PHY117 HS2024

Find the lecture notes for today here:

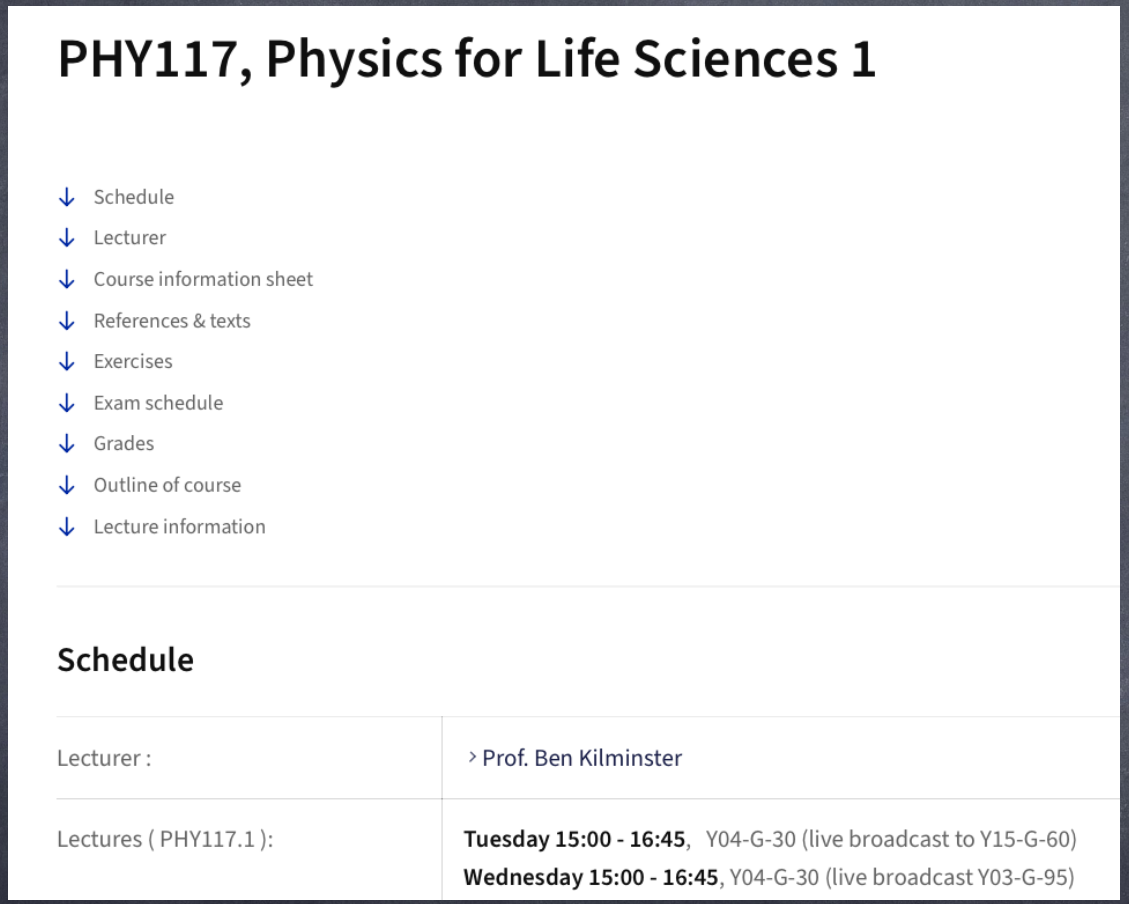
https://www.physik.uzh.ch/de/lehre/PHY117/HS2024.html

Prof. Ben Kilminster

Sept. 17th, 2024

Week 1, Lecture 1

Web page : https://www.physik.uzh.ch/de/lehre/PHY117/HS2024.html



PHY117, Physics for Life Sciences 1

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- Lecturer
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Schedule

Lecturer :	› Prof. Ben Kilminster
Lectures (PHY117.1):	**Tuesday 15:00 - 16:45**, Y04-G-30 (live broadcast to Y15-G-60) **Wednesday 15:00 - 16:45**, Y04-G-30 (live broadcast Y03-G-95)

Lectures and reference materials will be uploaded here

Course sheet (1): (on website)

PHY 117 HS 2024

Physics II for Biomed (Modern Physics)
Lectures: Tuesdays 13:00-15:00, Wednesdays 13:00-15:00 **Y04-G-30** (overflow Tues: Y15-G-60, Wed: Y03-G-95)

Professor Ben Kilminster (Email ben.kilminster@physik.uzh.ch)
Prof. K's office hours : 36-J-50 Tuesdays 12:00-13:00 (or by appointment)
Class page: https://www.physik.uzh.ch/de/lehre/PHY117/HS2024.html (user: physik-phy117, pass: einstein5%)

Teachers assistants :
Frau Ruth Bründler (ruth.bruendler@physik.uzh.ch) (English/German speaking) (In charge of exercises & sessions)
Fanqiang Meng (fanqiang.meng@uzh.ch) (English/Mandarin/Cantonese speaking) In-class TA

Exercise session groups :

1	**Classes**	Alessio Tassone	atassone@student.ethz.ch
2		Anson Kwok	tsz.hong.kwok@physik.uzh.ch
3		David Ulloa	dulloa@student.ethz.ch
4		Erin Barillier	erinbari@umich.edu
5		Eslam Shokr	eslam.shokr@physik.uzh.ch
6		Haojie Geng	haojie.geng@uzh.ch
7		Martha Rösler	martha.roesler@uzh.ch
8		Martin Schweighoffer	martin.schweighoffer2@uzh.ch
9		Miguel Hernandez	miguel.hernandez@physik.uzh.ch
10		Ozan Zeray	ozan.zeray@uzh.ch
11		Samuel Hauser	samuel.hauser@uzh.ch
12		Thomas Maher	thomas.maher@uzh.ch
13		Urs Boison	urs.boison@uzh.ch
14		Valeriia Lukashenko	valeriia.lukashenko@physik.uzh.ch
15		Yannic Göldi	yannic.goeldi@uzh.ch

Course sheet (2):

References:
Kilminster Physics 1 & 2 scripts (available on the course web site)
Introductory university physics text book. I use the following :

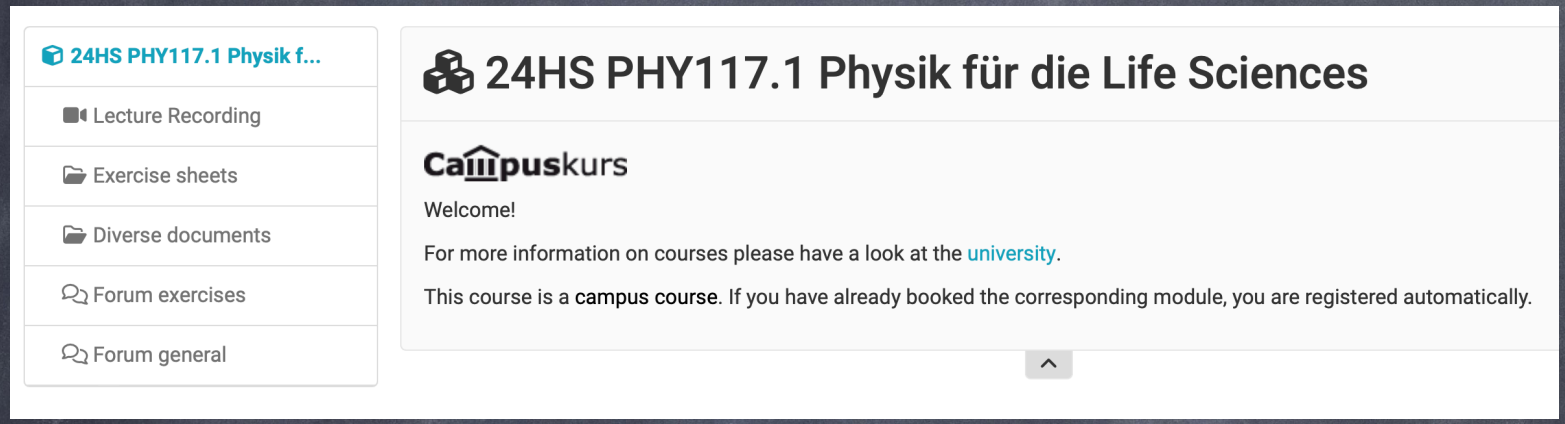
Tipler (Very good explanations, main text I follow)
Halliday & Resnick
Young & Freedman

(But these are all very similar. Find any one that explains the physics well for you.)

Assessments : **Please register on OLAT:** https://lms.uzh.ch/ This is how we send you assignments
Please log in to see if you can access the course. If not, check your UZH email is registered properly.

1) You will be assigned to one exercise session: Monday 13:00-15:00, 15:00-17:00, Thursday 8:00-10:00, 13:00-15:00, 15:00-17:00; Friday 8:00-10:00, 13:00-15:00. First exercise session: Monday Sept. 23rd. thursday
2) Written exercises: New exercise sheet every week, assigned on Monday/Tuesday. First homework assigned Sept. 25th/26th. You will not be graded on these. You should attempt to **solve the problems on your own** since this develops the neutral circuitry necessary to solve exercises. (To pass final exam!!)
3) TAs will show how to solve assigned weekly exercise sheets, answer questions, and go through additional exercises if time. TAs will keep an attendance list. **Note: You really have to go to the exercise sessions.** This is where you learn how to solve problems. In your exams, you will have to solve very similar problems. One problem will be almost the same. Remember, you will need to practice solving exercises **yourself.**
4) **Final exam. (Jan. 15th).** UZH exam schedule
   a. Exam style :
      1. **Similar style to written exercises, but different.** (Memorizing solutions doesn't help)
      2. Will be in German and English
      3. Expect question from exercise sessions & relating to experiments shown in lecture
      4. Formula sheet will be provided. (No private information allowed.)
5) Grade : 100% final exam

Make sure you are registered for OLAT at lms.uzh.ch



FAQ

Q: When do I get assigned to an exercise session?
A: Registration ends Sept. 20th, assignments will be published Sept. 23rd.
First exercise sessions: Sept. 26th. Thursday

For all questions not directly related to the lecture PHY 117 (e.g. Questions about booking chemistry, mathematics or biology modules):
-> Studienberatung from biologists/biomedical scientists or the relevant subject

For other questions related to the booking of PHY 117 (e.g. late booking), exercise group assignments:
-> Frau Bründler (ruth.bruendler@physik.uzh.ch)

For questions about the content of the exercises:
-> Frau Bründler (ruth.bruendler@physik.uzh.ch)

OLAT Forum for questions on lecture or exercises

For questions about how to solve exercises:
-> Contact the TA of your assigned exercise group

For questions about the transfer of credits from previous physics lectures (e.g. PHY 118 or lectures at ETH):
-> Christof Aegerter (aegerter@physik.uzh.ch)

Reference materials

Physics I:
Introduction to physics

Prof. Ben Kilminster

Introduction to mechanics, waves, and fluid dynamics

This script is the first part of an undergraduate course in introductory physics. It is typically taught in the first semester, with part 2 often taught in the second semester. The level of material is appropriate for physics majors as well as those in the life sciences. The latter may not be expected to learn the full level of detail included that would be expected of physics majors, but may still benefit from the additional material in order to understand better. It is recommended that students should be already familiar with geometry and also take or have taken a class in mathematics that covers vectors and calculus (derivatives and integrals).

Reference materials

Physics II:
Introduction to physics

PHYSIK INSTITUT
UNIVERSITÄT ZÜRICH

PROF. BEN KILMINSTER

INTRODUCTION TO ELECTRICITY, MAGNETISM, ELECTROMAGNETISM, AND THERMODYNAMICS

This script is the second part of an undergraduate course in introductory physics. It is typically taught in the second semester, with part 1 often taught in the previous semester. The level of material is appropriate for physics majors as well as those in the life sciences. The latter may not be expected to learn the full level of detail that would be expected of physics majors, but may still benefit from the additional material in order to understand some concepts in more depth. It is recommended that students should be already familiar with geometry and also take or have taken a class in mathematics that covers vectors and calculus (derivatives and integrals).

Reference materials

PHY 117 — Physics Terms helper — Prof. Ben Kilminster

physical quantity (SI base units in blue) (radiation physics units)	Deutsch	Symbol	SI unit	Simplified Formula to help with units	in other SI units	typical units in radiation physics	conversions
Length	Länge	ℓ	meter = m				
time	Zeit	t	second = s				
velocity	Geschwindigkeit	v	m/s			c=~3E8 m/s	
acceleration	Beschleunigung	a	m/s^2				
mass	Masse	m	kilogram = kg			$1eV/c^2$	$1eV/c^2$ = 1.78E-36 kg
momentum	Impuls	p	kg*m/s	p=mv			
force	Kraft	F	Newton = N	F = ma	$1N = kg*m/s^2$		
torque	Drehmoment	τ	N*m	$\tau = rF \sin\theta$	$kg*m^2/s^2$		
energy, work	Energie, Arbeit	E, W	Joule = J	W = Fx	$1J = kg*m^2/s^2$	1eV	1eV = 1.602E-19J
power	Leistung	P	Watt = W	P = E/t	$1W = kg*m^2/s$		
pressure	Druck	p	Pascal = Pa	p = F/area	$1Pa=1N/m^2$		
Electrical charge	Elektrische Ladung	q	Coulomb = C			e = electron charge	1e = 1.602E-19C

German-english helper

physical quantity (SI base units in blue) (radiation physics units)	Deutsch	Symbol	SI unit	Simplified Formula to help with units	in other SI units
Electrical current	Stromstärke	I	Ampere = Amp = A	I = q/t	1A=1C/s
Electric potential	Elektrische Spannung	V or ϕ	Volt = V	Power = IV	1V = 1W/A
Electric field	Elektrisches Feld	E	N/C = V/m		
Magnetic field	Magnetische Flussdichte	B	Tesla = T	$F=BI\ell$	1T=1N/(A*m)
Resistance	Elektrischer Widerstand	R	Ohms = Ω	V = IR	1Ω = 1V/A
Capacitance	Elektrische Kapazität	C	Farad = F	C=q/V	1F = 1C/V
Temperature	Temperatur	T	Kelvin = K		
amount of substance	Stoffmenge	N	Mol		
luminous intensity	Lichtstärke	I_v	Candela = cd		
radioactivity	Radioaktivität	A_{Bq}	Becquerel = Bq		1/s
Absorbed dose	Energiedosis	D_T	Gray = Gy		m^2/s^2 = J/kg
Equivalent dose	Åquivalentdosis	H_T	Sievert = Sv		m^2/s^2 = J/kg

Formula sheet (same as final exam)

PHY117 Formula Sheet

Mechanics

Velocity	$\vec{v} = \frac{d\vec{r}}{dt}$
Speed	$v = \lvert\vec{v}\rvert$
Acceleration	$\vec{a} = \frac{d\vec{v}}{dt}$
Acceleration components	$a_r = \frac{v^2}{r}$ and $a_T = \frac{d\lvert\vec{v}\rvert}{dt}$
Position	$x(t) = x_0 + v_0 t + \frac{1}{2}at^2$
Velocity	$v^2 = v_0^2 + 2a\Delta x$ and $v(t) = v_0 + at$
Newton's second law	$\sum \vec{F} = m\,\vec{a}$
Newton's third law	$\vec{F}_{12} = -\vec{F}_{21}$
Gravitational force	$\vec{F}_g = m\vec{g}$
Gravitational force law	$\vec{F}_g = \frac{Gm_1m_2}{r^2}$
Newtons second law of rotation	$\sum \tau = I\alpha$
Centripetal force	$F_r = \frac{m\,v^2}{r} = mr\omega^2$
Centripetal acceleration	$a_r = \frac{-v^2}{r}\hat{r} = -r\omega^2\hat{r}$
Angular position	$\Delta s = r\Delta\theta$ and $\theta(t) = \theta_0 + \omega_0 t + \frac{1}{2}\alpha t^2$
Angular velocity	$\omega = \frac{d\vartheta}{dt} = \frac{v}{r}$ and $\omega = \frac{2\pi}{T}$ and $\omega = \omega_0 + \alpha t$
Angular acceleration	$\alpha = d\omega/dt$
Angular momentum	$\vec{L} = \vec{r} \times \vec{p}$ and $\vec{L} = I\vec{\omega}$
Coordinates center of mass	$r_{cm} = \frac{\sum_i^n m_i\, r_i}{\sum_i^n m_i}$
Torque	$\vec{\tau} = \vec{r} \times \vec{F}$ and $\vec{\tau} = \frac{d\vec{L}}{dt}$
Impulse	$\vec{F}\Delta t = \Delta\vec{p} = m\Delta\vec{v}$

Energy and work

Kinetic energy:	$K = \frac{1}{2}mv^2$
Potential energy (gravity)	$U = mgh$
Potential energy (spring)	$U = \frac{1}{2}kx^2$
Work	$W_{1\to2} = \int_1^2 \vec{F}d\vec{r}$ and $W_{1\to2} = \int_1^2 \tau d\theta$
Work-energy theorem	$W_{1\to2} = K_2 - K_1$ and $W = \Delta K = -\Delta U$
Work and potential energy	$\Delta U = -W$
Law of conservation of energy	$K + U =$ constant

Fluids

Hydrostatic

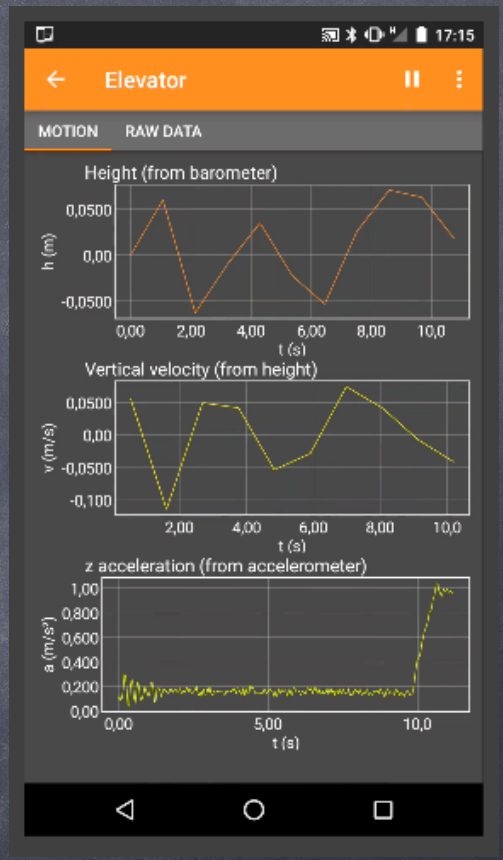
Pressure	$p = \frac{F}{A}$
Compressibility	$B = -\frac{p}{\frac{\Delta V}{V}}$
Pressure distribution in liquids	$p = p_0 + \rho gh$
Capillarity	$\Delta h = \frac{2\gamma\,\cos\theta_c}{\rho g r}$
Buoyancy	$F_b = \rho_l V_{\text{dis}} g$
Bouyancy in centrifuge	$F_b = m_l\omega^2 r$
Centrifugal "force"	$F_c = m_o\omega^2 r$

Hydrodynamics

Flow rate	$I_V = \frac{\Delta V}{\Delta t} = Av$ v: homogeneous velocity
Continuity equation	$I_V =$ constant $\Rightarrow v_1 A_1 = v_2 A_2$

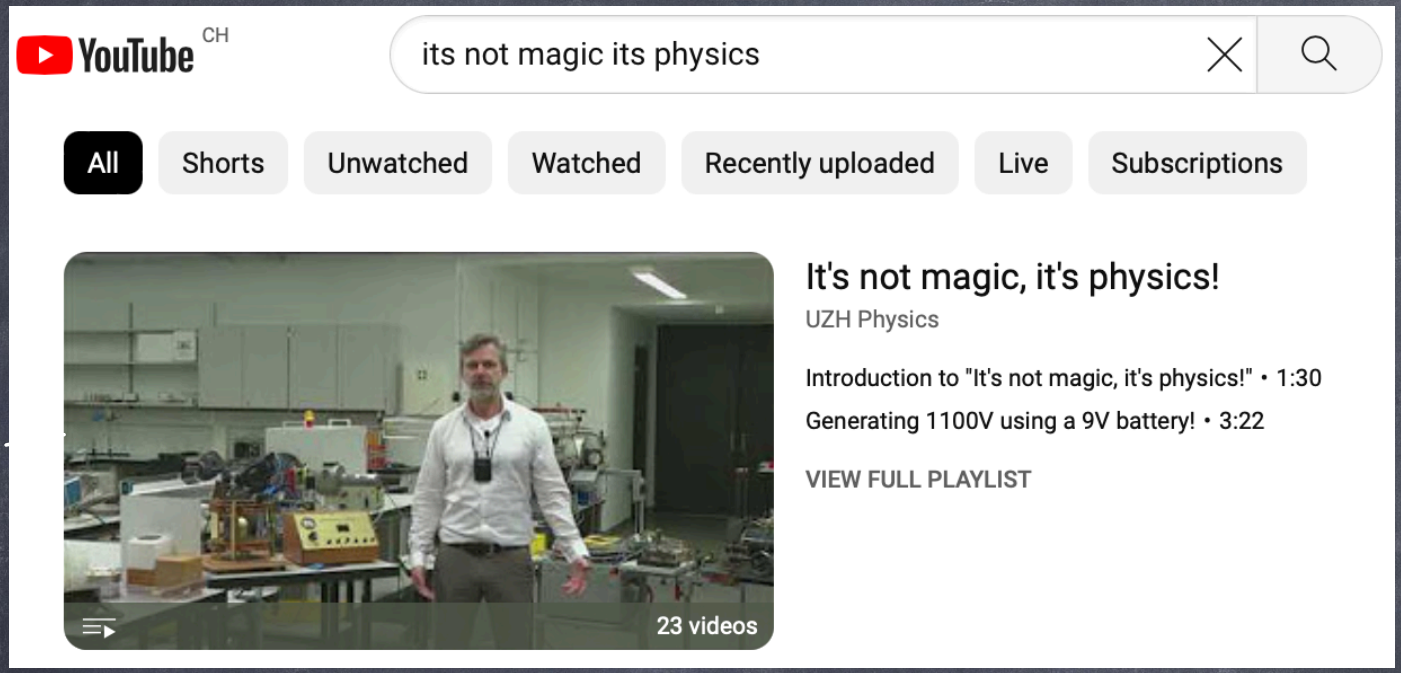
If you need extra help, ↘

Tools for exercises



Download for your smartphone:
(If your handy is not so handy, find a partner)

Youtube channel



https://youtu.be/tR4B0jQ0DPU?feature=shared

Physics

Deals with matter, energy, & the principles of motion for particles and waves.

- Interactions of particles
- Properties of:
  - small [molecules, atoms, nuclei, quarks]
  - large [gases, liquids, solids]

Physics explains the basics of chemistry, biology, geology, astronomy, cosmology, ...

PN4117 is the foundation for PN4127 (modern physics) will allow you to understand measurement & diagnostics tools like MRI, NMR, PET scans, CT scans, x-rays, synchrotrons, free electron lasers.

Some basic units

measurement	symbol	unit
distance	x	meter [m]
time	t	second [s]
mass	m	kilogram [kg]

From these units, we can derive other units

velocity	$v = \frac{x}{t}$	$\frac{m}{s}$
acceleration	$a = \frac{v}{t}$	$\frac{m}{s^2}$
Force	$F = ma$	$\frac{kg \cdot m}{s^2} \rightarrow$ Newton [N]
Energy	$E = F \cdot x$	$\frac{kg\,m^2}{s^2} \rightarrow$ Joule [J]

Dimensional analysis of units is a powerful tool

Is this a valid formula?

$$x = \frac{\epsilon}{F} + vt + \frac{a}{V}$$

Do the units work?

$$[m] \stackrel{?}{=} \frac{\frac{kg\,m^2}{s^2}}{\frac{kg\,m}{s^2}} + \frac{m}{s}\cdot s + \frac{\frac{m}{s^2}}{\frac{m}{s}}$$

$$[m] \neq [m] + [m] + \left[\frac{L}{s}\right]$$

NO

How many meters does light travel in one year?

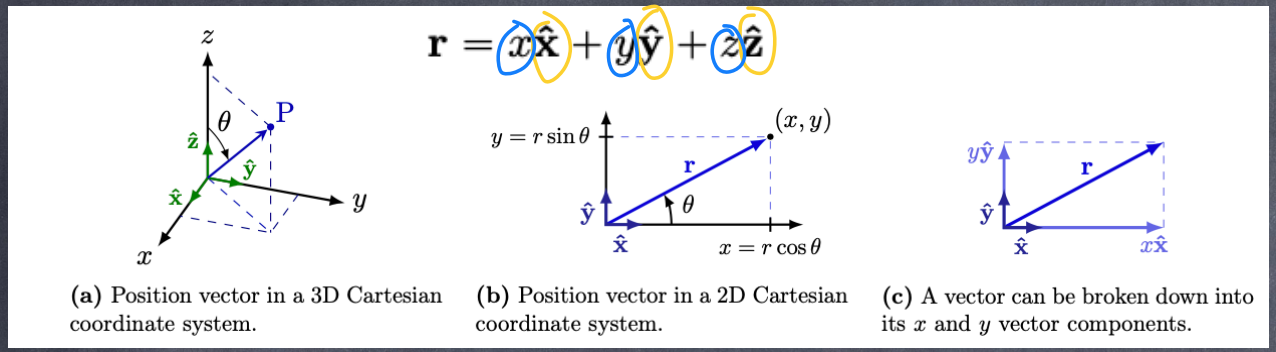
$$C = \underbrace{3.00}_{\text{3 significant figures}} \epsilon 8 \ \frac{m}{s}$$

$$x = v\cdot t = c\cdot t = \left(3.00\epsilon 8 \frac{m}{s}\right)(1\,year)\left(\frac{365\,d}{1\,year}\right)\left(\frac{24\,h}{1\,d}\right)\left(\frac{60\,min}{1\,h}\right)\left(\frac{60\,s}{1\,min}\right)$$

$$x = \underbrace{9.46}_{\text{3 significant figures}} \epsilon 15 \ m$$

$\therefore$

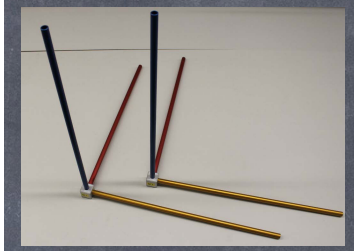
Vectors are useful for describing a quantity that has a magnitude & direction. (distance, velocity, force, ..)



(a) Position vector in a 3D Cartesian coordinate system.

(b) Position vector in a 2D Cartesian coordinate system.

(c) A vector can be broken down into its x and y vector components.



A vector has components that are perpendicular (⊥)

The symbol for a vector $\bar{r}$ or $\vec{r}$ or $\mathbf{r}$

unit vectors: $\hat{x}, \hat{y}, \hat{z}$ $\quad |\hat{x}| = |\hat{y}| = |\hat{z}| = 1$

The magnitude or length of a vector in 3-D is:

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

Example: $\bar{a} = 3\hat{x} + 2\hat{y} - 4\hat{z}$ $\quad |\bar{a}| = \sqrt{3^2 + 2^2 + (-4)^2} = \sqrt{29}$

In the script, you find rules for vector operations.
dot product $\bar{a} \circ \bar{b}$
(als. taught in MAT.182)

Motion is described by formulas (or functions) of time:

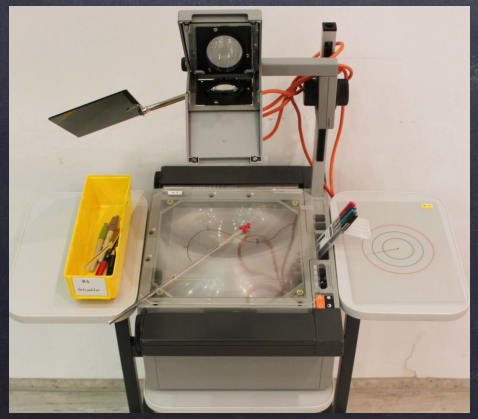
$$x = x(t)$$
$$y = y(t)$$
$$z = z(t)$$

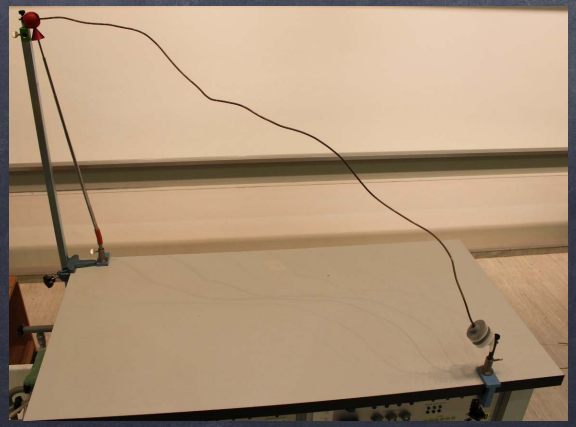
means that the formula depends on time.

Each component can be treated separately although time is the same in each formula.

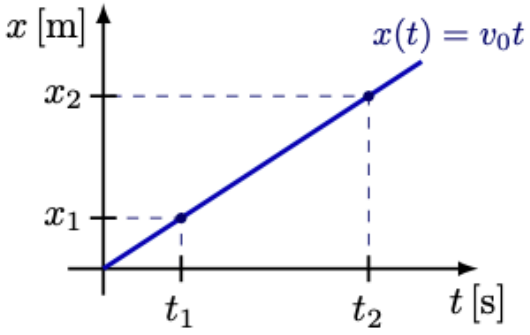
The motion in 3 dimensions is described by a vector that depends on time

$$\vec{r}(t) = x(t)\,\hat{x} + y(t)\,\hat{y} + z(t)\,\hat{z}$$

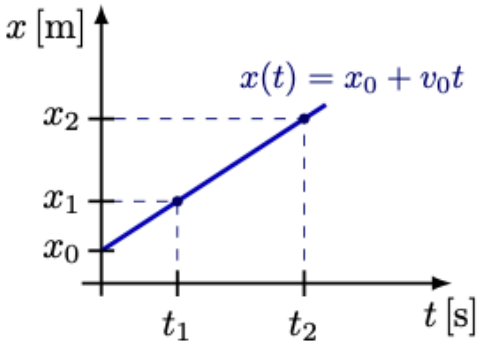




Motion in 1-dimension : constant velocity



(a) Starting at $x(0) = 0$ at $t = 0$.



(b) Starting at an offset $x(0) = x_0$ at $t = 0$

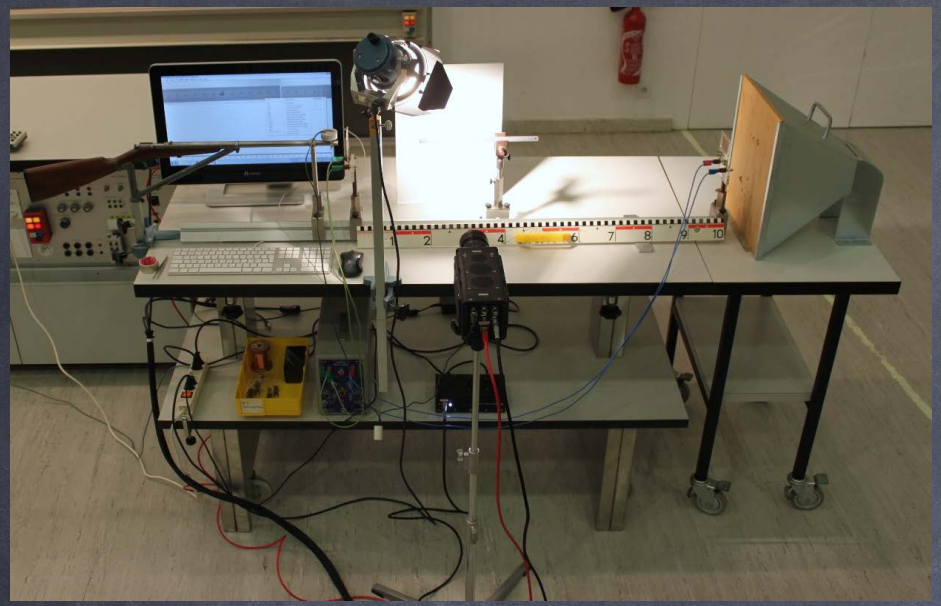
velocity is the slope of x vs. t

$$v = \frac{x_2 - x_1}{t_2 - t_1} = v_0$$ (initial velocity) doesn't change

$$x(t) = x_0 + v_0 t$$

constant velocity, 1 direction

Is our bullet faster than the speed of sound ? (343 $\frac{m}{s}$)



$1.4 \Rightarrow 7.6$ cm

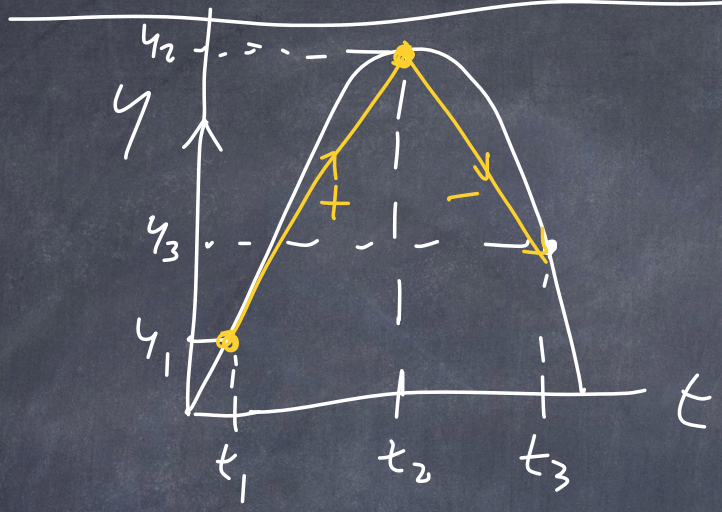
$\Delta x = 7.6 - 1.4\,\text{cm} = 6.2\,\text{cm}$

$\Delta t = 6$ frames

1 frame $\left[\begin{array}{l} 25{,}000 \text{ Frames/sec} \\ \uparrow \\ \Delta t = \frac{1}{25{,}000\ f/s} = \\ = 0.00004\ s \\ = 4\epsilon\text{-}5\ s \end{array}\right.$

$$V = \frac{\Delta x}{\Delta t} = \frac{0.062\ m}{6(4\epsilon\text{-}5\ s)} = 258\ \frac{m}{s}$$

what if velocity changes?



+ y

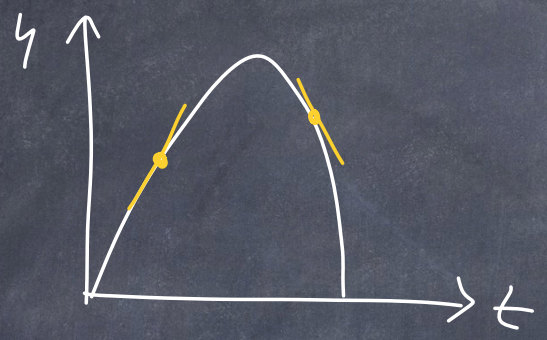
example:
something thrown up in the air

we can calculate an average velocity between any two points:

$t_1 \to t_2$: $V = \dfrac{y_2 - y_1}{t_2 - t_1}$ + slope

$t_2 \to t_3$: $V = \dfrac{y_3 - y_2}{t_3 - t_2}$ − slope

As time Δt gets smaller, we approach the instantaneous velocity at each moment in time.



The tangent of the curve of distance vs. time is the instantaneous velocity

As $\Delta t \to 0$ (As Δt approaches 0)

vector

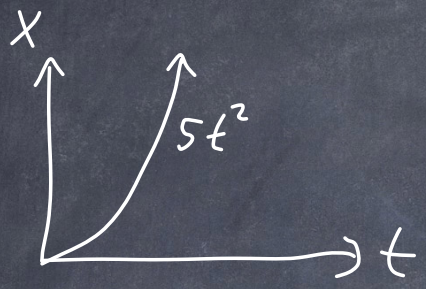
$$\vec{V} = \lim_{\Delta t \to 0} \frac{\Delta y}{\Delta t} = \frac{dy}{dt} = \text{slope of the line tangent to the } y \text{ vs. } t \text{ curve}$$

magnitude of $\frac{dy}{dt}$ is $\left|\frac{dy}{dt}\right| = \text{speed}$

↑ not a vector

ex: If $x(t) = 5\left(\frac{m}{s^2}\right) t^2$, then what is $v(t)$?

(check units: $[m] = \frac{m}{s^2} s^2$)



Let's calculate $v(t)$ the "old-fashioned" way.

we know $x(t) = 5t^2$

At a later time, $t + \Delta t$, the position is:

$$x(t+\Delta t) = 5(t+\Delta t)^2 = 5t^2 + 10t(\Delta t) + 5(\Delta t)^2$$

The change $\Delta x = x(t+\Delta t) - x(t)$

$$\Delta x = 5t^2 + 10t(\Delta t) + 5(\Delta t)^2 - 5t^2$$

$$\Delta x = 10t(\Delta t) + 5(\Delta t)^2$$

The average velocity $= \frac{\Delta x}{\Delta t} = \frac{10t(\Delta t) + 5(\Delta t)^2}{\Delta t} = 10t + 5\Delta t$

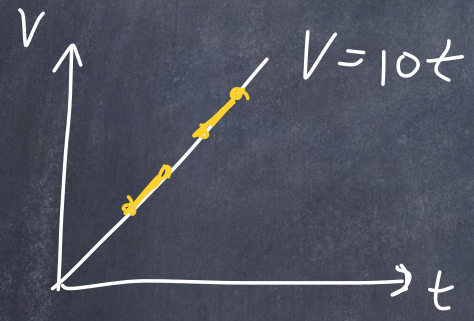
The instantaneous velocity $V = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = 10t + 5\Delta t^{0}$

$V = 10t$

with units $V = 10\left(\frac{m}{s^2}\right)t$

what about the acceleration?

$a = \lim_{\Delta t \to 0} \frac{\Delta V}{\Delta t} = \frac{dv}{dt}$



slope is constant

this is the line tangent to the V vs. t curve.

Repeat, we find that

$\Delta V = V(t+\Delta t) - V(t)$

$= 10(t+\Delta t) - 10t$

$= 10t + 10\Delta t - 10t$

$= 10\Delta t$

$a = \frac{\Delta V}{\Delta t} = \frac{10\,\Delta t}{\Delta t} = 10$

$$a = \frac{dv}{dt} \qquad v = \frac{dx}{dt}$$

$$a = \frac{d}{dt}\left(\frac{dx}{dt}\right) = \frac{d^2x}{dt^2}$$

acceleration is the second derivative of the position "with respect to" (wrt) time.

MAT. 182

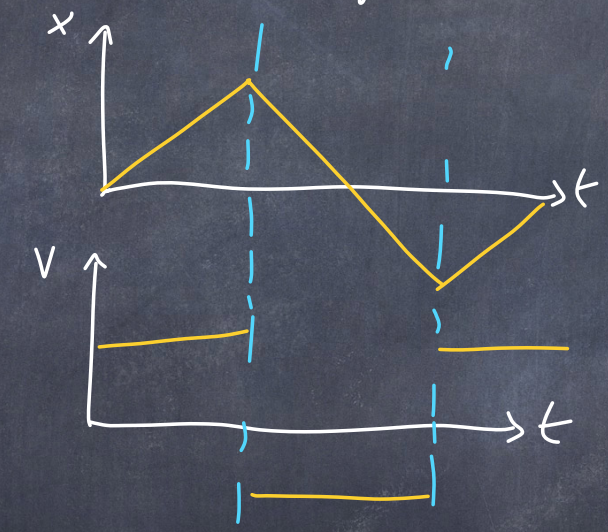
General rules for derivatives:

IF $x(t) = ct^n$ ← n ← number

↑ constant

then $\frac{dx}{dt} = cnt^{n-1}$

Air car experiment:

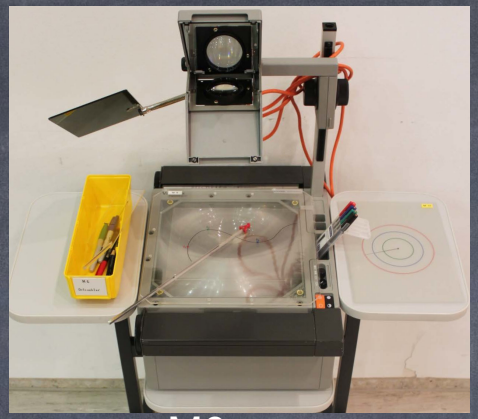


velocity is the slope of x vs. t

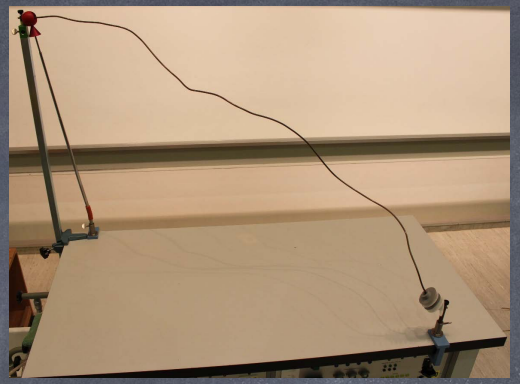
acceleration is the slope of v vs. t

Experiments

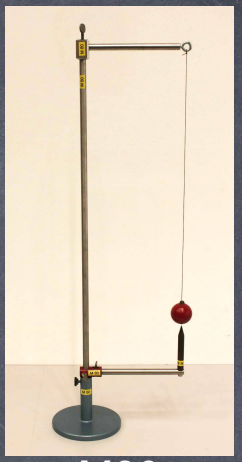
M1



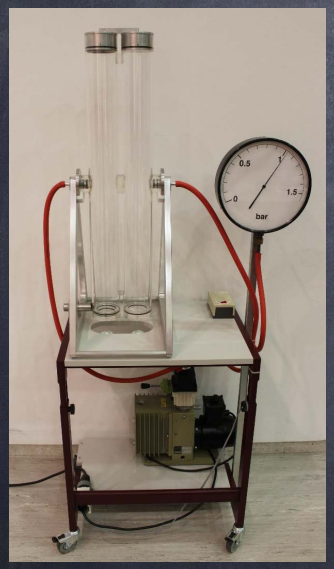
M6



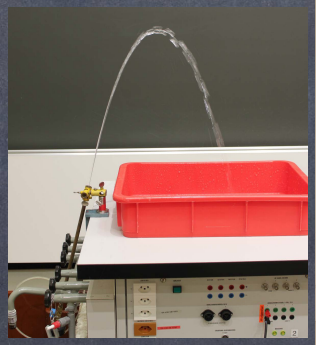
M10



M80

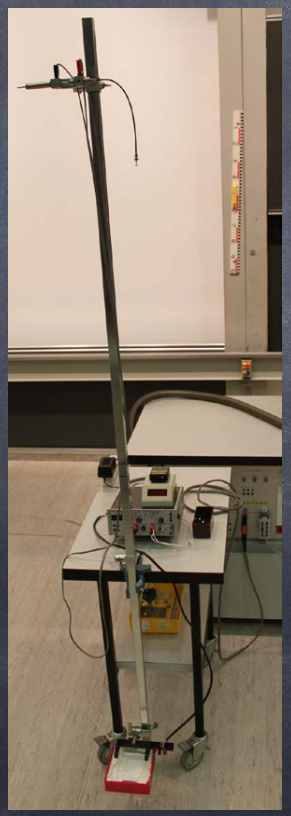


M46



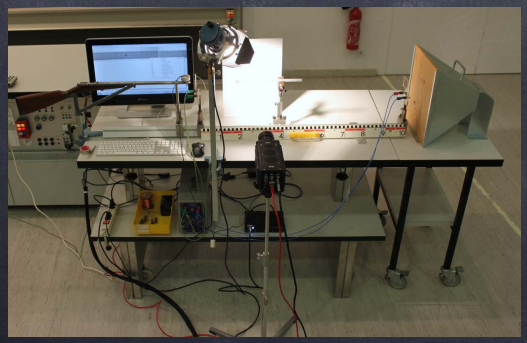
M48

M82



M40

M198



M12

M27