileo and Aristotle
  - Galileo asked “How?” ; Aristotle asked “Why?”
  - Aristotelian Reasoning: Assumption(s) → Logic → Consequences
    - assumptions largely unquestioned and therefore needed to be as “obvious” as possible
    - consequences applied to the world as it is observed, in its full complexity
    - physical predictions were less important than underlying “truths”
  - Galilean Reasoning: Assumption(s) → Mathematics → Predictions → Experiment
    - assumptions are to be tested through the agreement of their predictions with experiment
    - specific predictions were critical, but could apply to artificially designed experiments – rather than observations “as is”
    - simplifying assumptions can be made (e.g. “ignore the medium”) as long as predictions based on them are reasonably accurate
  - Falsifiability: this was a cornerstone of Galileo's ideas
    - if prediction disagrees with experiment then the theory (assumption) is wrong
    - no theory can truly be proved to be correct, theories are accepted if they
      - a) do not make incorrect predictions (at least in regime of interest)
      - b) are useful – explain things we didn't understand before
      - c) point the way toward a deeper understanding
• Galileo’s theory of motion
  – Why did Galileo study motion
    ▶ to show people that it was not unreasonable to think that the earth moved around the sun
  – Galileo’s Assertions about Motion
    ▶ Falling Motion:
      ▶ 1) All objects fall at the same speed in a medium devoid of resistance
      ▶ 2) In equal amounts of time a falling object will gain equal amounts of velocity.
        ○ this is equivalent to saying: acceleration near Earth is constant
    ▶ General Principles of Motion
    ▶ 3) Principle of Inertia
      ○ An object moving on a level surface will continue to move in the same direction at constant speed unless disturbed
    ▶ 4) Principle of Superposition
      ○ If an object is subjected to two separate influences, each producing a characteristic type of motion, it responds to each without modifying its response to the other.
        ○ motion in independent directions is independent

• Experiments Galileo did and Arguments that he used
  – 1) to address the common view that if the Earth is moving, we would get left behind when we jump into the air
    ▶ dropping a ball from the mast of a moving ship
  – 2) to show that it was sensible to consider motion independent of the medium
    ▶ dropping objects in liquids of varying density and in air
  – 3) experiments to quantitatively test the predictions of his assertions
    ▶ a) inclined plane: reduced acceleration compared to falling
    ▶ b) ski jump: eliminate time from prediction
    ▶ c) pendulum: reduced acceleration compared to falling
  – the main experimental difficulty in studying motion: measuring small times
    ▶ see Homework 1, Problem 3

• Strengths and Weaknesses of Galileo’s Theory
  ▶ strength: made fairly accurate (quantitative) predictions
  ▶ strength: provided a framework for future understanding
  ▶ weakness: approximation of neglecting the medium isn’t always very good

• Description of Motion
  – definitions of acceleration, velocity, position (see Formula Sheet)
    ▶ note that these are not assumptions, they are definitions
  – understand consequences of these definitions
    ▶ acceleration does not just mean speeding up or slowing down – can also result in changes in the direction of motion

• 1D and 2D (Ballistic) Motion under constant acceleration
  – motion in x and y directions is independent
    ▶ understand the components of the 1D equation of motion (see formula sheet)
  – be able to break up velocity into x and y components (conceptually – no math)
  – acceleration in ballistic motion
    ▶ g (downwards) in the vertical direction
    ▶ no acceleration in horizontal direction
  – velocity and acceleration at three critical points on ballistic trajectory
    ▶ see Homework 1, Problem 6

• Air Resistance
  – understand qualitatively how it modifies the no-air-resistance trajectories of 1D and 2D motion
    ▶ see Homework 1, Problem 8
MOMENTUM
- Why was the concept of momentum developed
  - trying to understand how motion was transferred between objects
  - collisions are the simplest example of this
  - system's momentum turned out to be conserved in collisions
    - understand the concept of a system as opposed to its parts
- Momentum Conservation
  - General concept of conservation laws
    - some quantity remains the same before and after an event that changes a system in other ways
  - \( P_{\text{system}}(\text{before}) = P_{\text{system}}(\text{after}) \)
    - remember that these are total momenta (the vector sum of the momenta of all the objects participating in the event)
    - only true if \( F_{\text{ext}}(\text{total}) \) acting on the system is 0
    - internal forces, acting between objects in the system, cancel when considering the system’s motion
- Collisions
  - Types of Collisions
    - 1) Elastic
      - momentum and kinetic energy (vis viva) conserved
    - 2) Inelastic
      - momentum conserved, but not kinetic energy
    - 3) Totally Inelastic
      - momentum conserved, objects stick together
  - Be able to give examples of various types of collisions/explosions

FORCES AND NEWTON’S LAWS
- Newton’s Laws
  - 1) Principle of Inertia
    - \( F = 0 \rightarrow a = 0 \rightarrow \Delta v = 0 \)
    - remember this doesn’t necessarily mean \( v=0 \), just that it’s constant
  - 2) Force produces Acceleration
    - \( F = ma \)
    - understand the difference between the cause (F) and the effect (a)
    - can also write this as: \( F_{\text{net}} = \frac{dp}{dt} \) (\( p = mv \))
  - 3) Action – Reaction
    - these are forces acting on different bodies
    - No specific experiments were discussed in relationship to these laws, but you should be able to give examples of them in action
- Kinds of Forces we will deal with
  - Gravity
    - \( F = mg \) near earth
  - Contact Forces
    - Normal Force perpendicular to contact plane
    - Friction parallel to contact plane
  - Air Resistance
    - \( F \) proportional to \( v^2 \)
    - don’t worry about understanding this in detail – just remember that it exists
    - if I want you to consider this, I will explicitly say so in the problem
- Friction
  - Difference between Static and Kinetic Friction
  - Static Friction
    - the magnitude of this force is just enough to keep things stationary
    - \( F_{\text{max}} = \mu_s N \) and \( a = 0 \)
    - direction of force depends on the situation
  - Kinetic Friction
    - \( F_k = \mu_k N \)
    - direction of force opposes motion
• Force Problems to Understand Conceptually
  − Objects with constant velocity ↔ sum of forces is zero
  − Objects falling near earth
  − Elevators and Weight
  − Objects moving on horizontal surfaces and inclined planes
    ▶ with and without friction
  − be able to draw free-body diagrams for these
  − understand the important principles they demonstrate

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**USEFUL FORMULAS**

**Geometry/Trigonometry**

- $v^2 = v_x^2 + v_y^2$
- $v_x = v \cos \theta$
- $v_y = v \sin \theta$
- $\tan \theta = v_y / v_x$

**Constants**

- $g = 9.8 \text{ m/s}^2$  
  acceleration of gravity near earth

**Motion Equations**

- $\langle a \rangle = \Delta v / \Delta t$
- $\langle v \rangle = \Delta x / \Delta t$
- $\Delta x = v_x \Delta t + \frac{1}{2} a \Delta t^2$  
  constant acceleration

**Force & Momentum**

- $p = m v$  
  definition of momentum
- $F_{ax} = m \ a = dp/dt$  
  Newton's 2nd Law
- $F_{fs} = \mu_s N$  
  Kinetic Friction
- $F_{fs\ max} = \mu_s N$  
  Static Friction