Welcome to IIT Guwahati

PH101: PHYSICS-I

Lecture 1

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Topics

1. **Analytical (Classical) mechanics**

   (Up to **Mid-Sem Exam**; Of 50% marks)

Prof. P. Poulose
Prof. Girish Setlur

2. **Relativity**

3. **Quantum mechanics**

   (For End-Sem Exam; Of 50% marks)

Evaluations

Quiz-I of 10% marks on 27th August 2018 (*tentatively*)

Mid-Semester Exam of 40% (as per institute time table)

Quiz-II of 10 marks (Dates will be announced later)

End-Semester exam of 40% (as per institute time table)

Course Web Page:

http://www.iitg.ac.in/physics/fac/padmakumarp/Courses/PH101/JulyNov2018.htm

PHYSICS-I (PH101) July-Nov, 2018

Syllabus & Textbooks	Tutorial Groups	Tutors

Lectures	DIV-I/DIV-II (am)	DIV-III/DIV-IV (pm)
Tuesday	9-10 (am)	4-5 (pm)
Wednesday	10-11 (am)	3-4 (pm)
Thursday	11-12 (am)	2-3 (pm)
Tutorials	Monday: 8:00-8:55 (For All)	

Lecture Notes & Tutorial Assignments

Month	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
July 2018		24 Lecture#1	25 Lecture#2	26 Lecture#3	27	28	29
	30 Tutorial#1	31 Lecture#4					
August 2018			1 Lecture#	2 Lecture#	3	4	5
	6 Tutorial#2	7 Lecture#	8 Lecture#	9 Lecture#	10	11	12
	13 Tutorial#3	14	15 Holiday	16	17	18	19
	20 Tutorial#4	21	22 Holiday	23	24	25	26

Syllabus

PH101: Physics - I (2-1-0-6)

Calculus of variation: Fermat's principle, Principle of least action, Euler-Lagrange equations and its applications.

Lagrangian mechanics: Degrees of freedom, Constraints and constraint forces, Generalized coordinates, Lagrange's equations of motion, Generalized momentum, Ignorable coordinates, Symmetry and conservation laws, Lagrange multipliers and constraint forces.

Hamiltonian mechanics: Concept of phase space, Hamiltonian, Hamilton's equations of motion and applications.

Special Theory of Relativity: Postulates of STR. Galilean transformation. Lorentz transformation. Simultaneity. Length Contraction. Time dilation. Relativistic addition of velocities. Energy momentum relationships.

Quantum Mechanics: Two-slit experiment. De Broglie's hypothesis. Uncertainty Principle, wave function and wave packets, phase and group velocities. Schrödinger Equation. Probabilities and Normalization. Expectation values. Eigenvalues and eigenfunctions.

Applications in one dimension: Infinite potential well and energy quantization. Finite square well, potential steps and barriers - notion of tunnelling, Harmonic oscillator problem zero point energy, ground state wavefunction and the stationary states.

Books

Text Books:

1. **Introduction to Classical Mechanics by Takwale R and Puranik P** (McGraw Hill Education, 1 st Ed., 2077) **.**
2. **Classical mechanics by John Taylor** (University Science, 2005).
3. Quantum Physics of Atoms, Molecules, Solids, Nuclei and Particles by R. Eisbergand R, Resnick [f ohn-Wiley, 2nd Ed., 2006).

References:

1. A Student's Guide to Lagrangians and Hamiltonians by Patrick Hamill (Cambridge University Press, 1st edition, 2013).
2. Theoretical Mechanics by M. R. Spiegel (Tata McGraw Hill, 2008).
3. The Feynman Lectures on Physics, Vol. Iby R. P. Feynman, R. B. Leighton, and M.Sands, [Narosa Publishing House, 1998J.

Intro. Classical Mechanics, David Morin (Cambridge)

Layout of mechanics course

- Mathematical concepts of partial differentiation and coordinate systems.
- Constraints, degree's of freedom and generalized coordinates.
- Challenges with unknown nature of constrain forces in Newtonian Mechanics
- D'Alembert's Principle of virtual work to remove the constrain forces from analysis.
- Lagrange's equation: An alternative to Newton's law
- Variational method and Lagrange's equation from variational principle
- Hamiltonian equations of motion

Analytical mechanics

Introduction of new concepts of mechanics beyond Newton's law: Largangian and Hamiltonian equations

Why this is important?

- Making the analysis easier, in particular complex dynamical situations with imposed constrains/conditions.

- More general concepts extendable to other modern area of physics like quantum mechanics, field theory etc.

Review of certain mathematical concepts

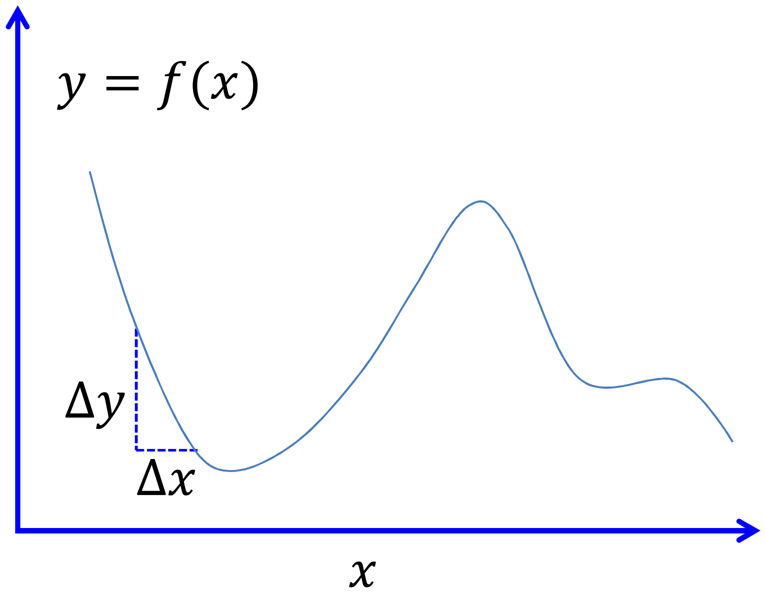
Key to understand classical mechanics

Total Differential: Function of one variable

$y = f(x)$ *is a function of one variable* x

$$f'(x) = \frac{dy}{dx} = \underset{\Delta x \to 0}{Lt} \frac{\Delta y}{\Delta x} = \underset{\Delta x \to 0}{Lt} \frac{f(x + \Delta x) - f(x)}{\Delta x}$$

$$dy = [f'(x)]\, dx$$



- Infinitesimal change of y around certain point (x) =(rate of change of y around the point) (magnitude of change in x)

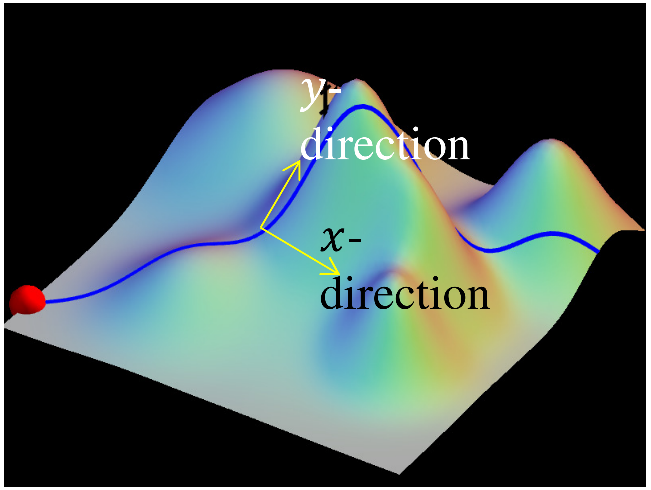
- At stationary points (A,B, C), y does not changes $[dy = 0]$ even if x is changed infinitesimally,

which implies that at those points $f'(x) = 0$.

Partial differential: function of more than one variables

$f(x, y)$ depends on two independent variables x and y.

Example: Height (f) of a hill as function of position coordinate (x, y).



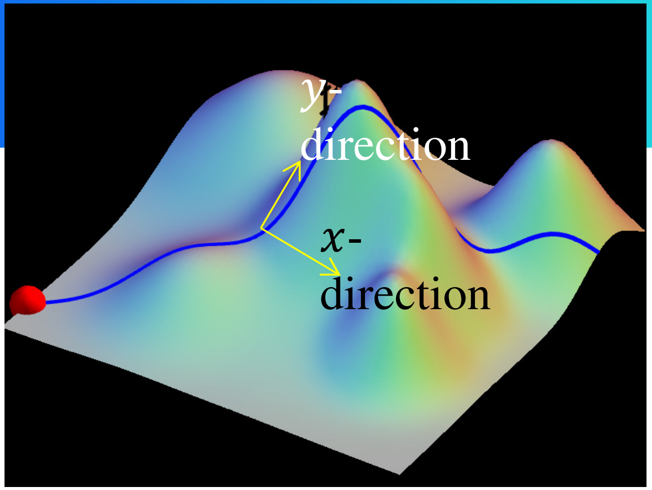
- The rate of change (slope) in the '$x'direction$, when y remains constant is denoted by

$$\left(\frac{\partial f}{\partial x}\right)_y = \underset{\Delta x \to 0}{Lt} \frac{f(x+\Delta x, y) - f(x, y)}{\Delta x}$$

- The rate of change in the '$y'direction$, when x remains constant is denoted by

$$\left(\frac{\partial f}{\partial y}\right)_x = \underset{\Delta y \to 0}{Lt} \frac{f(x, y+\Delta y) - f(x, y)}{\Delta y}$$

Partial differential



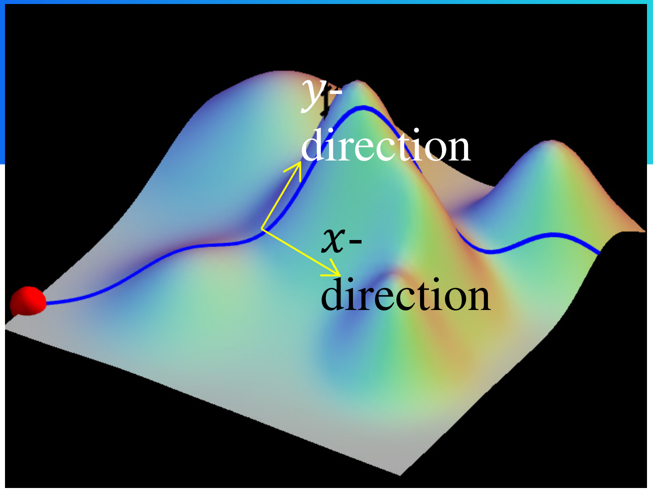
- **Change in height if I walk in the 'x' direction** [keeping 'y' fixed] **by 'dx'** ?

$$[df]_{dx} = \left(\frac{\partial f}{\partial x}\right) dx$$

$$= (rate\ of\ change\ in\ 'x'\ direction)(\ amount\ of\ change\ in\ x)$$

- Similarly, $[df]_{dy} = \left(\frac{\partial f}{\partial y}\right) dy$

Partial differential



Change in height if I go in the arbitrary direction so that 'x' changes by 'dx' and 'y' also changes by 'dy'

$$\boldsymbol{df = (\frac{\partial f}{\partial x})dx + (\frac{\partial f}{\partial y})dy} \qquad = [df]_{dx} + [df]_{dy}$$

- Generalization for a function which depends on several variables $f(x_1, x_2, x_3 \ldots . x_n)$

$$df = (\frac{\partial f}{\partial x_1})dx_1 + (\frac{\partial f}{\partial x_2})dx_2 + \ldots \ldots . + (\frac{\partial f}{\partial x_n})dx_n = \sum (\frac{\partial f}{\partial x_i})dx_i$$

Partial differential (Examples)

- $f(x,y) = a\,x^2 + b\,y^2$

$$\frac{\partial f}{\partial x} = 2\,a\,x \qquad \frac{\partial f}{\partial y} = 2\,b\,y$$

- $f(x,y) = a\,x^2 y + b$

$$\frac{\partial f}{\partial x} = 2\,a\,x\,y \qquad \frac{\partial f}{\partial y} = ax2$$

- $f(x,\theta) = a\,x\,\mathrm{Sin}(\theta) + b\,\theta^2$

$$\frac{\partial f}{\partial x} = a\,\mathrm{Sin}(\theta) \qquad \frac{\partial f}{\partial \theta} = a\,x\,\mathrm{Cos}(\theta) + 2b\,\theta$$

Differentiation of function of functions

$f(x, y)$ is such that x and y are function of another variable say, u.
We wish to find the derivative $\frac{df}{du}$.

Example: $f = xy + \ln y^2$

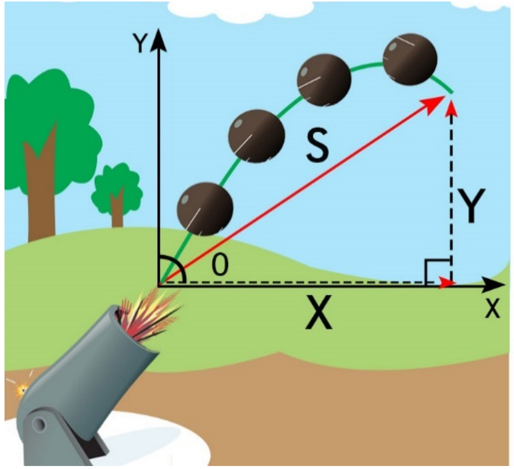
(we say, f depends x & y explicitly;
f depends u implicitly!)

Let, $x = a \cos u$ and $y = a \sin u$
How to calculate $\frac{df}{du}$?

Method 1: Direct substitution
Step 1: $f = (a \cos u)(a \sin u) + \ln(a \sin u)^2$
Step 2: Find $\frac{df}{du}$

Example

Distance of the Projectile from the origin,



$$S(x, y) = \sqrt{x^2 + y^2}$$

But

$$x(t) = u_0 \cos(\theta)\, t$$

&

$$y(t) = u_0 \mathrm{Sin}(\theta)\, t - \frac{1}{2} g\, t^2$$

Chain rule of partial differential

Method 2: Chain rule

You know, $df = (\frac{\partial f}{\partial x})dx + (\frac{\partial f}{\partial y})dy$

$$\frac{df}{du} = (\frac{\partial f}{\partial x})\frac{dx}{du} + (\frac{\partial f}{\partial y})\frac{dy}{du}$$

Find the First differentials individually

$$\frac{\partial f}{\partial x}, \quad \frac{\partial f}{\partial y}, \quad \frac{dx}{du}, \quad \frac{dy}{du}$$

and then substitute in the above relation.

Chain rule of partial differential

- Generalization for a function depends on several variables $f(x_1, x_2, x_3 \ldots. x_n)$ and the variables are function of another set of variables, Let, $x_i\ (u_1, u_2, \ldots. u_n)$

$$df = \left(\frac{\partial f}{\partial x_1}\right)dx_1 + \left(\frac{\partial f}{\partial x_2}\right)dx_2 + \ldots\ldots. + \left(\frac{\partial f}{\partial x_n}\right)dx_n = \sum_1^n \left(\frac{\partial f}{\partial x_i}\right)dx_i$$

$$\frac{\partial f}{\partial u_1} = \left(\frac{\partial f}{\partial x_1}\right)\frac{\partial x_1}{\partial u_1} + \left(\frac{\partial f}{\partial x_2}\right)\frac{\partial x_2}{\partial u_1} + \ldots\ldots. + \left(\frac{\partial f}{\partial x_n}\right)\frac{\partial x_n}{\partial u_1} = \sum_1^n \left(\frac{\partial f}{\partial x_i}\right)\frac{\partial x_i}{\partial u_1}$$

$$\frac{\partial f}{\partial u_j} = \sum_1^n \left(\frac{\partial f}{\partial x_i}\right)\frac{\partial x_i}{\partial u_j}$$

Questions?