Physics 101 Course Notes #1

INTRODUCTION TO THE STUDY OF PHYSICS

Physics and its relevance

Central Goal: To discover basic knowledge enabling one to predict and explain many observable phenomena

-Generality

1) Highly successful in explaining and predicting phenomena
2) Essential knowledge for other pure and applied sciences
3) Some knowledge need for the appropriate use of many devices
4) Reasoning and problem solving methods
5) Philosophical and psychological interest
6) Physics -> Technologies -> Consequences

MECHANICS

-Science of Motion

Central Goal: Explain and predict how objects move, and how their motion is influenced by the presence of other objects

Importance

1) World is full of motions: we need to understand and predict for practical purposes

2) Basic Mechanics can be extended in increasingly sophisticated ways to encompass most of physics

a) Statistical Mechanics

b) Relativistic Mechanics

c) Quantum Mechanics

d) Understanding how the interactions between objects affect their motions

3) All matters consist of atomic particles. If we can understand motion and interaction of such particles, we can understand the properties of all forms of matter.

Learning Implications

Scientific Goal: To discover knowledge that can be used or explain the maximum number of observable phenomena on the basis of a minimum number of basic concepts and principles.

What needs to be learned?
-Memorize a large collection of facts and formulas, solutions of problems??

1) Learn a small number of concepts

2) Learn problem-solving methods

3) Learn not only to reason accurately, but also to explore effectively

Result: Ability to predict, explain new phenomena

We will emphasize
-Scientifically important reasoning methods
- New ways of thinking
- Active involvement: Experiments, solve physics problems, discuss with friends, raise and answer questions

Physics 101 Course Notes #2

Description of particle Motions

- How can we devise useful ways of describing **how objects move**?

Length, Time, and Units

Length:???

-Definition must be operational (it must specify what one must actually do to identify the concept)

Dictionary: "A measure of how long a thing is" ??

- Scientific definition is needed

Standards and Units

Standard: A standard for some quantity is a particular object with which all quantities can be compared

Unit: An algebraic symbol denoting the value of the quantity sepcified by a standard.

SI standards and units of length: (SI: Systeme International)

Old standard: A particular metal bar stored near Paris

New Standard: Distance traversed by light in vacuum during a time of 1/299, 792, 458 second. Permanent, more precise.

Unit: meter or m.

BASIC AND DERIVED UNITS

Basic Unit: Directly defined in terms of a standard (meter)

Secondary Units: Defined in terms of a basic unit (km, mm)

UNIT CONSISTENCY: Both sides of an equation must be exoressible in terms of the same basic units.

TIME

"Duration in which things are considered as happening in the past, present or future"

-Scientifically meaningless

Rough Definition: Property describing the relation between two events

Clock: A system which repeatedly returns to the same state

-Pendulum, conventional clock, earth rotation

SI Old Standard Clock: Earth rotating around itself

New standard: Atomic clocks

-Earth slows down about one second per year.

Inadequacy of the definition of time:

-Formation of the special theory of relativity

-Important for fast moving objects and precise measurements

PRECISION AND ERRORS

$Q \pm \varepsilon$ ε:probable error

L=(1.524 ± 0.002) m. $1.522 < L < 1.526$

SIGNIFICANT FIGURES

- Th elast digit is at least ±1

1.524   1.5240

-How about zeros? Use scientific notation

0.3×10^{2}m. =??   3.0x111 m. = ??

DISPLACEMENT AND VECTORS

Reference Frame: A chosen set of objects relative to which one specifies the positions of various points of interest

Coordinate System: A particular point (called origin) and a set of mutually perpendicular reference directions specidfied relative to some reference frame

Specification of position

a) distance from P to O (i.e. length)

b) direction of this line relative to some particular directions (i.e. θ)

Displacement: A quantity specifying jointly the length of a staright line and its direction relative to some reference frame

Position: The position of a point is specification of the displacement of this point from a particular point in a reference frame

VECTORS

Vector: A quantity specified jointly by a magnitude and a direction relative to the some reference frame

Arrow Representation: (arrow is not a vector, but represents a vector)

a) length of the arrow proportional to the magnitude

b) Direction of arrow is the same as of that a vector

Multiple of a vector

mA: magnitude = m|A| direction = same

Dvision of a vector by a number

Sum of vectors

Associate property

Distributive property

Vector Difference

Changes of position

r: position vector (the displacement from O)

Motion: Change of position. Relative to reference frame.

Physics 101 Course Notes #3

Velocity and Acceleration

Time variation of position

Velocity

-average velocity (between specified times)

-unit: meter/second

$$\mathbf{v}_{av} = \frac{\Delta\vec{\mathbf{r}}}{\Delta\vec{\mathbf{t}}}$$

Velocity at an instant

- very short time interval

$\Delta\vec{\mathbf{r}}$, $\Delta\mathbf{t}$ small $\frac{\Delta\vec{\mathbf{r}}}{\Delta\mathbf{t}} \rightarrow$ limiting value

$\Delta\vec{\mathbf{r}}$ approaches to the tangent of the particle's path at time t.

Infinitesimal quantity: A very small quantity. Small enough that some ratio or other specified quantity differs negligibly from its limiting value.

$\Delta\vec{\mathbf{r}}$, $\Delta\mathbf{t}$: differences

dt, d$\vec{\mathbf{r}}$: infinitesimals

velocity $\vec{\mathbf{v}} = \frac{\mathbf{d}\vec{\mathbf{r}}}{\mathbf{dt}}$

Definition: velocity is the rate of change of position with time

Defining Method

1) Original Position

2) New position

3) Displacement $\Delta\vec{\mathbf{r}}$ for $\Delta \mathbf{t}$ = t-t`

4) $\vec{\mathbf{v}}_{\mathbf{av}} = \dfrac{\Delta\vec{\mathbf{r}}}{\Delta \mathbf{t}}$

5) velocity $\vec{\mathbf{v}} = \dfrac{\mathbf{d}\vec{\mathbf{r}}}{\mathbf{dt}}$, determine the limiting value.

Properties

1) Velocity is a vector

2) Direction of velocity

3) Magnitude of velocity (speed) $v = \dfrac{|\mathbf{d}\vec{\mathbf{r}}|}{\mathbf{dt}} = \dfrac{\mathbf{dr}}{\mathbf{dt}}$

APPLICATIONS

Finding position from velocity: If we know velocity at all instants, then we can find the particle's displacement at all times.

ACCELERATION

average acceleration $\vec{\mathbf{a}}_{\mathbf{av}} = \dfrac{\Delta\vec{\mathbf{v}}}{\Delta \mathbf{t}}$

acceleration at an instant $\vec{\mathbf{a}} = \dfrac{\mathbf{d}\vec{\mathbf{v}}}{\mathbf{dt}}$

Defining Method

1) Original velocity $\vec{\mathbf{v}}$

2) New velocity $\vec{\mathbf{v}}\,'$

3) Find $\Delta\vec{\mathbf{v}}$

4) $\vec{\mathbf{a}}_{\mathbf{av}} = \dfrac{\Delta\vec{\mathbf{v}}}{\Delta \mathbf{t}}$

5) $\vec{\mathbf{a}} = \dfrac{d\vec{\mathbf{v}}}{dt}$ limiting value determination

Properties

-Vector

-Units: (m/s)/s or m/s^2

Applications

Finding velocity from acceleration

Motion Along a Straight Line

Component description of motion

-Particle moving along a straight line
-best coordinate system?
-velocity and acceleration parallel to $\hat{\imath}$

Component of a vector
A_i: component of a vector along the direction $\hat{\imath}$

Components of motion quantities

$\vec{\mathbf{r}} = r_x\,\hat{\imath}$ x: position coordinate
$\vec{\mathbf{v}} = v_x\,\hat{\imath}$
$\vec{\mathbf{a}} = a_x\,\hat{\imath}$

Alternate Descriptions of Linear Motion
TABLE: Specify x versus t

GRAPH: Plot numerical values in a graph x vs. t
- Not as precise but presents entire motion

EQUATION: relation between numerical quantities.

CHANGES AND RATES

Finite Change:
Infinitesimally small change:
Rate of Change:

General Relations

Simple Infinitesimal changes and rates

1) Q=c

2) Q = t
Q = ct

3) $Q = t^2$
$Q = ct^2$

Calculating Velocity and Acceleration

- Use position to find velocity and acceleration

Motion with constant velocity

Motion with constant acceleration

$t=0$ a_x = constant $v_x = v_{x0}$ $x = x_0$

- Relation between velocity and displacement: $D_x(v_x)$??

$v_x - v_{x0} = a_x t$
$D_x = v_{x0}t + a_x t^2/2$
$v_x^2 - v_{x0}^2 = 2a_x D_x$

Gravity near the surface of earth
- falling
- gravitational interaction

Observations and precise experiments have led to
" Any particle interacting with the earth, moves at any point with a downward acceleration independent of the nature of the particle"
-same acceleration
$\vec{g} \cong 9.80$ m/s^2 downward near sea level
-motion with constant acceleration so entire discussion is applicable

Physics 101 Course Notes #4

Problem Solving

What is a problem?

"A task which requires one to devise a sequence of actions leading from some initial situation to some specified goal"

What is a solution?

"A sequence of well-specified legitimate actions leading from the initial situation to the desired goal."

Legitimate actions

-they should involve logical steps on a few well-specified basic scientific relations
- velocity, acceleration and the relations between position, velocity and acceleration

Well specified actions

- Easily understood and checked by other people
- explanatory comments for actions

Central difficulties

1) Decision making: Which sequence to choose?
2) Initial problem analysis: Identify possible actions

Process for problem solving

Initial Analysis of a Problem

Basic Description

-Situation: known information, diagram and useful symbols

- Goals: Specify compactly the goals of the problem

Refined Description

-Time sequence and intervals: Specify time sequence of events (like a movie). Identify time intervals where the situation of distinctly different

-Physics Description: Describe Situation in terms of important physics concepts

Importance of adequate analysis: good enough such that, no need to refer back to the original problem

Analysis of a Problem

*Basic Description

-**Situation:** known information, diagram and useful symbols
- **Goals**

*Refined Description

-Time sequence and intervals:
-Physics Description: (velocity, acceleration etc.)

Example:

"A girl standing on the balcony of a building, throws a ball vertically upward. She observes that the ball reaches its maximum height 1.20 s after leaving her hand. (Air resistance can be assumed negligible)
a) With what speed did the ball leave the girl's hand?
b) How high above the balcony did the ball rise?
c) With what speed the ball hit the ground?
Analysis of the problem:

Construction of a solution

Decomposition into subproblems
-divide and conquer
-solve simple subproblems until the solution of original problem

Choice of subproblem
-Examine status of problem
- Identify available options
-Select useful subproblem among options

Main kinds of subproblems

Finding useful relations
-Apply a **basic relation** (from general physics knowledge)
-to some **object**
-at some **time** (or times)
-along some **direction**
-Only 3 relations: simple
e.g.: Apply rel(vel,t) to the ball 2.0 sec after it is thrown in the upward direction
Eliminate unwanted quantities: combine two relations

Comments: Explanatory
a) Comments about what particular direction is being applied to what object
b) Comments about what particular relations are being combined

Solution of the previous problem:

Checking a solution
1) Goals attained?
-All wanted info found?
2) Well-specified?
-Answers in terms of knowns?
-Units?
-Vector magnitudes and directions
3) Self-consistent?
- Units?
-signs or directions?
4) Other-consistent:
-sensible values?
-special cases?
-known dependence?
-other solutions?
5) Optimal?

-clear and simple?
- General

Check of the previous example

More suggestions

Lot of practice, not just homework

Good form:

a) Write legibly
b) Number all important equations for easy referral
c) Highlight important results and final answers by boxes

Use of symbols

Obtain an algebraic result and substitute number at the end
a) General solution, applicable to special cases
b) Important relationships and qualitative insights not apparent from specific numbers
c) Calculation facilitated, reduced chance for arithmetic mistake

-Identify unknown quantities

-Underline twice the wanted knowns

- underline once the unwanted unknowns

Physics 101 Course Notes #5

Curved motion with constant acceleration

Projectile motion

-constant acceleration (g)
- can be done by adding vector but cumbersome, we need a better method

Component Vectors

A can be expressed as sum of two vector parallel and perpendicular to the specified direction

Defining method

1) Parallel guideline, draw a parallel

2) Perpendicular guideline, draw perpendicular

3) Component vectors, draw

Numerical Components

A_i: numerical component of A along $\hat{\imath}$, number

Relations:

Component relative coordinate systems

Component Description of Projectile Motion

a = g constant downwards

-Horizontal component of velocity remains unchanged

- Vertical component does change like a 1-D motion with constant acceleration

Numerical Components

Separate into horizontal and vertical components
$a_x = 0$ $a_y = -g$
Horizontal motion:
Vertical motion:
-same as 1-D motion of a falling particle

Projectile Problems

Problem: A projectile is launched from the horizontal ground with a speed v0 at an angle θ. What's the range?

Circular and Relative Motions

Circular motion with constant speed

Direction

Magnitude

Period and Frequency

Period: Time required for one revolution

Frequency: Number of revolutions per unit time

Example:

Relations:

l

General Circular motion

-v may change with time

perpendicular component

-how rapidly the direction of v changes with time?

Parallel component

-How rapidly magnitude of velocity (speed) changes with time?

Applicability to any path

- any smooth curve can be approximated

-radius of curvature

Projectiles and Satellites

-avoid atmosphere (300 km)

-assume still g

Motion Relative to Different Frames

Velocities

Example:

“The water in a river flows east relative to the ground with a speed of 3 km/h. A boat travels relative to the river with a speed of 4 km/hr. What then the velocity of the boat relative to the ground for various conditions?

A) Boat velocity along water flow

B) Boas velocity opposite to water flow

C) Boat velocity perpendicular to water flow

GRAND SUMMARY ABOUT PARTICLE MOTION

Basic Descriptive Concepts
Position vector
Velocity
Acceleration

Special Motions
A) Straight-line motion (acceleration a_x = constant)
Rel (vel, t)
Rel (disp, t)
Rel (vel, disp)

B) Circular Motion (speed v, radius r)
Acceleration components
-along v
-perpendicular to v (to center)

Period
Frequency

Motions relative to different frames