Introduction
Vectors
Motion in 1 and 2-D

Phys 2101

Gabriela González

Phys 2101 – Section 7

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Office hours: Mon-Tue 4-5pm, 271-C Nicholson Hall

Textbook: *Fundamentals of Physics*, Halliday, Resnick, and Walker,
LSU custom 8th edition (or regular textbook, 8th or 9th ed.)

Course website: www.phys.lsu.edu/classes/fall2010/phys2101/

Our section's website: www.phys.lsu.edu/faculty/gonzalez/Teaching/Phys2101/
will have lecture slides, grades for our section, etc.

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My research : gravitational waves

EinsteinsMessengers.org

www.ligo.org

LIGO Livingston Observatory

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Homework

- WileyPLUS online homework: you can login using your paws email xxxNN@lsu.edu as both username and password. If you have not received an email, please register yourself for our section in http://edugen.wiley.com/edugen/class/cls189381/ using your paws email xxxNN@lsu.edu as username.
- First homework assignment posted (Chapters 2-4).
- Homework due date is Monday 9pm (every week).
- On Thursdays, there will be a quiz on homework completed (first quiz on Sept 2).

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Exams, grades

- There will be three 1-hour exams during the semester: Tuesdays September 7, October 12, and November 9, at 6pm and a 2-hour final exam on December 9, 7:30am
- **First "review" exam on September 7 is on Ch 1-7 (material you should know already); it will only have multiple choice questions.**

- Your final grade will be based on 550 total points;
  - HW — 50 pts (grade computed at 90% of the total amount of points)
  - Quiz – 50 pts (lowest 2 dropped – NO make-ups)
  - Review exam – 50 pts.
  - Two regular exams – 100 pts. each
  - Final Exam – 200 pts.

A: 90-100%
B: 80-90%
C: 60-80%
D: 50-60%
F: 0-50%

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Let's start!

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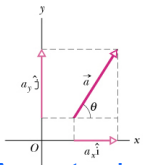
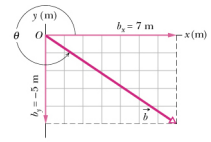


Vectors



- A vector is represented by an arrow in space, with a length (magnitude) and direction (arrow pointing).
- To describe a vector mathematically, we need a coordinate system (x,y,z or east,north and up).
- A vector has three components: $\vec{A} = A_x\,\hat{i} + A_y\,\hat{j} + A_z\,\hat{k}$

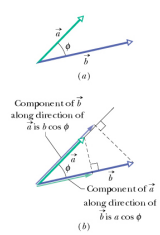
- The magnitude of the vector is $A=(A_x^2+A_y^2+A_z^2)^{1/2}$
- In two dimensions, $\vec{A} = A_x\,\hat{i} + A_y\,\hat{j} = A\left(\cos\theta\,\hat{i} + \sin\theta\,\hat{j}\right)$

Vector multiplication

We can multiply vectors to get …

- a scalar

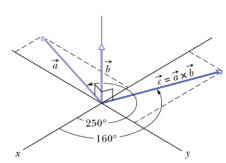
$$\vec{A}\bullet\vec{B} = A_xB_x + A_yB_y + A_zB_z = AB\cos\phi$$



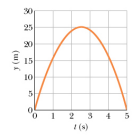
- or another vector

$$\vec{A}\times\vec{B} = (A_yB_z - A_zB_y)\;\hat{i} + (A_zB_x - A_xB_z)\;\hat{j} + (A_xB_y - A_yB_x)\;\hat{k}$$

with magnitude $|\vec{A}\times\vec{B}| = AB\sin\phi$
and direction perpendicular to **A** and **B**

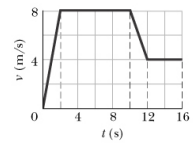


Motion in one dimension



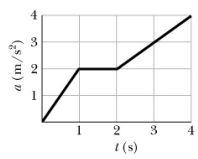
- Position is a function of time: *x(t)*
  (or y(t), or z(t)…)
- Velocity is also a function of time, defined as:

$$v(t) = \frac{dx(t)}{dt} \quad \Rightarrow \quad x(t) = \int_0^t v(t)\,dt$$



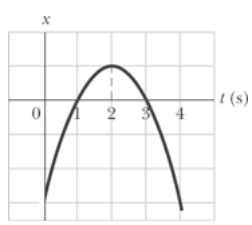
- Acceleration is defined as:

$$a(t) = \frac{dv(t)}{dt} = \frac{d^2x(t)}{dt^2} \quad \Rightarrow \quad v(t) = \int_0^t a(t)\,dt$$



Learn to read information from graphs!

(a) Describe in words the motion of a particle whose position versus time graph is shown below.
(b) When is the particle's velocity zero? Positive? Negative?
(c) When is the acceleration of the particle zero? Positive? Negative?



(a) The particle starts left of the origin moving to the right, it moves through the origin slowing down until it reaches its maximum distance on the right at t=2s, when it stops and begins moving to the left, going throug hthe origin now speeding up until it gets back to the original point at t=4s.
(b) Velocity is positve between t=0s and t=2s, it's zero at t=2s, and it's negative between t=2s and t=4s.
(c) The acceleration is always negative (the velocity is always getting smaller)

The position of an object moving along an *x* axis is given by $x=3t-4t^2+t^3$, where *x* is in meters and *t* in seconds.
Find the position and velocity of the object at the following values of *t*: 1s, 2s, 3s and 4s.
What is the object's displacement between t=0s and t=4s?
What is its average velocity for the time interval from t=2s to t=4s?

[redacted]

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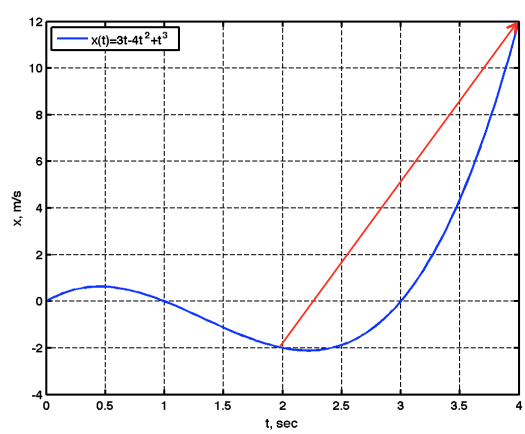
Find the position and velocity of the object at the following values of *t*: 1s, 2s, 3s and 4s.
Ans: 0m, -2m, 0m, and 12m
What is the object's displacement between t=0s and t=4s?
Ans: 12m (but the distance traveled is much longer!)
What is its average velocity for the time interval from t=2s to t=4s?
Ans: distance =14m, time = 2s: avg velocity is 7m/s.



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Constant 1-D acceleration

$$x(t) = x_0 + v_0 t + \frac{1}{2} a t^2$$

$$v(t) = v_0 + a t$$

$$a(t) = a_0$$

the only formulas you need!

$$v^2 = v_0^2 + 2a(x - x_0)$$

$$x = x_0 + \frac{1}{2}(v + v_0)t$$

$$x = x_0 + vt - \frac{1}{2}at^2$$

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Constant acceleration

A model rocket fired vertically from the ground ascends with a constant vertical acceleration of 5 m/s^2 for 6 s. Its fuel is then exhausted, so it continues upward as a free-fall particle and then falls back.
Assume g~10 m/s^2.

- Plot the acceleration, velocity and position as a function of time.
- What is the maximum altitude reached?
- What is the total time elapsed from take off until the rocket strikes the ground?

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- Plot the acceleration, velocity and position as a function of time.
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- What is the total time elapsed from take off until the rocket strikes the ground?

For t<6s,
$a(t) = +5\ m/s^2$ (up);
$v(t) = 5\ t\ m/s^2$ (up);
$z(t) = 2.5\ t^2\ m/s^2$ (up)

We know that v(6s)=+30 m/s= v_0 - 60 m/s

We know that z(6s)=+90 m= z_0 + 540 m – 180m

For t>6s,
$a(t) = -10\ m/s^2$ (down);
$v(t) = v_0 - 10\ t\ m/s^2 = 90\ m/s - 10\ t\ m/s^2$ (up until t=9s, then down)
$z(t) = z_0 + v_0\ t - ½\ at^2 = -270m + 90\ t\ m/s - 5\ t^2\ m/s^2$

Maximum altitude at t=9s: z(9s)=135m
Reaches ground when z=0. Two solutions: t=3.8s (wrong), 14.2 s (right)

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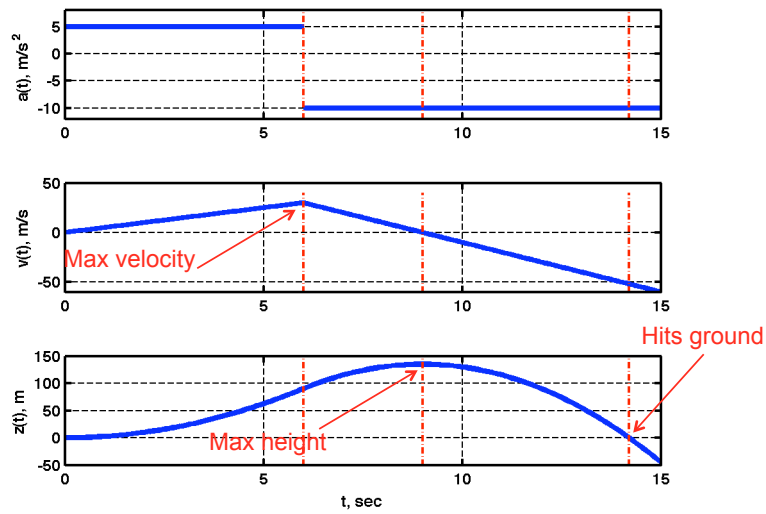

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Motion in ~~one~~ two, three… dimension

- Position is a vector, function of time:

$$\vec{r}(t) = x(t)\ \hat{i} \ + \ y(t)\ \hat{j} \ + \ z(t)\ \hat{k}$$

- Velocity:

$$\vec{v}(t) = \frac{d\vec{r}(t)}{dt} \quad \Rightarrow \quad \vec{r}(t) = \int_0^t \vec{v}(t)\ dt$$

- Acceleration:

$$\vec{a}(t) = \frac{d\vec{v}(t)}{dt} = \frac{d^2\vec{r}(t)}{dt^2} \quad \Rightarrow \quad \vec{v}(t) = \int_0^t \vec{a}(t)\ dt$$

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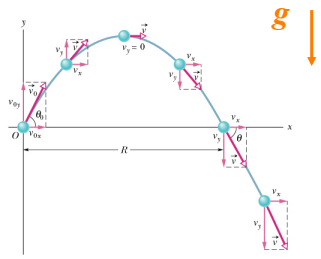
2-D motion: Projectile motion

Motion in two dimensions, with constant acceleration:



$$\vec{a}(t) = -g\,\hat{j}$$

$$\vec{v}(t) = \vec{v}_0 - gt\,\hat{j}$$

$$\vec{x}(t) = \vec{x}_0 + \vec{v}_0 t - \frac{1}{2} g t^2\,\hat{j}$$

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Projectile motion

A football player punts the football so that it will have a "hang time" (time of flight) of 5 s and land 50m away. If the ball leaves the player's foot 150cm above the ground, what must be the magnitude and direction of the ball's initial velocity?

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$a(t) = -9.8\ m/s^2\ j$
$v(t) = v_{0x}\ i + (v_{0y} - 9.8\ t\ m/s^2)\ j$
$r(t) = v_{0x}\ t\ i + (1.5m + v_{0y}\ t - 4.9\ t^2\ m/s^2)\ j$

We know that at t=5s, r(t)=50m i, so:
$50m = v_{0x} \times 5s \rightarrow v_{0x} = 10\ m/s$
$0m = 1.5m + v_{0y}\ 5s - 4.9 \times 25\ s^2\ m/s^2 = -121\ m/s + v_{0y}\ 5s \rightarrow v_{0y} = 24.2\ m/s$

Velocity magnitude: $v = \sqrt{(10^2 + 24.2^2)}\ m/s = 26.2\ m/s$
Velocity direction: $\theta = atan(24.2/10) = 67.5^o$

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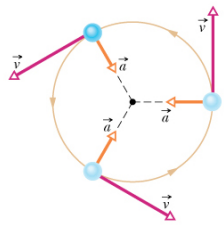
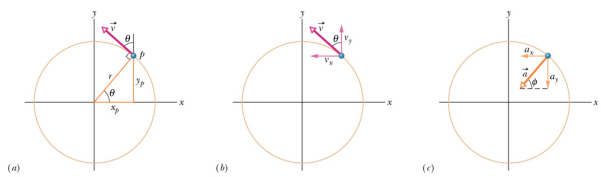
2-D motion: Uniform circular motion



$$\vec{r} = x\ \hat{i} + y\ \hat{j}$$
$$= R(\cos\theta\ \hat{i} + \sin\theta\ \hat{j})$$
$$\vec{r}(t) = R(\cos\omega t\ \hat{i} + \sin\omega t\ \hat{j})$$
$$\vec{v}(t) = R\omega(-\sin\omega t\ \hat{i} + \cos\omega t\ \hat{j})$$
$$\vec{a}(t) = -R\omega^2(\cos\omega t\ \hat{i} + \sin\omega t\ \hat{j})$$

- Uniform: constant speed (angular speed = ω, linear speed=v=ωR)
- Circular: constant radius R, velocity vector is not constant!
- Acceleration: constant magnitude, points towards the center
- a = v^2/R : smaller radius with same speed needs larger acceleration



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Uniform circular motion

A rotating fan completes 1200 revolutions every minute.
Consider a point on the tip of a blade, at a radius of 0.1 m.

(a) Through what distance does the point move in one revolution?
(b) What is the speed of the point?
(c) What is the magnitude of its acceleration?
(d) What is the period of the motion?

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