PH105

GENERAL PHYSICS I

PROF. LECLAIR

PH105: GENERAL PHYSICS I

- Dr. Patrick LeClair; leclair.homework@gmail.com

  offices: 2012 Bevill, 323 Gallalee

  cell: 857-891-4267 (txt preferred, call if urgent)

- office hours: (email/txt ahead ideally)

  12-1 Gallalee, 4-5 Bevill

  other times by appointment

GRADUATE ASSISTANTS

- meet them on Wednesday ...
- they will mostly run the labs, and will have office hours

- Abhishek Srivastava
- Ezhil Manoharan

OFFICIAL THINGS, CONT.

- Lecture:

  1-2:45 every day

  short break in the middle

- will go over problems, but only so many
- a big part of learning is solving problems on your own ...
- some notes provided, will follow the book
- no attendance policy for lectures (but there may be quizzes)

- <u>Syllabus</u>

TOPICS

1. Distance, velocity, & acceleration
2. Newton's laws of motion
3. Energy
4. Momentum & collisions
5. Rotational motion
6. Gravitation
7. Solids & fluids
8. Thermal physics
9. Sound & oscillations

GRADING

- **3 exams** (during lab period) + **final** (exam period)
- **homework**: a few daily problems - turn in only one
- **lab**: turn in one report per week. more detail tomorrow
- **quizzes**: during lab period (mostly)

Homework	15%
Labs	15%
Quizzes	15%
Exam I	15%
Exam II	15%
Exam III	15%
Final	10%

LAB EXPERIMENTS

Lab session: MWR 8-10:50, Gallalee 203

- some days we may start later
- also time for quizzes, HW help, discussion

usually related to current lecture material

work in groups of 3 of your choosing

write 1 lab report per week

LAB REPORTS

- we do 2-3 experiments per week
- as a group, pick 1 to write a formal report on
  - raw data from other 2 labs as an appendix
- template for report will be provided
- due each Monday

HOMEWORK

- just paper & pencil, no online homework
- collaboration is OK
- assigned every day, turn one specific problem by end of next lecture
- problems not turned in are not graded, but may show up later …
- use template format (next slide; can be handwritten)

Name & ID ________________________________

1.

Find / Given:	**Sketch:**

Relevant equations:	**Symbolic solution:**

Numeric solution:	**Double Check**	
	Dimensions	Order-of-magnitude

PROBLEM SOLVING

- Conceptualize
  - Think and understand
  - Make a drawing
  - Known and unknowns
  - Estimate
- Categorize
  - Simplify
  - Substitution or analysis?
  - Classify
- Analyze
  - List relevant formulae
  - Apply mathematical principles to calculate the result
- Finalize
  - Check units
  - Examine extremes
  - Compare to other results
  - What have you learned?

SCHEDULE

May
T26 Intro / 1D motion
W27 1D motion / 2D motion | uncertainty analysis; diagnostic exam
R28 2D motion | 1D motion, free-fall
F29 Motion along arbitrary paths / misc.

June
M 1 Force & motion 1 | 2nd law experiment
T 2 Force & motion 1/2
W 3 Force & motion 2 | friction lab
R 4 KE and work | **Exam 1**
F 5 KE and work / PE and CoE
M 8 PE and CoE | momentum
T 9 Center of mass & momentum
W10 Rotation / rolling, torque, angular momentum | TBD
R11 Rolling, torque, angular momentum / equilibrium & elasticity | **Exam 2**
F12 Gravitation
M15 Oscillations | Simple Harmonic Motion
T16 Waves 1
W17 Waves 2 | standing waves
R18 Temperature, heat, first law | **Exam 3**
F19 Fluids
M22 Kinetic theory | calorimetry
T23 2nd law / END
W24 Final exam / 12-1:45pm

- Feynman lectures online (useful supplement)

	primary topic	secondary topic	tertiary / activity	in lab	HRW	Feynman
26-May	syllabus, overview	motion	modeling		2.1-6	1.2, 1.11, 1.22
27-May	motion in 1D	motion in 2D	uncertainty	safety, uncert	2.6-10, 4.1-5	1.5, 1.8
28-May	motion in 2D	projectiles		1D motion	4.5-7	
29-May	arbitrary motion	circular motion			4.8-9, notes	
1-Jun	Newton's laws			2nd law experiment	5.1-8	1.9, 1.10
2-Jun	Newton's laws	free body diagrams			5.9, 6.1-3	1.12
3-Jun	Newton's laws	Friction, drag	motion on curved paths	friction lab	6.4-5, notes	
4-Jun	kinetic energy	work		**EXAM 1**	7.1-6	
5-Jun	kinetic energy & work	potential energy	conservation of energy		7.6-9, 8.1-5	1.4, 1.13, 1.14
8-Jun	potential energy	conservation of energy	momentum	momentum	8.6-8, 9.1-4	1.52
9-Jun	center of mass	momentum			9.5-11	1.10
10-Jun	rotation	rolling	torque & angular momentum	TBD	10.all	1.18, 1.19
11-Jun	torque	angular momentum		**EXAM 2**	11.all	1.20
12-Jun	gravitation				13.all	1.7
15-Jun	oscillations	simple harmonic motion		simple harmonic motion	15.1-7	1.21, 1.23, 1.24
16-Jun	waves	sound			16.all	1.47, 1.48
17-Jun	waves	standing waves	resonance	standing waves	17.all, 15.8-9	1.50, 1.51
18-Jun	temperature	heat	1st law of thermo	**EXAM 3**	18.all	2.40, 2.41
19-Jun	fluids				14.all	
22-Jun	kinetic theory	ideal gas law	Boltzman distribution	calorimetry	19.all	1.39, 1.40, 1.41
23-Jun	2nd law of thermo				20.all	1.44, 1.45
24-Jun	**FINAL EXAM 12-1:45**					

INTERTUBES

- http://ph105.blogspot.com/ RSS feed, updated often
- grades will be posted, occasionally, on blackboard
- you can always ask me what your average is to check
- you should get all your work back

STUFF YOU NEED

- textbook
- writing implements
- basic calculator (trig/log is enough)

SHOWING UP

- we hope you will find some utility in the class
- homework/labs/exams may rely on stuff I say in class
- missing an exam is seriously bad.

  acceptable reason ... makeup or weight final

OTHER

- the pace is brutal. can't be helped
- algebra, trigonometry, calculus I fluency assumed
- glance through Ch. 1 to make sure it is mostly review
- **Read most of Ch. 2 & lab 1** for tomorrow
- you have problems due tomorrow (can ask in morning lab …)
- lecture ~ discussion of material; relies on you having read!

TODAY & NEXT TIME:

MOTION IN 1D

Our friend the vector

- we will be doing terrible things with them

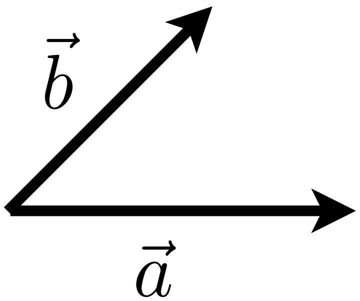
- vector = quantity requiring an arrow to represent
  - *coordinate-free* description
  - described by basis (unit) vectors of a coordinate system

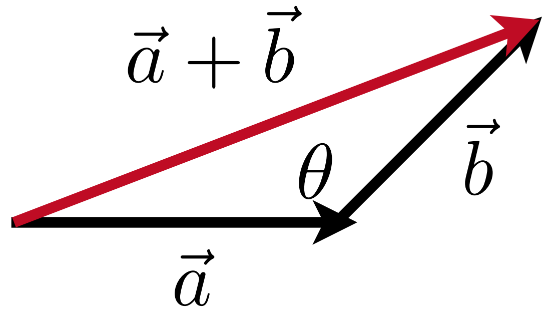
- proper vectors are unchanged by coordinate transformations ...

Adding & subtracting vectors

- commutative, A+B = B+A
- associative, A + (B+C) = (A+B) + C
- subtracting = add negative (reverse direction)

- add head-tail geometrically (law of cosines)
- add by component (using unit vectors)





Geometrically:

$$|\vec{a} + \vec{b}| = |\vec{a}| + |\vec{b}| - 2|\vec{a}||\vec{b}|\cos\theta$$

By components: first choose a basis/coordinate system

$$\vec{a} = a_x\,\hat{i} + a_y\,\hat{j} \qquad \vec{b} = b_x\,\hat{i} + b_y\,\hat{j}$$

$$\vec{a} + \vec{b} = (a_x + b_x)\,\hat{i} + (a_y + b_y)\,\hat{j}$$

magnitude identical to geometric approach

Scalar multiplication

- Duh, the vector gets longer.
- By component:

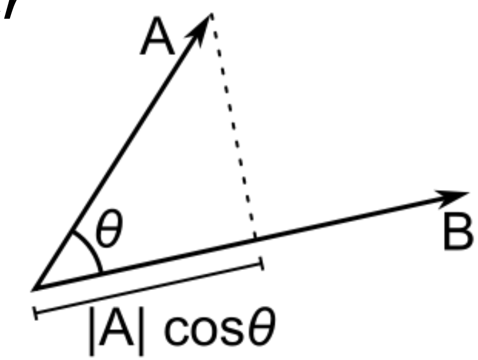
$$c\vec{a} = c\left(a_x\,\hat{i} + a_y\,\hat{j}\right) = ca_x\,\hat{i} + ca_y\,\hat{j}$$

- Geometrically: the arrow gets *c* times longer
- Distributive.

$$c\left(\vec{A} + \vec{B}\right) = c\vec{A} + c\vec{B}$$

Scalar (“dot”) product

- product of vector A and the projection of B onto A
- scalar product of two vectors gives a *scalar*



$$\vec{A} \cdot \vec{B} = a_x b_x + a_y b_y = |\vec{A}||\vec{B}| \cos \theta_{AB}$$

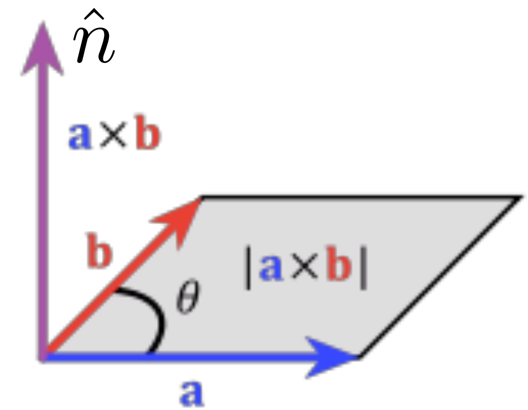
- commutes, distributes

$$\vec{A} \cdot \vec{B} = \vec{B} \cdot \vec{A} \qquad \vec{A} \cdot \left(\vec{B} + \vec{C}\right) = \vec{A} \cdot \vec{B} + \vec{A} \cdot \vec{C}$$

- two vectors are perpendicular if and only if their scalar product is zero

vector ("cross") product

- product of vector A and B, gives 3rd vector perpendicular to A-B plane



$$|\vec{A} \times \vec{B}| = |\vec{A}||\vec{B}| \sin\theta_{AB}$$

$$\vec{A} \times \vec{B} = \vec{A}\vec{B} \sin\theta_{AB}\,\hat{n}$$

- Distributes, does **NOT** commute

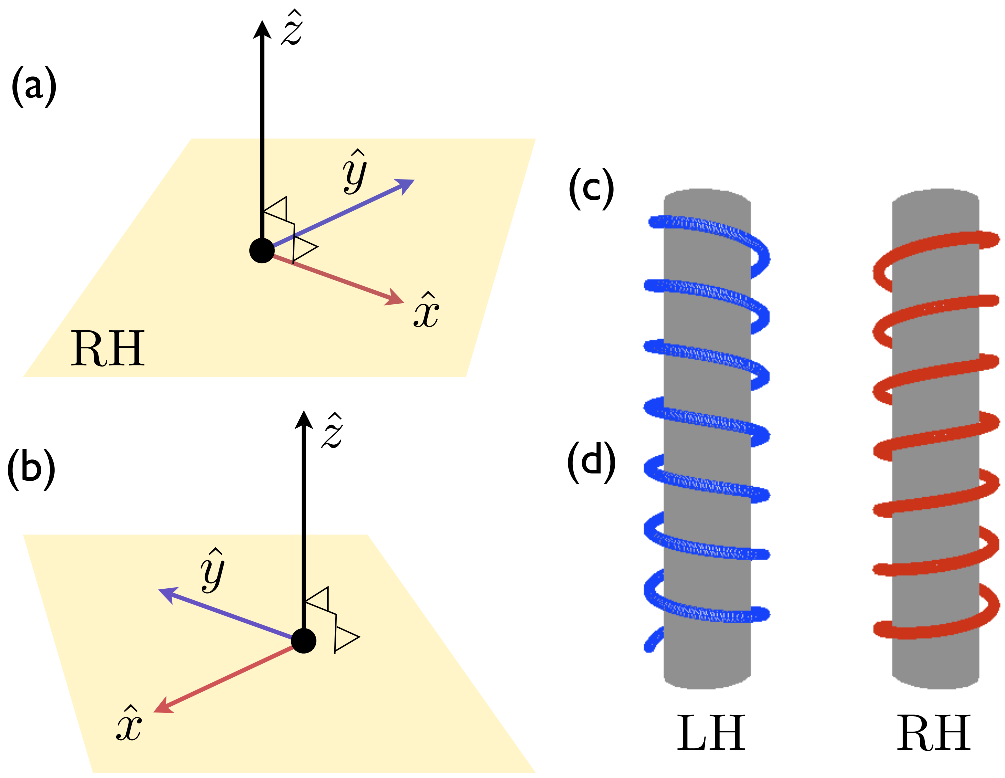
$$\vec{A} \times \left(\vec{B} \times \vec{C}\right) = \left(\vec{A} \times \vec{B}\right) + \left(\vec{A} \times \vec{C}\right)$$

$$\vec{A} \times \vec{B} = -\left(\vec{B} \times \vec{A}\right)$$

vector ("cross") product

- 'perpendicular' direction not unique!

  choice of 'handedness' or chirality. we pick RH.



cross products are not the same as their mirror images

$$\hat{\imath}\times\hat{\jmath}=\hat{\mathbf{k}} \qquad -\reflectbox{$\hat{\mathbf{k}}$} = \reflectbox{$\hat{\jmath}$}\times\reflectbox{$\hat{\imath}$}$$

$$\hat{\jmath}\times\hat{\mathbf{k}}=\hat{\imath} \qquad -\reflectbox{$\hat{\imath}$} = \reflectbox{$\hat{\mathbf{k}}$}\times\reflectbox{$\hat{\jmath}$}$$

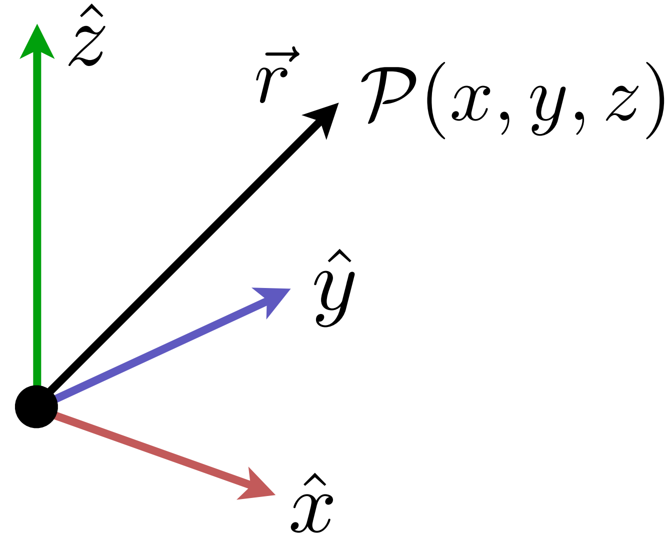
$$\hat{\mathbf{k}}\times\hat{\imath}=\hat{\jmath} \qquad -\reflectbox{$\hat{\jmath}$} = \reflectbox{$\hat{\imath}$}\times\reflectbox{$\hat{\mathbf{k}}$}$$

some things that may prove handy later ...

formula	relationship
$\vec{\mathbf{a}} \cdot \vec{\mathbf{b}} = \vec{\mathbf{b}} \cdot \vec{\mathbf{a}}$	commutative
$\vec{\mathbf{a}} \cdot (\vec{\mathbf{b}} + \vec{\mathbf{c}}) = \vec{\mathbf{a}} \cdot \vec{\mathbf{b}} + \vec{\mathbf{a}} \cdot \vec{\mathbf{c}}$	distributive
$\vec{\mathbf{a}} \cdot (r\vec{\mathbf{b}} + \vec{\mathbf{c}}) = r(\vec{\mathbf{a}} \cdot \vec{\mathbf{b}}) + r(\vec{\mathbf{a}} \cdot \vec{\mathbf{c}})$	bilinear
$(c_1\vec{\mathbf{a}}) \cdot (c_2\vec{\mathbf{b}}) = (c_1 c_2)(\vec{\mathbf{a}} \cdot \vec{\mathbf{b}})$	multiplication by scalars
if $\vec{\mathbf{a}} \perp \vec{\mathbf{b}}$, then $\vec{\mathbf{a}} \cdot \vec{\mathbf{b}} = 0$	orthogonality

formula	relationship
$\vec{\mathbf{a}} \times \vec{\mathbf{b}} = -\vec{\mathbf{b}} \times \vec{\mathbf{a}}$	anticommutative
$\vec{\mathbf{a}} \times \left(\vec{\mathbf{b}} + \vec{\mathbf{c}}\right) = \left(\vec{\mathbf{a}} \times \vec{\mathbf{b}}\right) + (\vec{\mathbf{a}} \times \vec{\mathbf{c}})$	distributive over addition
$(r\vec{\mathbf{a}}) \times \vec{\mathbf{b}} = \vec{\mathbf{a}} \times (r\vec{\mathbf{b}}) = r(\vec{\mathbf{a}} \times \vec{\mathbf{b}})$	compatible with scalar multiplication
$\vec{\mathbf{a}} \times (\vec{\mathbf{b}} \times \vec{\mathbf{c}}) + \vec{\mathbf{b}} \times (\vec{\mathbf{c}} \times \vec{\mathbf{a}}) + \vec{\mathbf{c}} \times (\vec{\mathbf{a}} \times \vec{\mathbf{b}}) = 0$	not associative; obeys Jacobi identity
$\vec{\mathbf{a}} \times (\vec{\mathbf{b}} \times \vec{\mathbf{c}}) = \vec{\mathbf{b}}(\vec{\mathbf{a}} \cdot \vec{\mathbf{b}}) - \vec{\mathbf{c}}(\vec{\mathbf{a}} \cdot \vec{\mathbf{b}})$	triple vector product expansion
$(\vec{\mathbf{a}} \times \vec{\mathbf{b}}) \times \vec{\mathbf{c}} = -\vec{\mathbf{c}} \times (\vec{\mathbf{a}} \times \vec{\mathbf{b}}) = -\vec{\mathbf{a}}(\vec{\mathbf{b}} \cdot \vec{\mathbf{c}}) + \vec{\mathbf{b}}(\vec{\mathbf{a}} \cdot \vec{\mathbf{c}})$	triple vector product expansion
$\vec{\mathbf{a}} \cdot (\vec{\mathbf{b}} \times \vec{\mathbf{c}}) = \vec{\mathbf{b}} \cdot (\vec{\mathbf{c}} \times \vec{\mathbf{a}}) = \vec{\mathbf{c}} \cdot (\vec{\mathbf{a}} \times \vec{\mathbf{b}})$	triple scalar product expansion†
$\lvert\vec{\mathbf{a}} \times \vec{\mathbf{b}}\rvert^2 + \lvert\vec{\mathbf{a}} \cdot \vec{\mathbf{b}}\rvert^2 = \lvert\vec{\mathbf{a}}\rvert^2 \lvert\vec{\mathbf{b}}\rvert^2$	relation between cross and dot product
if $\vec{\mathbf{a}} \times \vec{\mathbf{b}} = \vec{\mathbf{a}} \times \vec{\mathbf{c}}$ then $\vec{\mathbf{b}} = \vec{\mathbf{c}}$ iff $\vec{\mathbf{a}} \cdot \vec{\mathbf{b}} = \vec{\mathbf{a}} \cdot \vec{\mathbf{c}}$	lack of cancellation

vectors are how we define positions & directions



$$\vec{r} = x\,\hat{i} + y\,\hat{j} + z\,\hat{z}$$

from origin to P

$$|\vec{r}|^2 = x^2 + y^2 + z^2 = \vec{r}\cdot\vec{r}$$

distance

$$\hat{r} = \frac{\vec{r}}{|\vec{r}|}$$

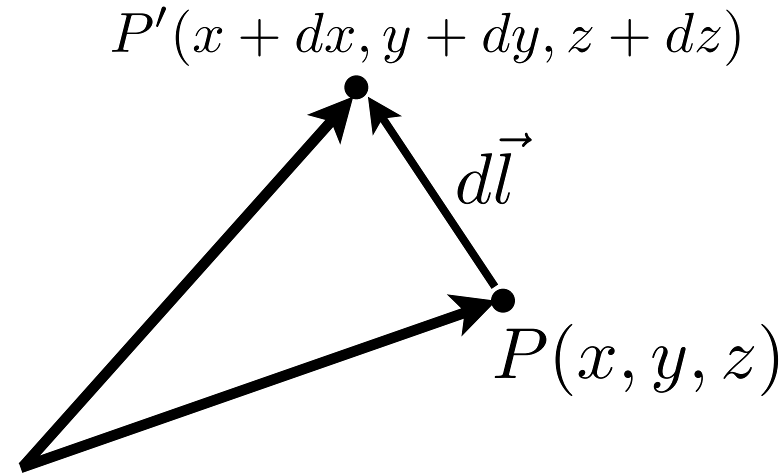
direction - unit vector

infinitesimal displacements along a path

$$(x, y, z) \rightarrow (x + dx, y + dy, z + dz)$$

described by a infinitesimal vector

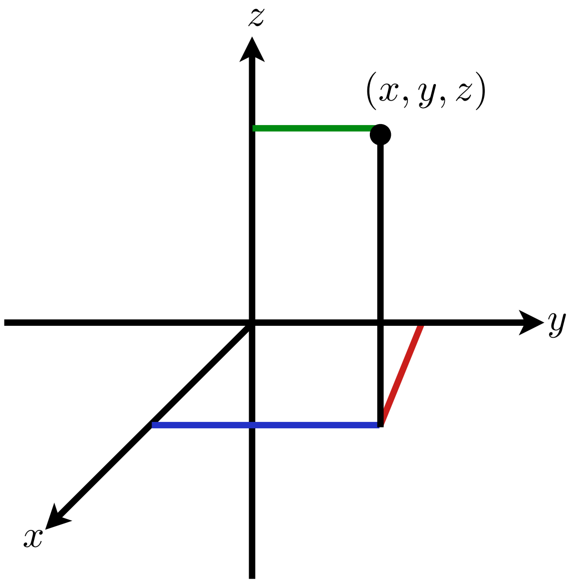
$$d\vec{l} = dx\,\hat{x} + dy\,\hat{y} + dz\,\hat{z}$$



build up a whole path by integrating all such dl's

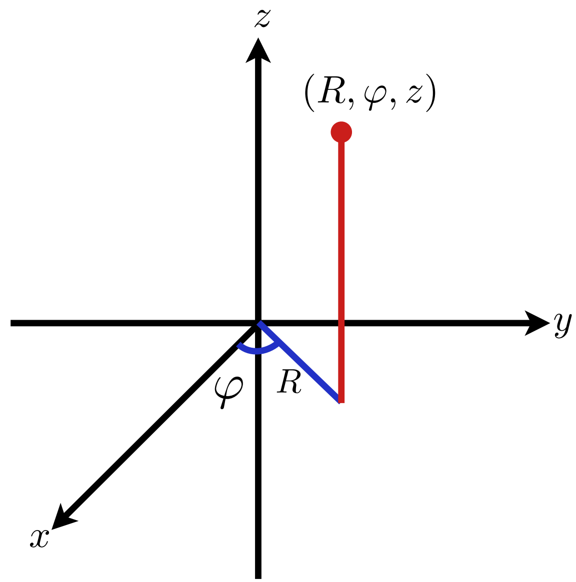
depends on coordinate system

$$d\vec{l} = dr\,\hat{r} + r\sin\theta\,d\theta\,\hat{\theta} + r\,dr\,d\theta\,\hat{\varphi} \quad \text{(spherical)}$$



cartesian

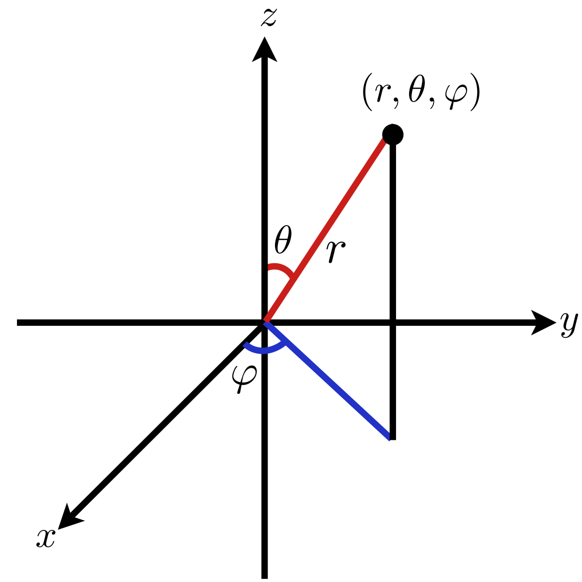
x,y,z



cylindrical

R,φ,z

s,φ,z



spherical

r,θ,φ