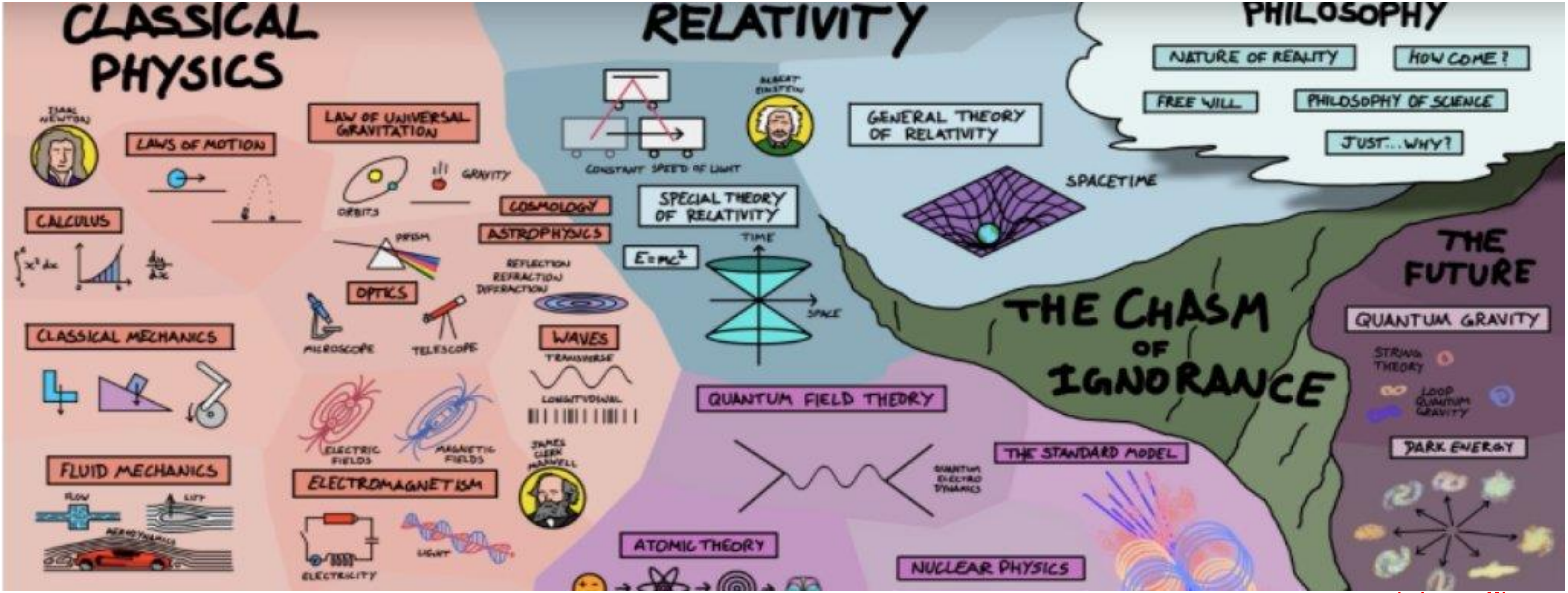

Image: Dominic Walliman

PH-103: Physics-I

Dr. Manas Kumar Sarangi

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Mon & Tue: 16:00-18:00
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Introduction

1. Co-ordinate System
2. Mathematical Formulation
3. Work-Energy Theorem
4. Rotation about fixed axis
5. Rigid body motion
6. Oscillation
7. Introductory Wave Theory
8. Failure of Classical Mechanics
9. Introductory Quantum Mechanics

Textbooks and Reference

Textbooks:

- D. Kleppner and R. J. Kolenkow, An introduction to Mechanics
- David Morin, Introduction to Classical Mechanics
- Eyvind H. Wichmann, Berkeley Physics Course Vol 4: Quantum physics

References:

- R. P. Feynman, R. B. Leighton and M. Sands, The Feynman Lecture in Physics, Vol I
- R. P. Feynman, R. B. Leighton and M. Sands, The Feynman Lecture in Physics, Vol III,
- R. Eisberg and R. Resnick, Quantum Physics of atoms, molecules, solids, nuclei and particles
- J. Dekker, Solid State Physics
- David J. Griffith, Introduction to Quantum Mechanics.
- B.H. Bransden & C.J. Joachain, Quantum Mechanics.

Evaluation

Total: 100

Mid Term: **30**

End Term: **40**

Quiz (2) + Tutorial: 20 + 10

Class Home Work Problem

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Dr Manas K Sarangi (mksarangi@iitp.ac.in)

Tutorial Instructor:

Dr. Jobin Jose
Dr. Raghavan K Eshwaran

Office Hours:
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Mon & Tue: 16:00-18:00

Choice of Co-ordinate systems

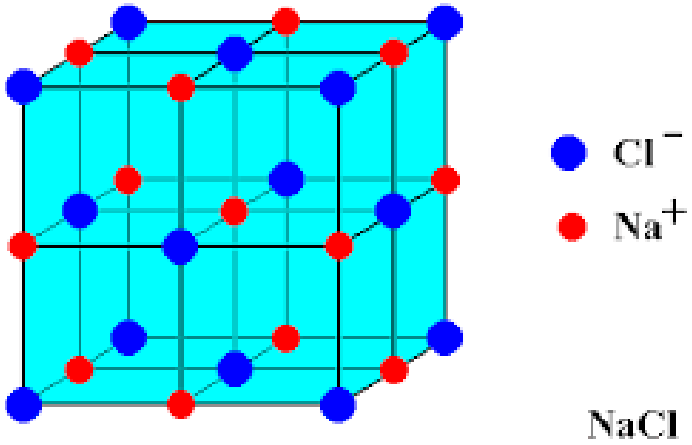
Cartesian Co-ordinates: Line, area and volume element

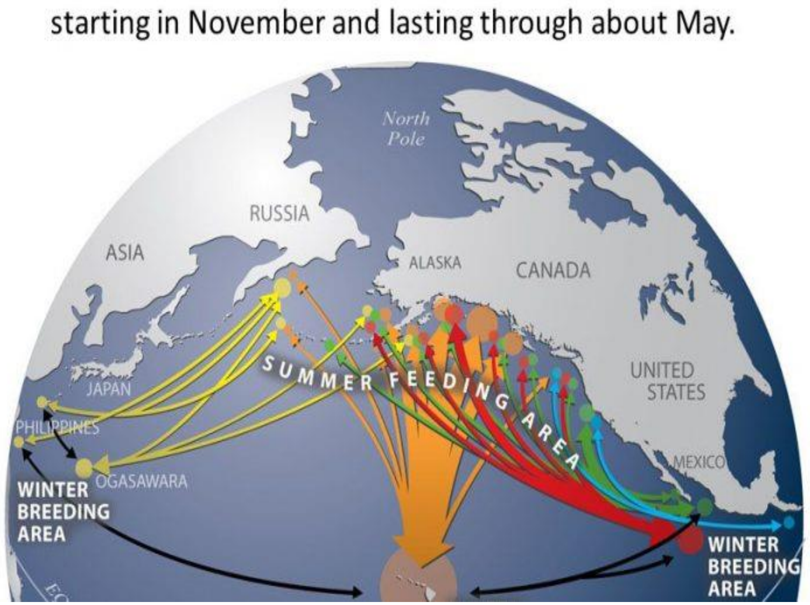
Plane-Polar Co-ordinates: Unit vectors, transformations, Rate of change, area element and volume element

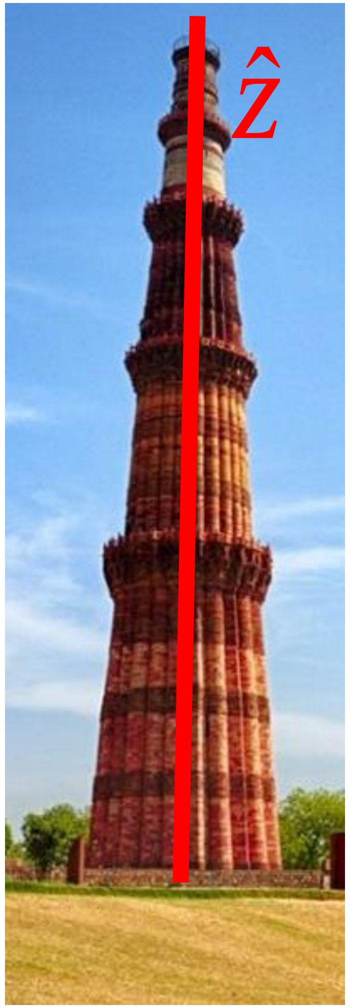
Cylindrical Co-ordinates: Unit vectors and its transformations, Rate of change, line, area and volume element

Spherical Polar Co-ordinates: Unit vectors and its transformations, Rate of change, line, area and volume element

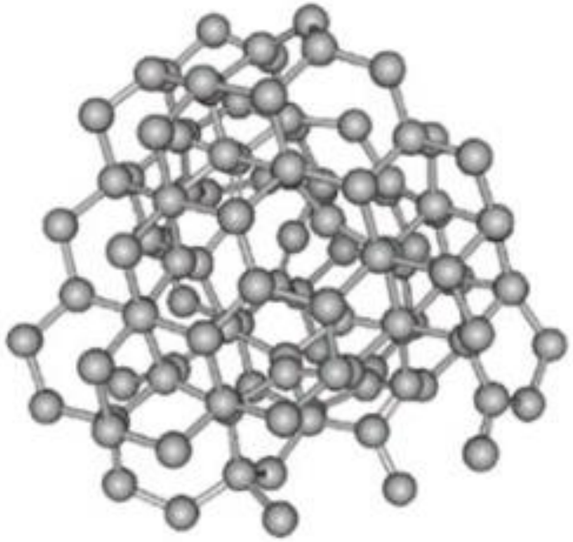
Why do we need different coordinate system?



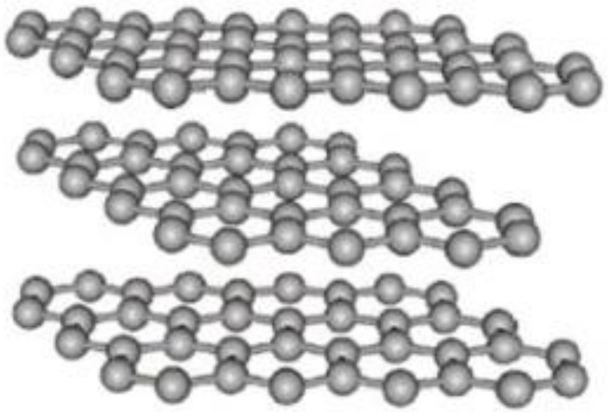




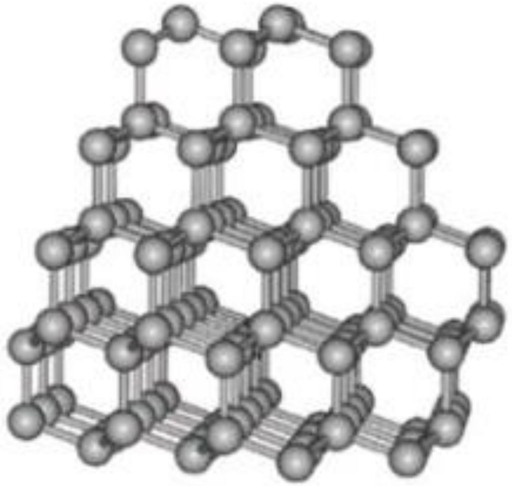
Why do we need different coordinate system?



Amorphous carbon

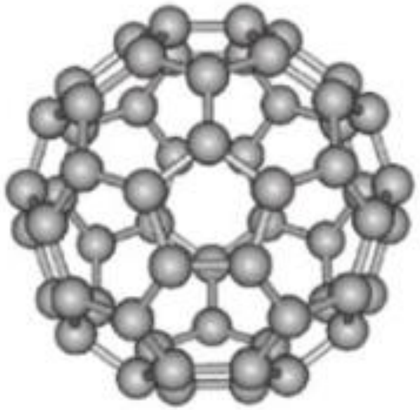


Graphite

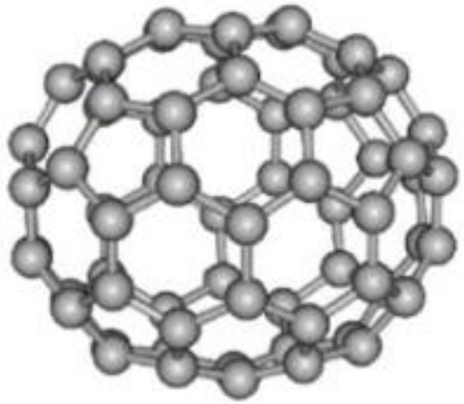


Nanodiamond

Carbon nanotubes



Buckyball C_{60}



Buckyball C_{70}

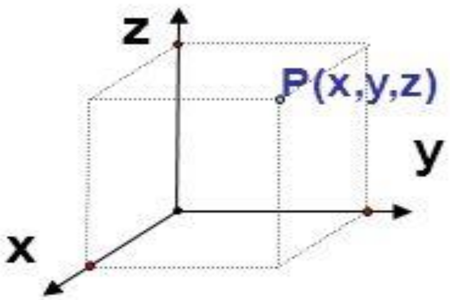
Orthogonal Coordinate Systems:

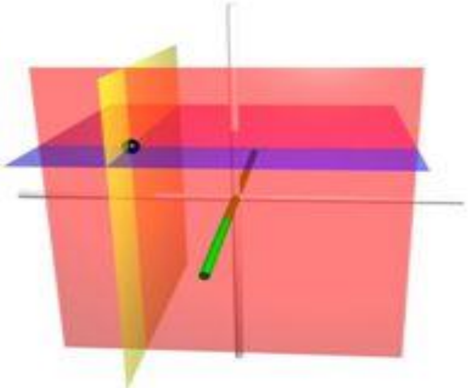
1. Cartesian Coordinates

Or

Rectangular Coordinates

P (x, y, z)

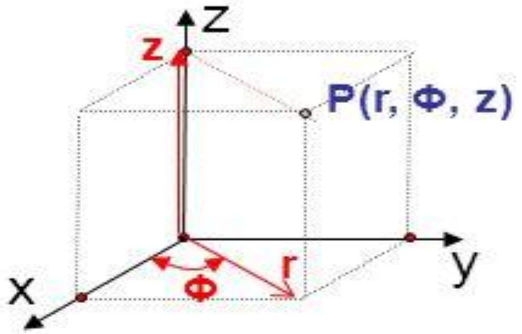


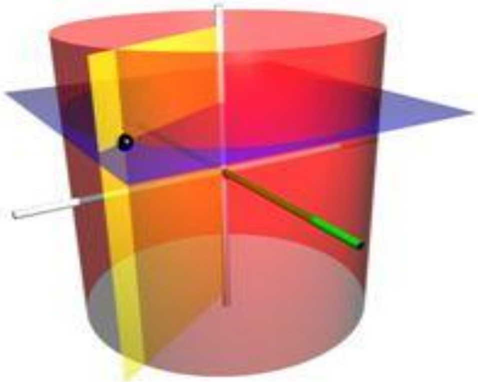


2. Cylindrical Coordinates

P (r, Φ, z)

$X = r\cos\Phi$,
$Y = r\sin\Phi$,
$Z = z$

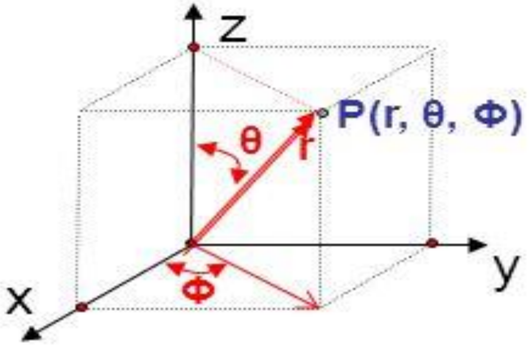


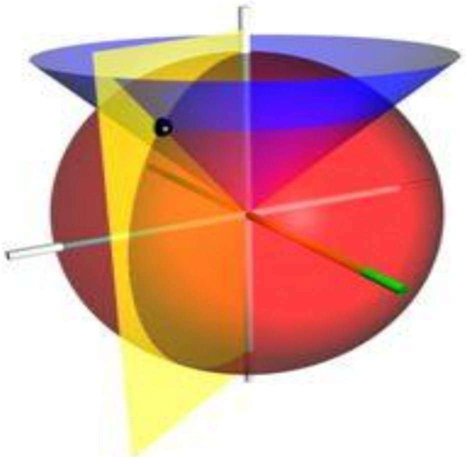


3. Spherical Coordinates

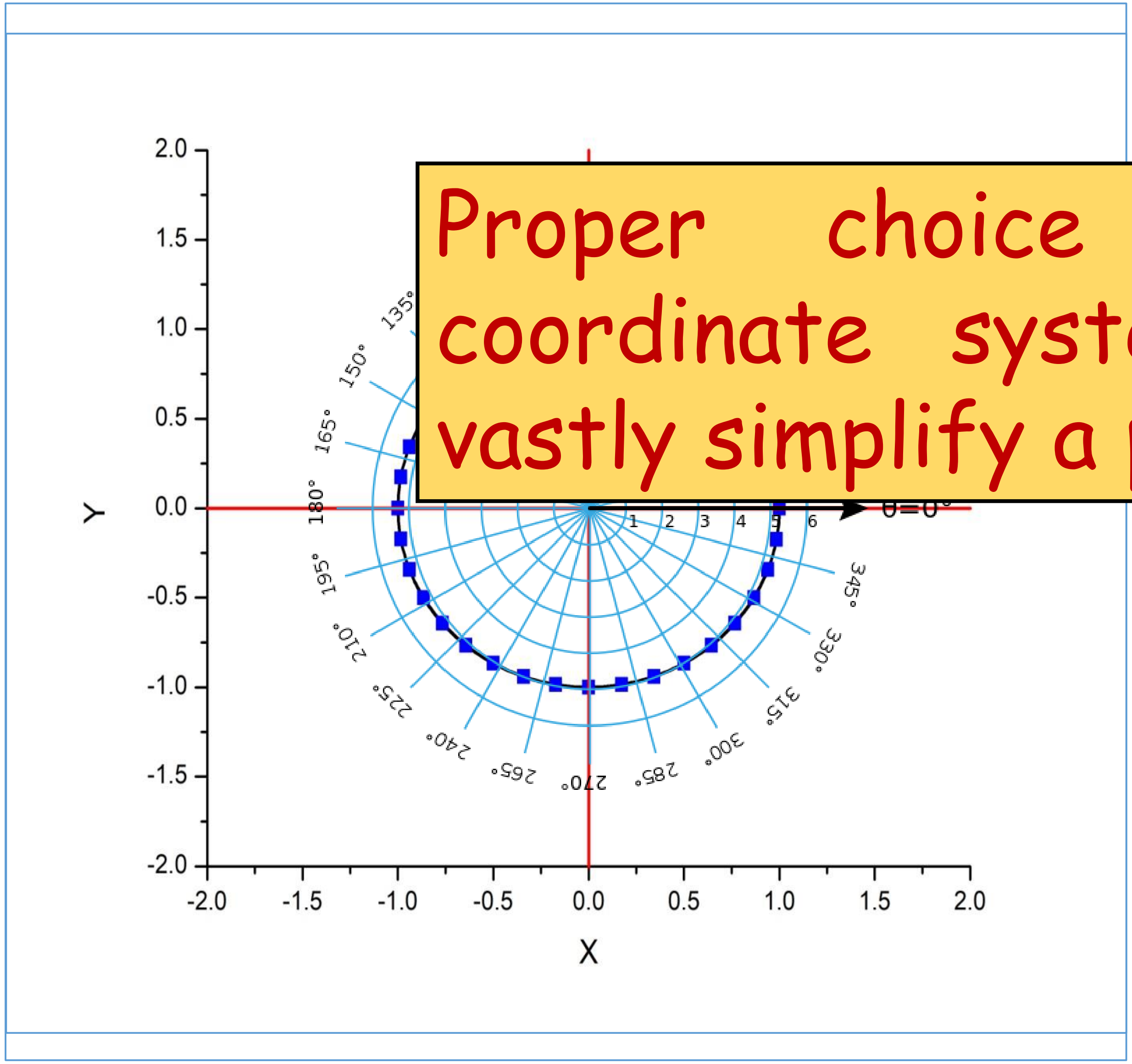
P (r, θ, Φ)

$X = r\sin\theta\cos\Phi$,
$Y = r\sin\theta\sin\Phi$,
$Z = z\cos\theta$





Why do we need different coordinate system?



Proper choice of a coordinate system can vastly simplify a problem

X	Y
1	0
[illegible]	[illegible]201
[illegible]	[illegible]277
[illegible]	[illegible]601
[illegible]	[illegible]

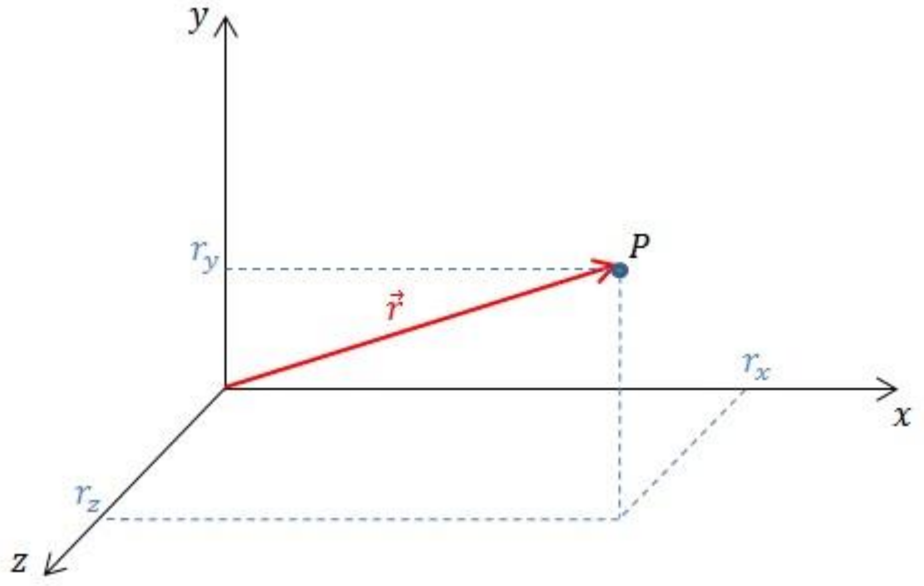
r	θ
1	0
1	20
1	40
1	60
1	90

Cartesian Co-ordinates

A coordinate system consists of four basic elements:

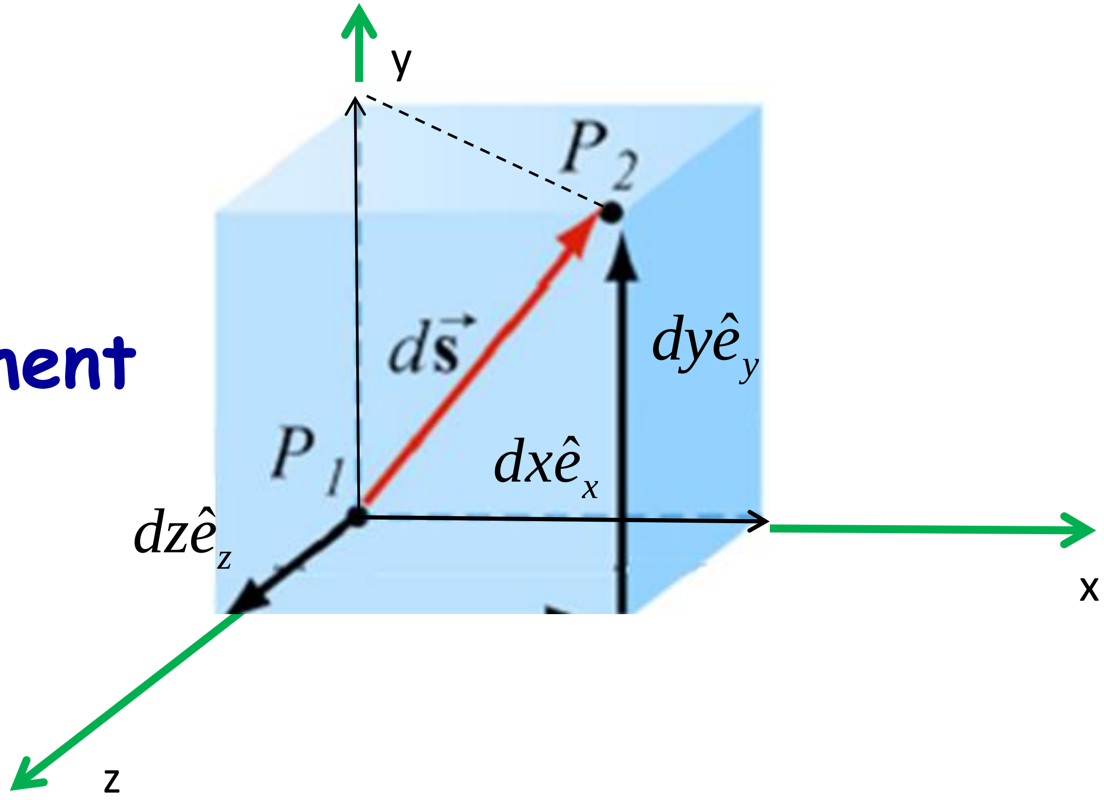
1) Choice of origin
2) Choice of axes
3) Choice of positive direction for each axis
4) Choice of unit vectors for each axis

$$\vec{r} = r_x \hat{e}_x + r_y \hat{e}_y + r_z \hat{e}_z$$



Cartesian Co-ordinates

Infinitesimal line element

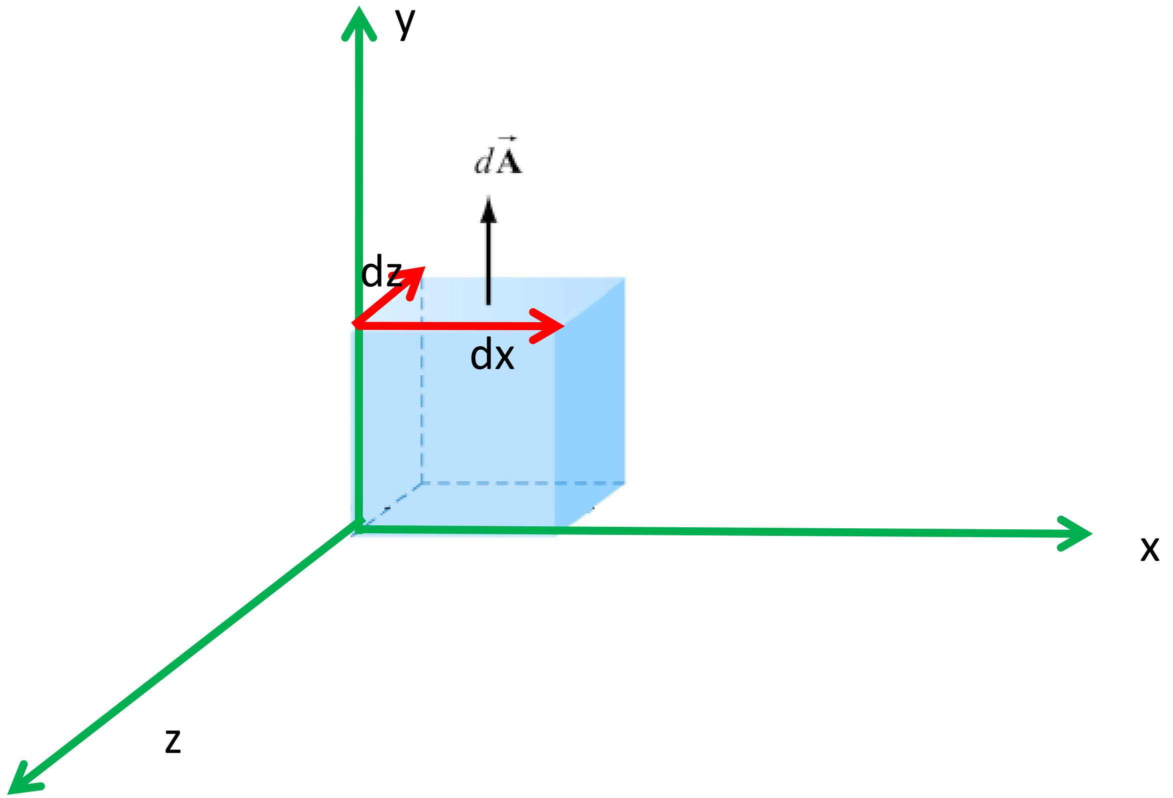


$$\boxed{d\vec{s} = dx\hat{e}_x + dy\hat{e}_y + dz\hat{e}_z}$$

Cartesian Co-ordinates

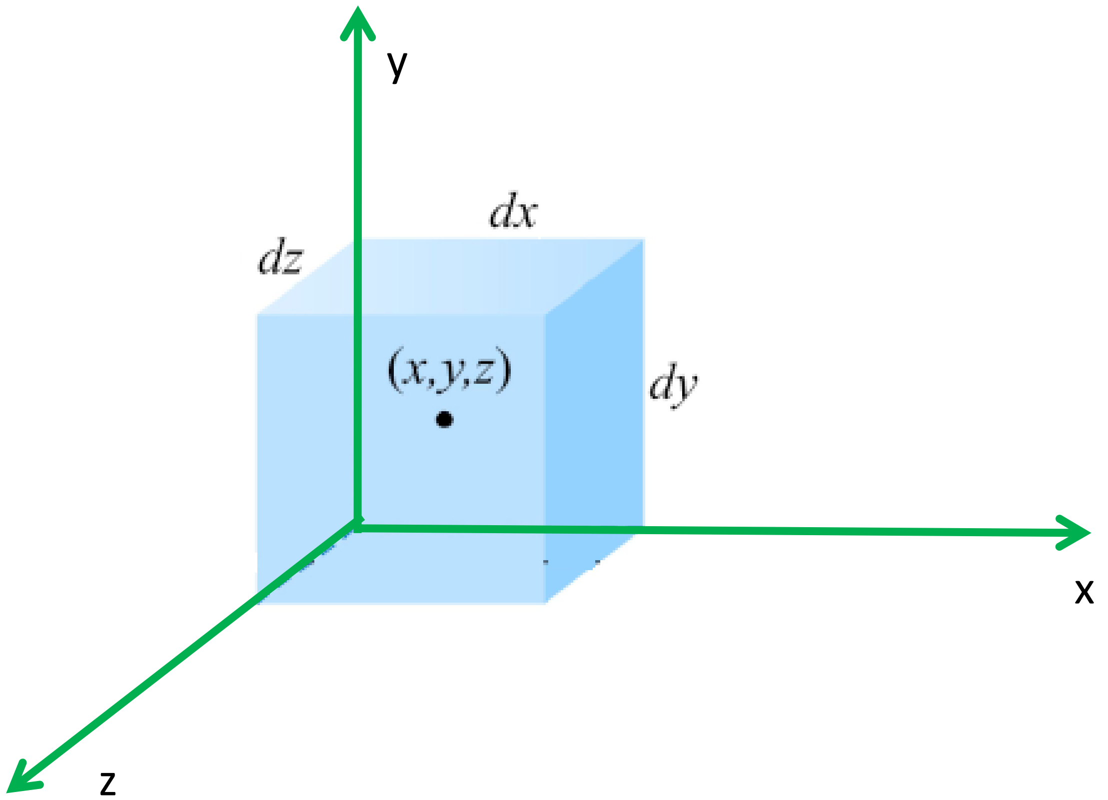
Infinitesimal Area element

$$\vec{dA} = dxdz\hat{e}_y$$



Cartesian Coordinates

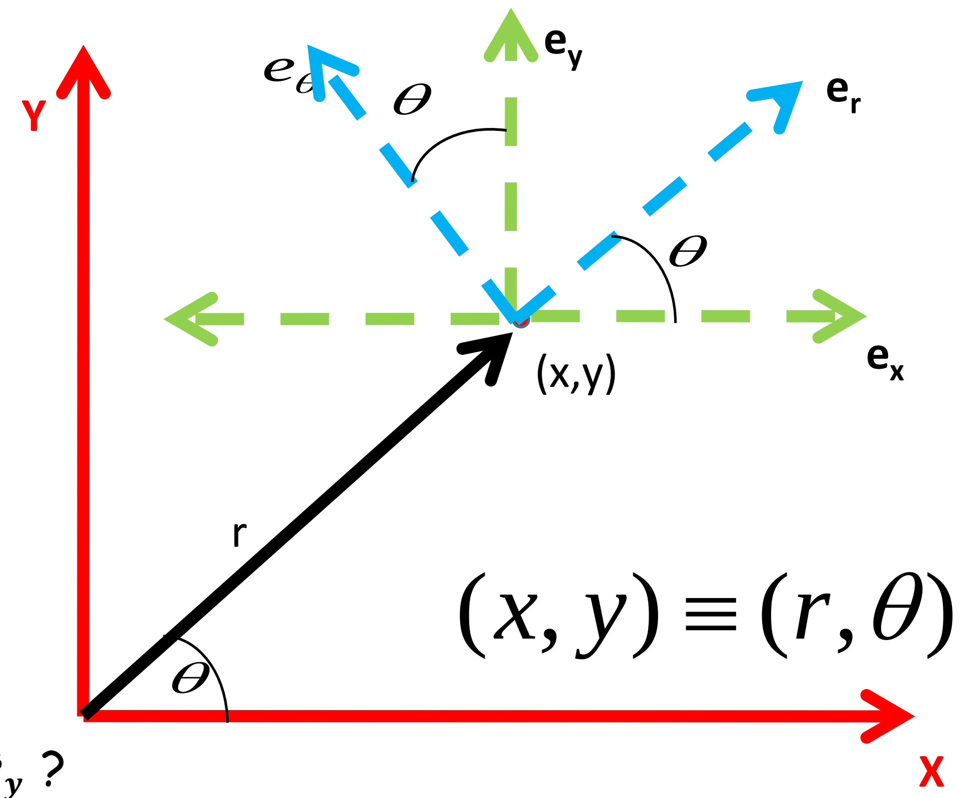
Infinitesimal Volume element $$\boxed{dV = dxdydz}$$



Plane Polar Coordinates

$$x = r\cos(\theta)$$
$$y = r\sin(\theta)$$

$$r = \sqrt{x^2 + y^2}$$
$$\theta = \tan^{-1}\left(\frac{y}{x}\right)$$



What is $\hat{e}_r$ and $\hat{e}_\theta$ in terms of $\hat{e}_x$ and $\hat{e}_y$?

$$\hat{e}_r = \hat{e}_x \cos(\theta) + \hat{e}_y \sin(\theta)$$
$$\hat{e}_\theta = -\hat{e}_x \sin(\theta) + \hat{e}_y \cos(\theta)$$

What is $\hat{e}_x$ and $\hat{e}_y$ in terms of $\hat{e}_r$ and $\hat{e}_\theta$?

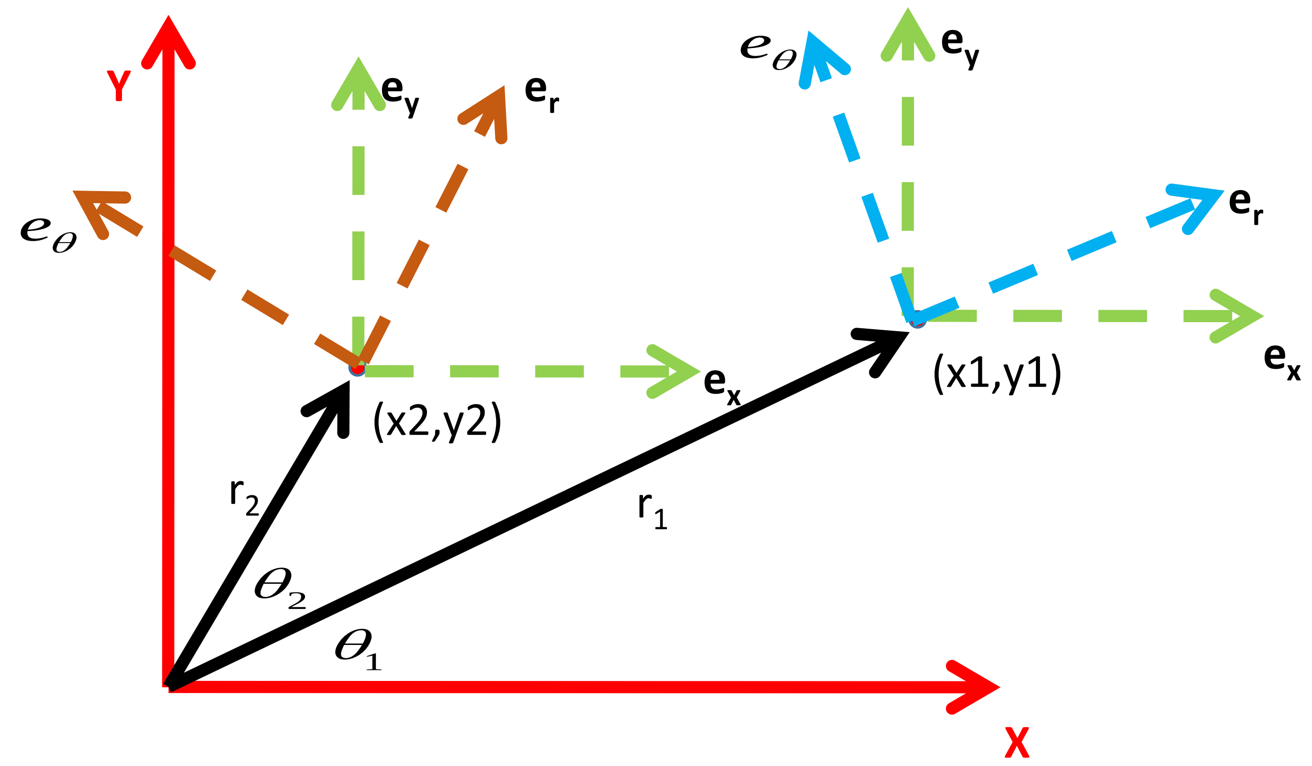
$$\hat{e}_x = \hat{e}_r \cos(\theta) - \hat{e}_\theta \sin(\theta)$$
$$\hat{e}_y = \hat{e}_r \sin(\theta) + \hat{e}_\theta \cos(\theta)$$

HW: Verify $\hat{e}_\theta . \hat{e}_r = 0$

Above vector in Polar Co-ordinates is represented as

$$\vec{r} = r\hat{e}_r$$

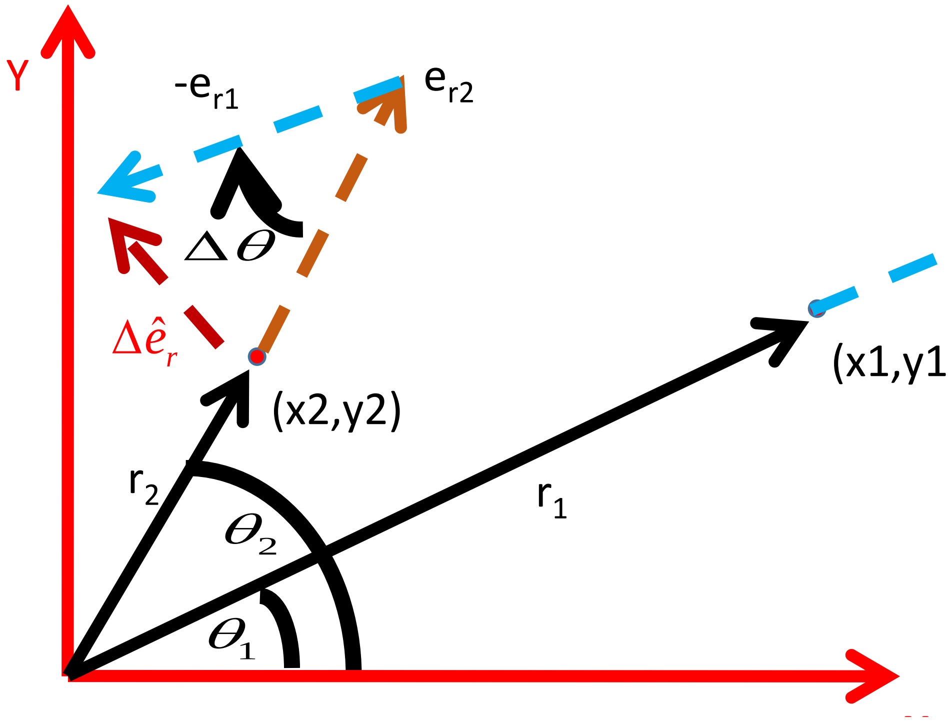
Motion in Plane Polar Coordinates



Cartesian coordinate system: Constant unit vectors

Plane polar coordinate system: Varying unit vectors

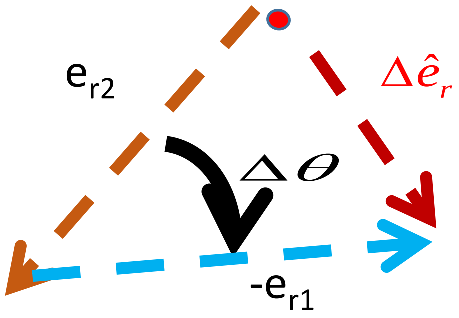
$\frac{d\hat{e}_r}{d\theta}$ through a geometrical consideration



$$\Delta\hat{e}_r = \Delta\theta\hat{e}_\theta$$

$$\boxed{\frac{d\hat{e}_r}{d\theta} = \hat{e}_\theta}$$

$$\boxed{\frac{d\hat{e}_r}{d\theta} \approx \lim_{\Delta\theta\to 0}\frac{\Delta\hat{e}_r}{\Delta\theta}}$$



Change in unit vectors in Plane Polar Coordinates

$$\Delta\hat{e}_r = \Delta\theta\hat{e}_\theta \quad\Longrightarrow\quad \frac{d\hat{e}_r}{d\theta} = \hat{e}_\theta$$

What about $\dfrac{d\hat{e}_r}{dr}$

$$\frac{d\hat{e}_r}{d\theta} = \hat{e}_\theta$$

$$\frac{d\hat{e}_r}{dr} = 0$$

Change in unit vectors in Plane Polar Coordinates

$$\frac{d\hat{e}_\theta}{d\theta}$$

$$\hat{e}_r = \hat{e}_x \cos(\theta) + \hat{e}_y \sin(\theta)$$

$$\hat{e}_\theta = -\hat{e}_x \sin(\theta) + \hat{e}_y \cos(\theta)$$

$$\frac{d\hat{e}_\theta}{dr} = 0$$

Change in unit vectors

HW: Use the geometrical consideration to get relation for $\hat{e}_\theta$.

$$\frac{d\hat{e}_r}{d\theta} = \hat{e}_\theta \qquad \frac{d\hat{e}_r}{dr} = 0$$

$$\frac{d\hat{e}_\theta}{d\theta} = -\hat{e}_r \qquad \frac{d\hat{e}_\theta}{dr} = 0$$

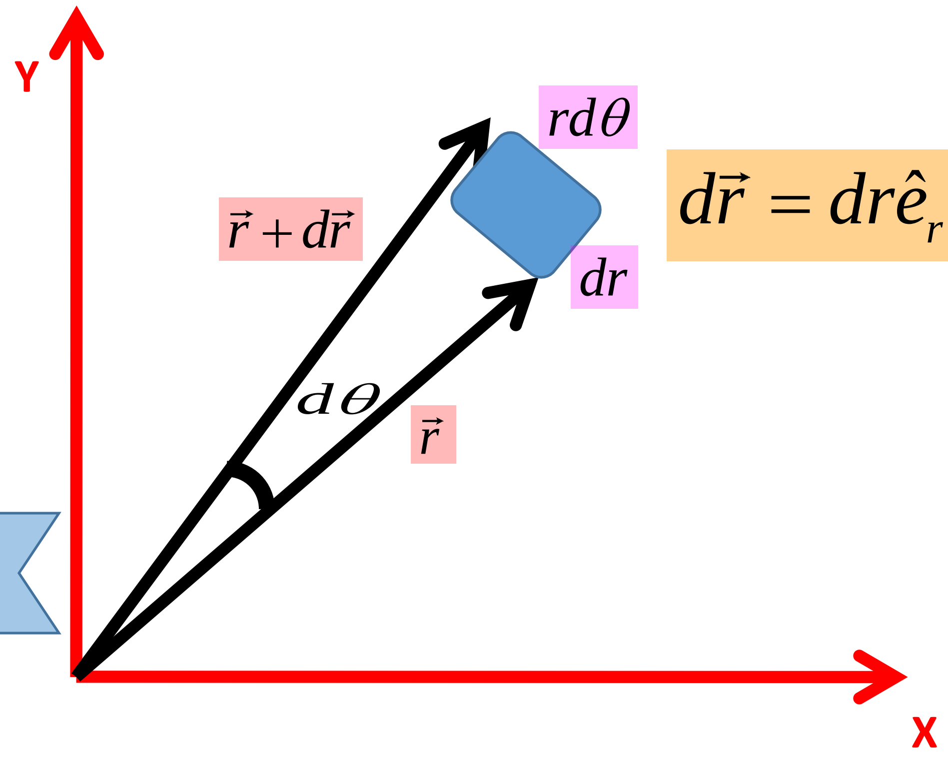
Elemental area in plane polar coordinates

Elemental area dA:

$rdrd\theta$

Area of Circle

Domain of integration



$$d\vec{r} = dr\hat{e}_r + rd\theta\hat{e}_\theta$$

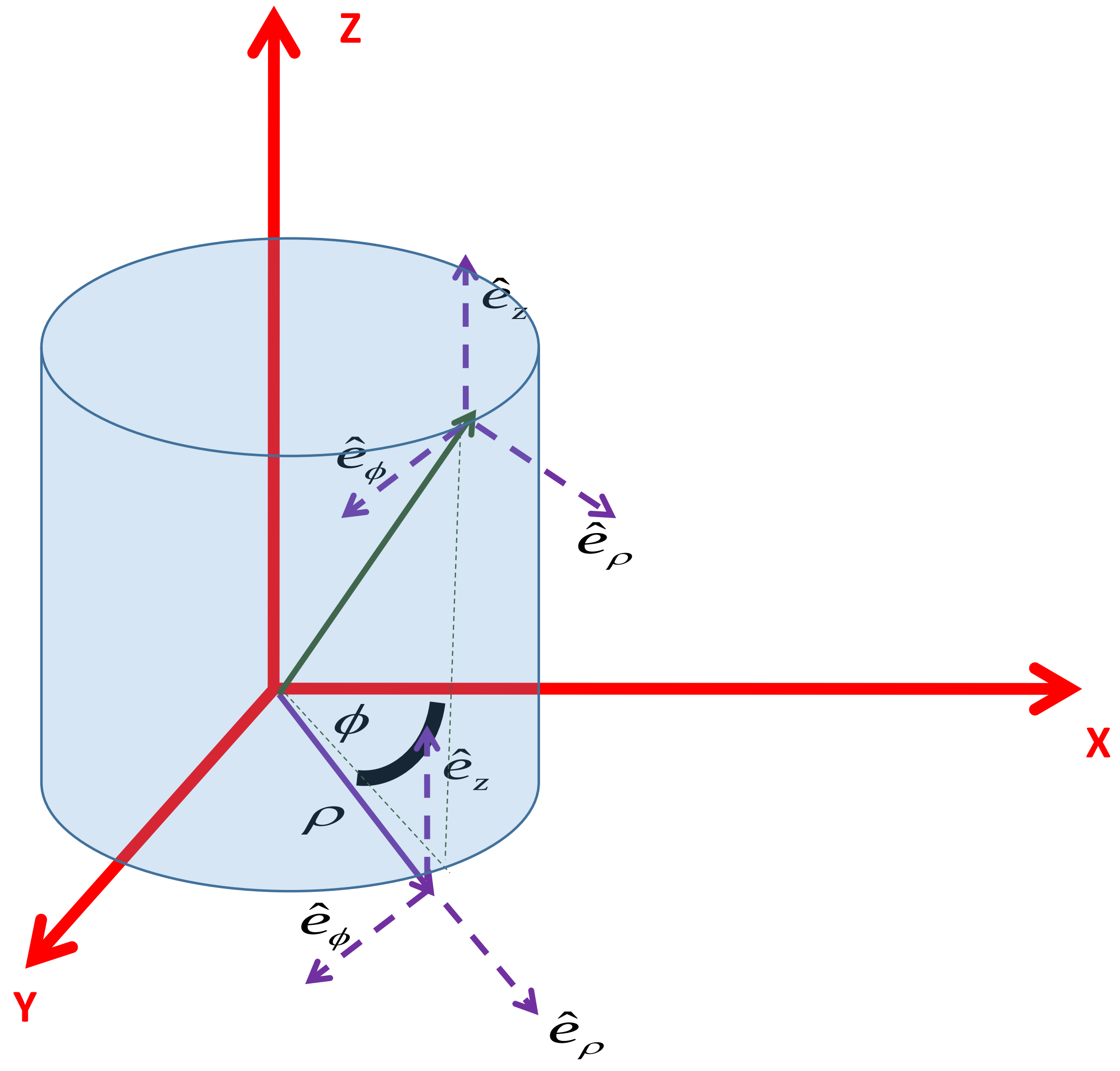
$$\vec{r} = r\hat{e}_r$$

$$d\vec{r} = dr\hat{e}_r + rd\hat{e}_r$$

$$\frac{d\hat{e}_r}{d\theta} = \hat{e}_\theta$$

$$\frac{d\hat{e}_r}{dr} = 0$$

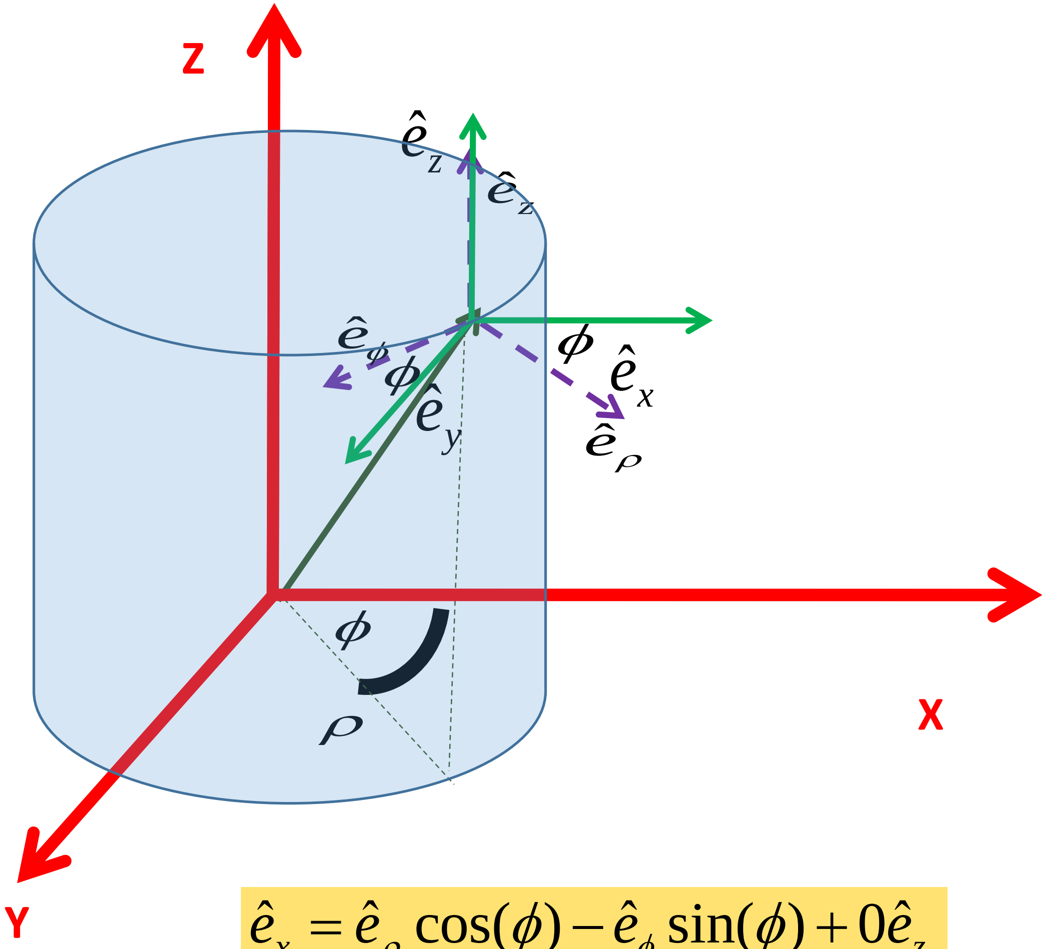
Cylindrical Coordinate System



Transformation of coordinates and unit vectors

$$x = \rho\cos(\phi)$$
$$y = \rho\sin(\phi)$$
$$z = z$$

$$\rho = \sqrt{x^2 + y^2}$$
$$\phi = \tan^{-1}\left(\frac{y}{x}\right)$$
$$z = z$$



$$\hat{e}_\rho = \hat{e}_x\cos(\phi) + \hat{e}_y\sin(\phi) + 0\hat{e}_z$$
$$\hat{e}_\phi = -\hat{e}_x\sin(\phi) + \hat{e}_y\cos(\phi) + 0\hat{e}_z$$
$$\hat{e}_z = \hat{e}_z$$

$$\hat{e}_x = \hat{e}_\rho\cos(\phi) - \hat{e}_\phi\sin(\phi) + 0\hat{e}_z$$
$$\hat{e}_y = \hat{e}_\rho\sin(\phi) + \hat{e}_\phi\cos(\phi) + 0\hat{e}_z$$
$$\hat{e}_z = \hat{e}_z$$

Derivatives of unit vectors

$$\frac{d\hat{e}_\rho}{d\phi} = \hat{e}_\phi$$

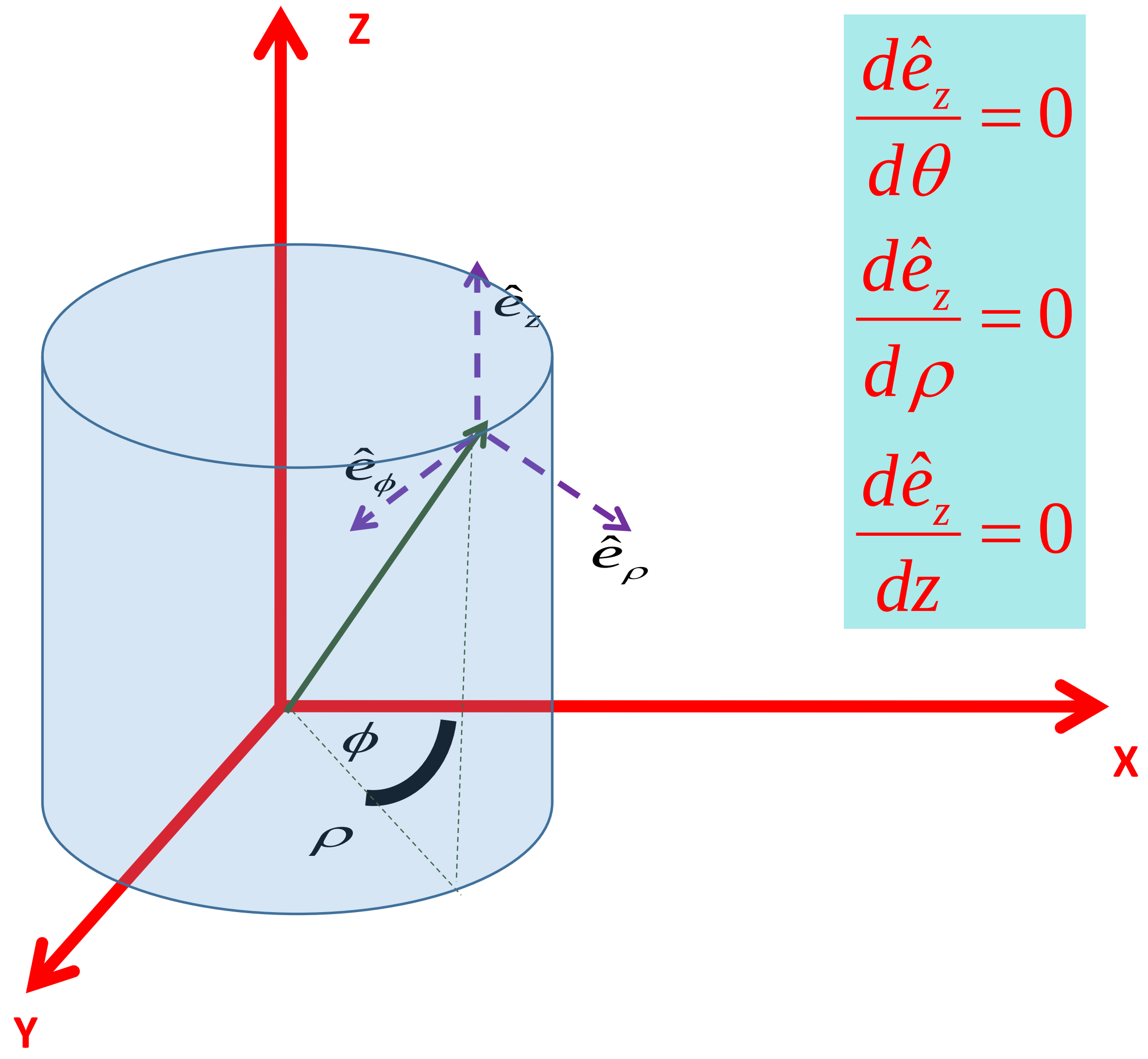
$$\frac{d\hat{e}_\rho}{dr} = 0$$

$$\frac{d\hat{e}_\rho}{dz} = 0$$

$$\frac{d\hat{e}_\phi}{d\phi} = -\hat{e}_\rho$$

$$\frac{d\hat{e}_\phi}{d\rho} = 0$$

$$\frac{d\hat{e}_\phi}{dz} = 0$$



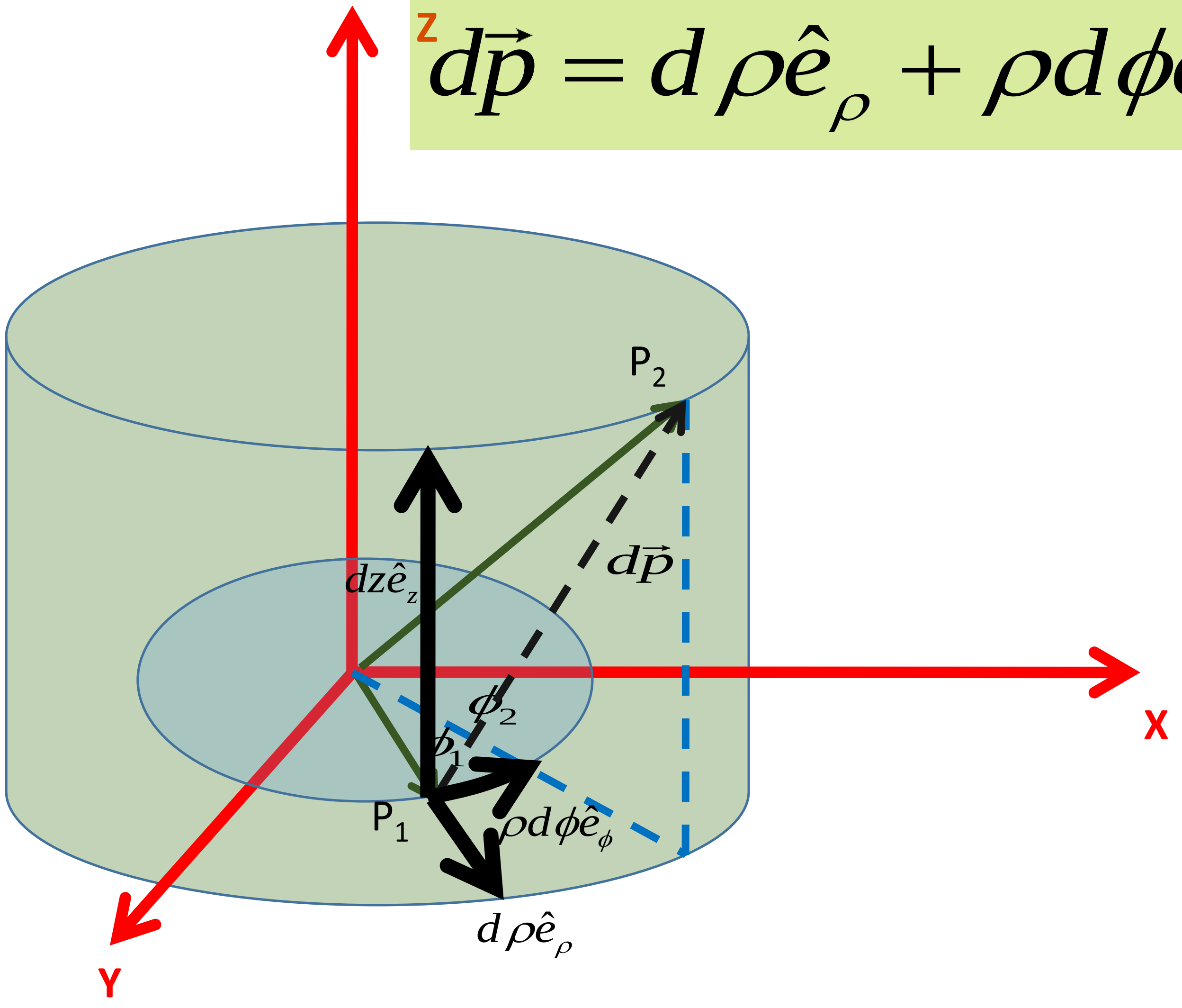
$$\frac{d\hat{e}_z}{d\theta} = 0$$

$$\frac{d\hat{e}_z}{d\rho} = 0$$

$$\frac{d\hat{e}_z}{dz} = 0$$

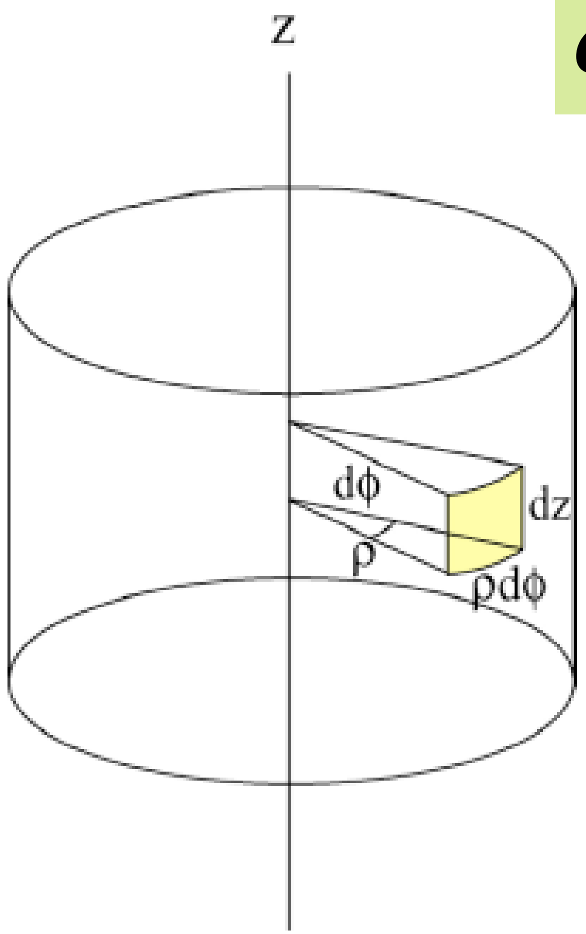
Infinitesimal line element

$$d\vec{p} = d\rho\hat{e}_\rho + \rho d\phi\hat{e}_\phi + dz\hat{e}_z$$



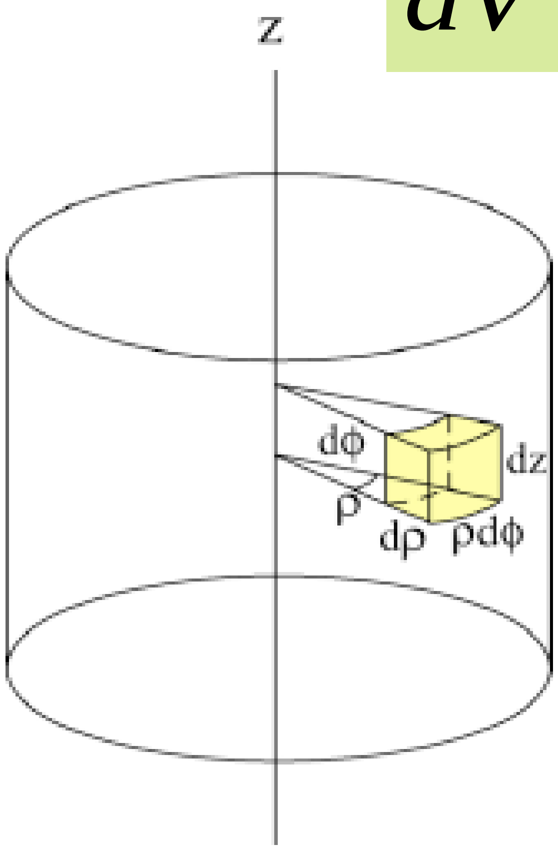
Infinitesimal area element

$$dA = \rho \, d\phi \, dz$$



Infinitesimal Volume element

$$dV = \rho d\rho d\phi dz$$

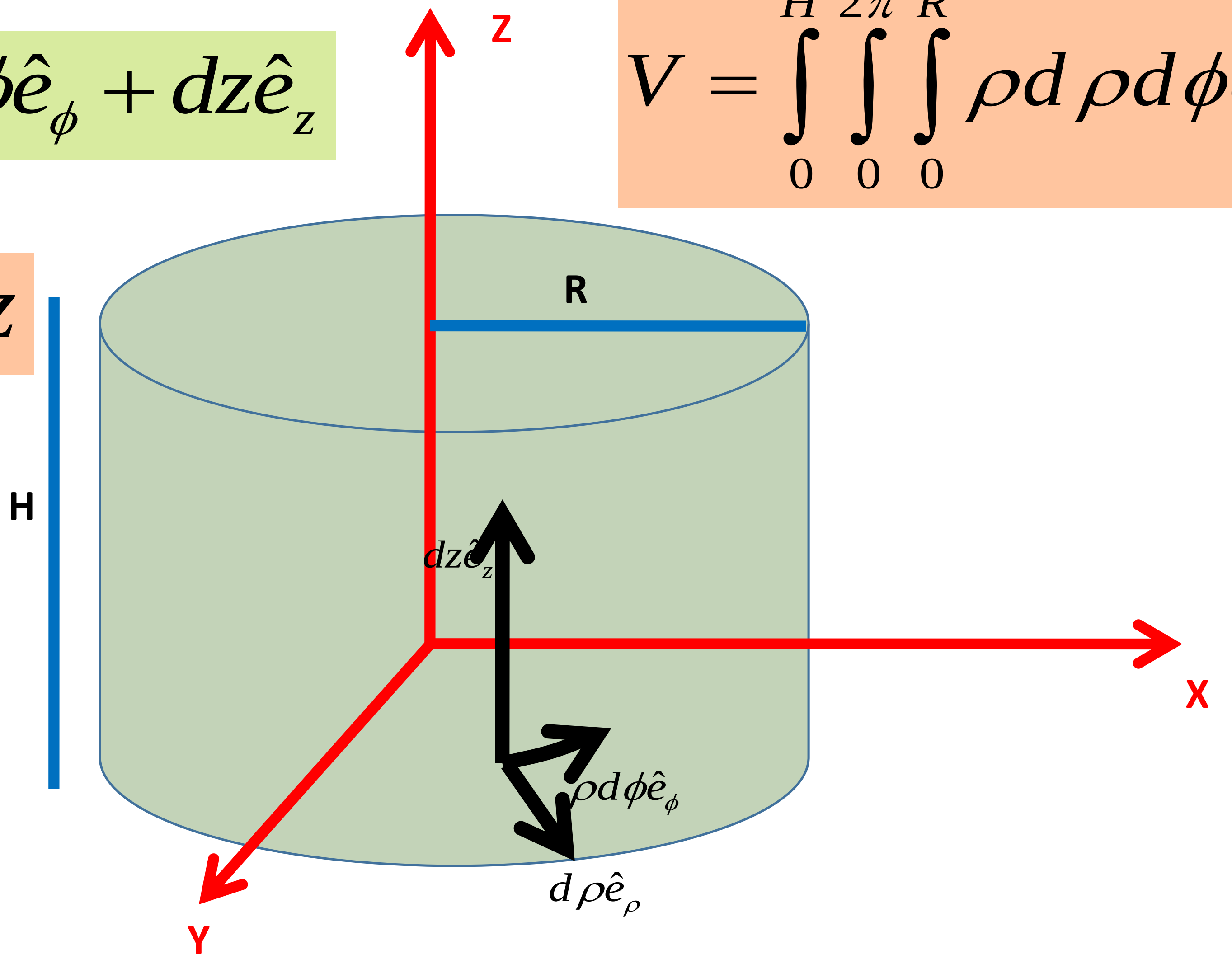


Domain of integration

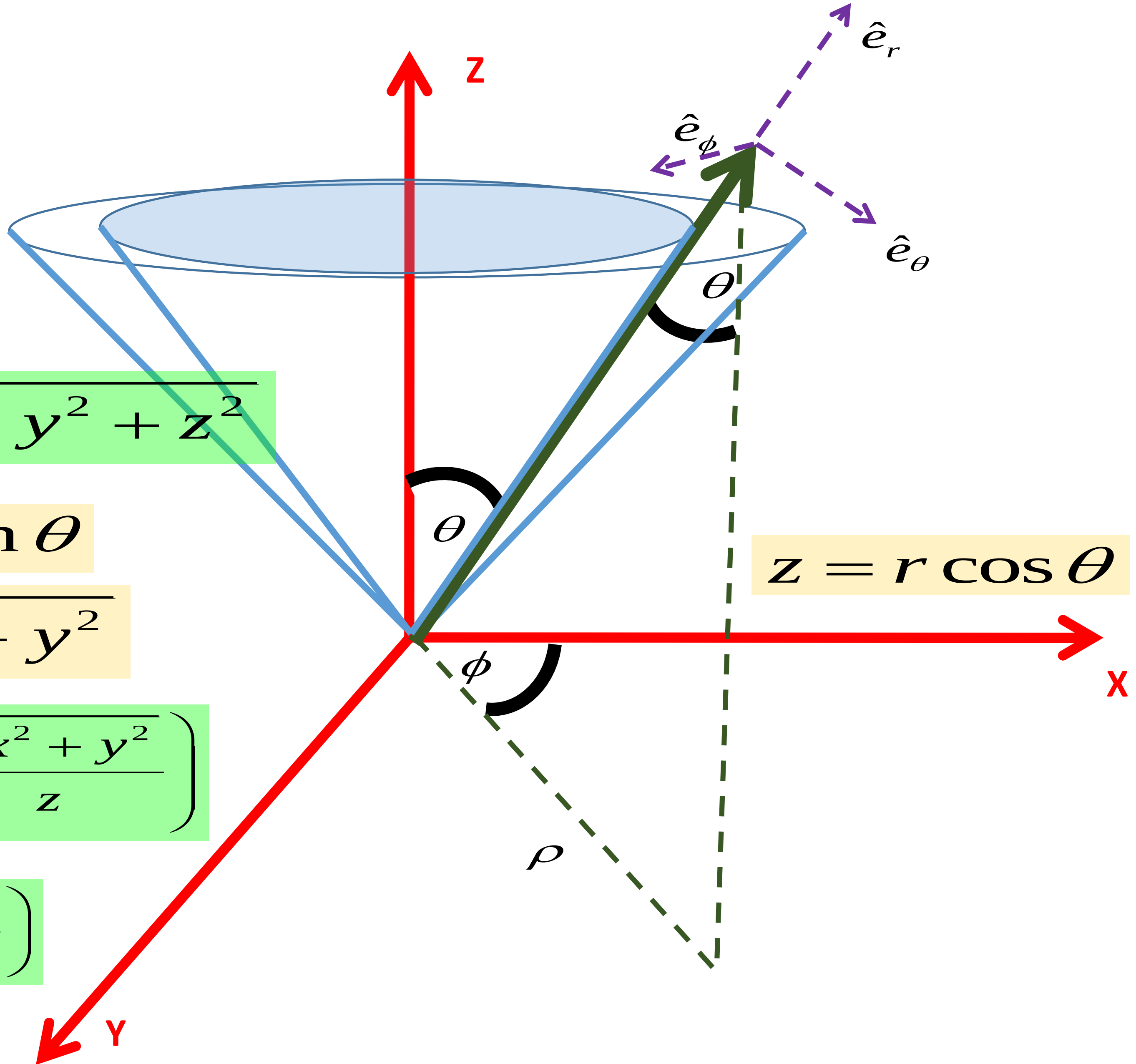
$$d\vec{p} = d\rho\hat{e}_\rho + \rho d\phi\hat{e}_\phi + dz\hat{e}_z$$

$$dV = \rho d\rho d\phi dz$$

$$V = \int_0^H \int_0^{2\pi} \int_0^R \rho d\rho d\phi dz$$



Spherical Polar Coordinate System



$$r = \sqrt{x^2 + y^2 + z^2}$$

$$\rho = r \sin\theta$$

$$\rho = \sqrt{x^2 + y^2}$$

$$\theta = \tan^{-1}\left(\frac{\sqrt{x^2 + y^2}}{z}\right)$$

$$\phi = \tan^{-1}\left(\frac{y}{x}\right)$$

$$z = r\cos\theta$$

Transformation of Coordinates

$$r = \sqrt{x^2 + y^2 + z^2}$$

$$\theta = \tan^{-1}\left(\frac{\sqrt{x^2 + y^2}}{z}\right)$$

$$\phi = \tan^{-1}\left(\frac{y}{x}\right)$$

$$x = r\sin\theta\cos\phi$$

$$y = r\sin\theta\sin\phi$$

$$z = r\cos\theta$$

Transformation of Unit Vectors