PHY127

Prof. Ben Kilminster

Lecture 1

Feb. 24th, 2023

we will cover modern physics in a way that targets modern techniques in medical & biology / chemistry research.

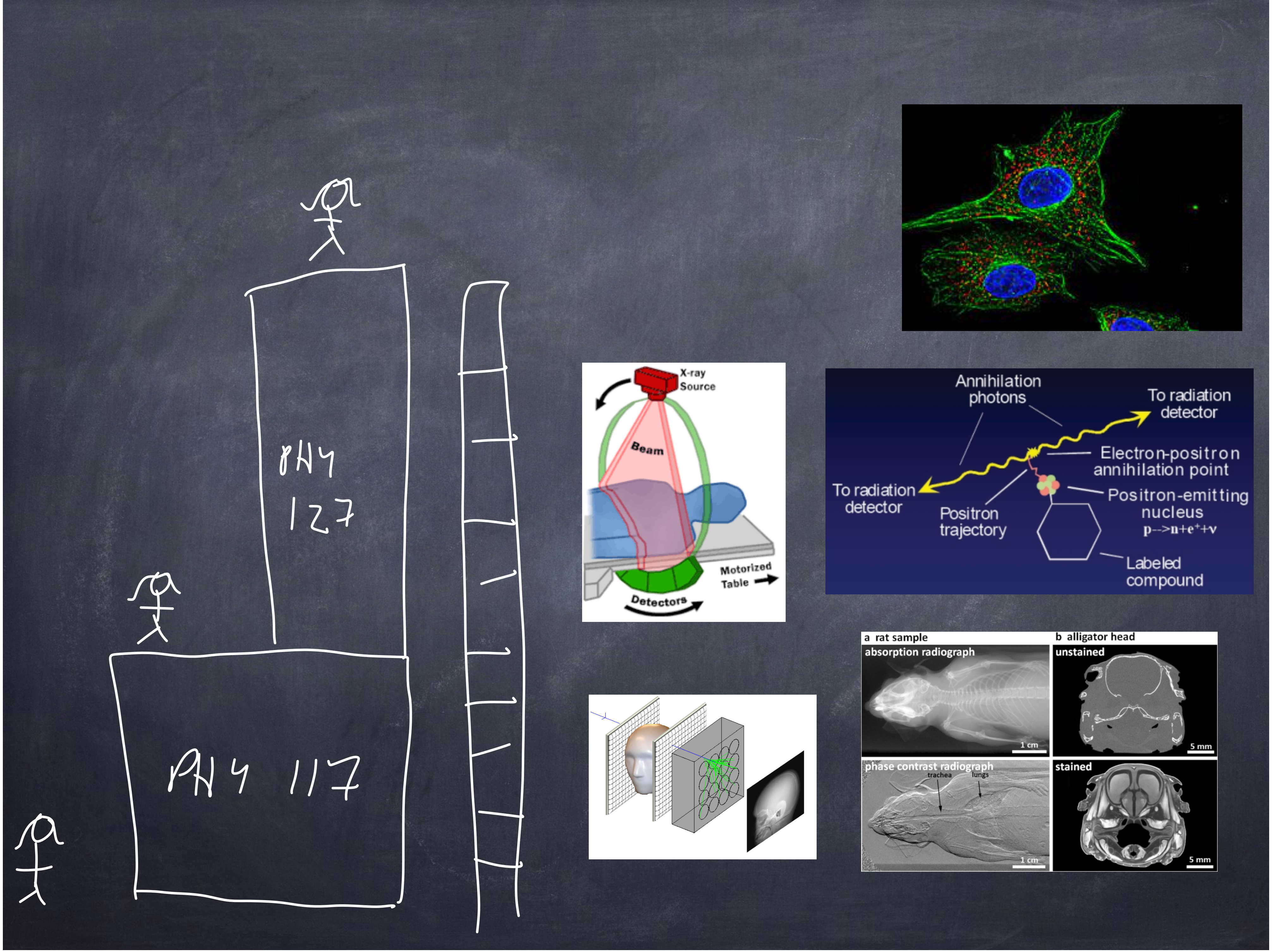
<u>physics</u>

- atomic physics
- nuclear physics
- particle physics
- anti-matter
- radiation
- relativity
- quantum physics

⟹

<u>bio-med</u>

- x-rays
- x-ray computed tomography
- CT scans
- PET scans
- NMR, MRI
- medical diagnostics
- treatment
- imaging


PHY 127
PHY 117
X-ray Source
Beam
Detectors
Motorized Table
Annihilation photons
To radiation detector
Electron-positron annihilation point
To radiation detector
Positron trajectory
Positron-emitting nucleus
p-->n+e$^+$+v
Labeled compound
a rat sample
absorption radiograph
1 cm
phase contrast radiograph
trachea
lungs
1 cm
b alligator head
unstained
5 mm
stained
5 mm

PHY 127 FS 2023

Physics II for Biomed (Modern Physics)
Lecture : Fridays 8:00-10:00, Y15-G20

Professor Ben Kilminster (Email ben.kilminster@physik.uzh.ch)
Prof. K's office hours : 36-J-50 Fridays 10:30 – 11:30 (or by appointment)
Class page: https://www.physik.uzh.ch/de/lehre/PHY127/FS2023.html (user: physik-phy127, pass: maxwell5%)

Teachers assistants :
Frau Ruth Bründler (ruth.bruendler@physik.uzh.ch) (English/German speaking) (In charge of exercises&sessions)
Matias Senger (matias.senger@physik.uzh.ch) (English/Spanish speaking) In-class TA

Exercise session groups :

Name		Mail address	class room
Sara	Erni	sara.erni@uzh.ch	03-G-95/44-H-05
Yannic	Göldi	yannic.goeldi@uzh.ch	27-H-35/36
Simon	Giesch	simon.giesch@uzh.ch	22-F-62
Patrick	van Workum	patrickblakemillen.vanworkum@uzh.ch	22-F-68
Alec	Strassen	alecmichael.strassen@uzh.ch	21-F-70
José	Cuenca Garcia	josejavier.cuencagarcia@physik.uzh.ch	23-G-04
Yuri	van der Burg	yuri.vanderburg@uzh.ch	36-K-08
James	OLeary	james.oleary@uzh.ch	23-G-04
Philipp	Maier	philippemanueljan.maier@uzh.ch	22-F-62
Maximinio	Adrover	maximinio.adrover@uzh.ch	22-F-68
Heba	Hussein	heba.hussein@uzh.ch	21-F-70
Mariana	Rajado	mariana.rajado@physik.uzh.ch	36-J-33

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 physics well for you.)
For modern physics, I will point you to other online resources when relevant.

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) Exercise sessions: Tuesdays/Wednesdays, 13:00-16:00, starting Feb. 28th. You will be assigned to a group above by Feb. 27th. TAs will explain homeworks, 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 similar problems. One problem will be the same.**

2) Written exercises: every 2 weeks. These will be assigned on Fridays, explained on the following Tuesday/Wednesday, and solutions will be presented the following week. First homework assigned Feb 24th.

3) Final exam. (date not known yet). UZH exam schedule

a. **Exam style :**
   1. **Similar style to written exercises**
   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.)**

4) Grade : 100% final exam

06:29 Fri 24 Feb 50%

physik.uzh.ch

Universität Zürich » de » Lehre » PHY127 Physik für Life Sciences II » FS2022

Google Suche

Home | Kontakt | Sitemap

Universität Zürich[UZH]

Physik-Institut

Institut • Forschung • Studium • Seminare • News • Interne Information • Schulen • Events

PHY127, Physics for Life Sciences 2

Schedule

Lecturer :	→ Prof. Ben Kilminster
Lectures (PHY127.1):	Friday, 08:00 - 09:45
Exercise sessions (PHY127.2):	Tuesday or Wednesday, 13:00 - 15:45 (First : 28th Feb 2023)
Office Hours	Fridays 10:30-11:30 at 36J50 or by email appointment

Lecturer

- Prof. Ben Kilminster
- → Webpage
- Office: Y36 J50
- Phone: → +41 44 635 58 02
- Email: → ben.kilminster@physik.uzh.ch

Course information sheet

↓ PHY127-info-sheet-2023 (PDF, 146 KB)

References & texts

References for each lecture will be added below.

↓ Here is a reference sheet (PDF, 95 KB) (handed out in class with key terms from PHY117, and german/english translation)

The following can serve as a reference for the basic physics (from PHY 117)

- Ben Kilminster, Introductory Physics 1. ↓ Kilminster-IntroPhysics1-PHY111-Script (PDF, 5 MB)

- Ben Kilminster, Introductory Physics 1. Kilminster-IntroPhysics1-PHY111-Script (PDF, 5 MB)
- Ben Kilminster, Introductory Physics 2. Kilminster-IntroPhysics2-PHY121-Script (PDF, 3 MB)

Texts:

- Paul A. Tipler, Gene Mosca: Physics for scientists and engineers.
- Halliday & Resnick : Fundamentals of Physics.

Additional resources to help with mathematics.

- MHP: Mathematische Hilfsmittel (PDF, 587 KB) (in german) derivatives, integrals, series expansions, statistics, vector algebra, coordinate transformations, tensors, ...)
- C.B. Lang und N. Pucker: *Mathematische Methoden der Physik,* Spektrum Verlag, Heidelberg und Berlin.

Formelsammlung Mittelschulphysik (PDF, 396 KB) is also useful for usage of basic formulas.

Exercises

Exercises are posted on OLAT every 2 weeks on Friday after lecture.

Exercise sessions in the following week will help you understand the terms and concepts of the exercises. Exercise sessions in the second week after the exercises are assigned will explain the solutions. It is expected that you will complete the exercises before this second exercise session.

There will be **no podcasts** of exercise classes.

Exam schedule

Exam guidelines :

Exams will be similar in style to the exercises. A formula sheet with all needed equations will be provided to you in the exams. The formula sheet will be sent to you by the end of the semester to help you study. We will provide you with paper and a calculator if needed. The final exam will be printed in english and in german. The following are forbidden in exams :

- Any means of communication (mobile phones, smart watches, etc.)
- Any kind of calculator, laptop, or electronic storage device
- Any additional formula sheets or written notes.

Grades

Your grade is based on the following assessments :

- 100% final examination

Attendance is expected and recorded for exercise sessions. The final examination will be composed of questions similar to those presented in the lectures and the weekly exercises.

Outline of course

The course will cover modern physics topics such as relativity, quantum physics, atomic, nuclear, and particle physics, radiation, particle-wave duality, particles interacting in matter, particle detection. These ideas will be used to explain the basics of modern radiation techniques for diagnostics and treatment, and such instruments as X-rays, CT scanners, PET scanners, NMR, MRI, etc.

Lecture information

06:31 Fri 24 Feb

physik.uzh.ch

PHY111:
Physics I for Physics Majors

PHYSIK INSTITUT
UNIVERSITÄT ZÜRICH

Prof. Ben Kilminster

Fall 2020

06:32 Fri 24 Feb

physik.uzh.ch

Contents

06:32 Fri 24 Feb

physik.uzh.ch

06:34 Fri 24 Feb

physik.uzh.ch

PHY121:
Physics II for Physics Majors

PHYSIK INSTITUT
UNIVERSITÄT ZÜRICH

PROF. BEN KILMINSTER
Spring 2020

06:32 Fri 24 Feb

physik.uzh.ch

Contents

06:32 Fri 24 Feb

physik.uzh.ch

4 of 200

Mathematische Hilfsmittel zur Physik I und II

mit ergänzenden Beispielen und Korrekturen, 15. Februar 2013

Physik - Institut Universität Zürich

Inhaltsverzeichnis

algebraisch rechnen, wie mit anderen Symbolen. Es gilt die Gleichung (6). Man beachte aber, dass dy null werden kann, wenn die Funktion horizontal verläuft. Dann muss man aufpassen, dass man nicht durch $dy = 0$ dividiert.

1.4 Ableitungsregeln für elementare Funktionen

Sei a konstant.

- $y = a$ . . . . . $y' = 0$
- $y = ax$ . . . . . $y' = a$
- $y = ax^p$ . . . . . $y' = apx^{p-1}$, wobei p≠0
- $y = \sqrt{x} = x^{\frac{1}{2}}$ . . . . . $y' = \frac{1}{2}x^{-\frac{1}{2}} = \frac{1}{2\sqrt{x}}$
- $y = 1/x = x^{-1}$ . . . . . $y' = (-1)x^{-2} = -1/x^2$
- $y = e^x$ . . . . . $y' = e^x$ also: $f(x) = f'(x)$
- $y = \ln x$ . . . . . $y' = 1/x$ (durch Umkehrfunktion)
- $y = \sin x$ . . . . . $y' = \cos x$
- Ableiten ist eine "lineare Operation": $\frac{d[af_1(x)+bf_2(x)]}{dx} = a\frac{df_1(x)}{dx} + b\frac{df_2(x)}{dx}$
- Produktregel: $y = f_1(x)f_2(x)$ . . . . . $\frac{dy}{dx} = \frac{df_1}{dx}f_2 + \frac{df_2}{dx}f_1$

5

Lecture information

Lecture schedule (12 lectures)	**Topics**	**PDF of chalkboard**	Additional resources
Week 1 (Feb. 24, 2023)	**Units, quantization**		
Week 2 (Mar.3, 2023)	**Electromagnetic radiation is made of photons.**		
Week 3 (Mar. 10, 2023)	**But are photons particles or waves ?**		
Week 4 (Mar. 17, 2023)	**Waves, standing waves, probabilities**		
Week 5 (Mar. 24, 2023)	**Wave-particle duality, wave packets, uncertainty principle, Schroedinger wave equation**		
Week 6 (Mar. 31, 2023)	**The quantum nature of electrons in an atom, and emitted light. Standing waves. Particle in a 3D box.**		
Holiday April 7th			
Holiday April 14th			
Week 7 (Apr. 21, 2023)	**Hydrogen atom in 3D, with 3 quantum numbers. Angular momentum. Standing waves.**		
Week 8 (April 28, 2023)	**Many-electron atoms, charge screening, X-rays, Bremsstrahlung, Characteristic X-rays, Thomson scattering, Compton effect, Bragg's law**		
Week 9 (May 5, 2023)	**X-ray penetration, attenuation, radiation dose, exposure dose, biological effects of radiation, CT scans with X-rays, pair production, pair annihilation, PET scans**		
Week 10 (May 12,	**microCT, nanoCT, phase-contrast imaging, Fresnel plate focusing, ~~synchrotron accelerators, X-ray synchrotron imaging~~, X-ray free electron**		

(Mar. 17, 2023)			
Week 5 (Mar. 24, 2023)	Wave-particle duality, wave packets, uncertainty principle, Schroedinger wave equation		
Week 6 (Mar. 31, 2023)	The quantum nature of electrons in an atom, and emitted light. Standing waves. Particle in a 3D box.		
Holiday April 7th			
Holiday April 14th			
Week 7 (Apr. 21, 2023)	Hydrogen atom in 3D, with 3 quantum numbers. Angular momentum. Standing waves.		
Week 8 (April 28, 2023)	Many-electron atoms, charge screening, X-rays, Bremsstrahlung, Characteristic X-rays, Thomson scattering, Compton effect, Bragg's law		
Week 9 (May 5, 2023)	X-ray penetration, attenuation, radiation dose, exposure dose, biological effects of radiation, CT scans with X-rays, pair production, pair annihilation, PET scans		
Week 10 (May 12, 2023)	microCT, nanoCT, phase-contrast imaging, Fresnel plate focusing, synchrotron accelerators, X-ray synchrotron imaging, X-ray free electron laser imaging		
Week 11 (May 19, 2023)	Angular momentum, precession of spinning object in gravity, precession of magnet in magnetic field, nuclear magnetic moment, nuclear magnetic resonance		
Week 12 (May 26, 2023)	nuclear magnetic resonance (NMR), magnetic resonance imaging (MRI), strong nuclear force, nuclear structure		
Week 13 (June 2, 2023)	Nuclear stability, nuclear decay, alpha, beta, gamma radiation. Decay series chains. Half lives. Bethe-Bloch energy loss. Dose delivered. Nuclear fission. Nuclear fusion.		

↓ Slide Handy (PDF, 249 KB)

↑ top

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	τ = rF sinθ	$kg*m^2/s^2$		
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
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=BIℓ	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		

Newton's second law: $\sum \bar{F} = m\bar{a}$

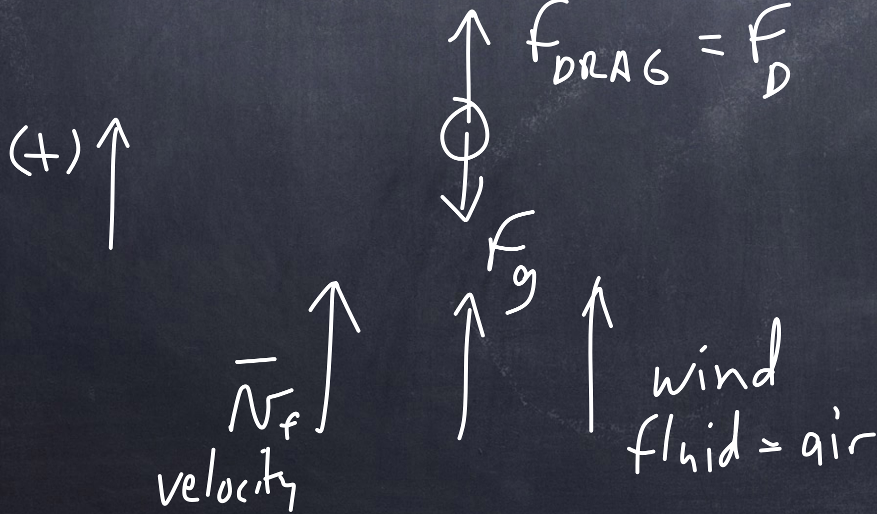
$\sum \bar{F} = -F_g = -m\bar{g} = m\bar{a}$

$-mg = m\bar{a}$

$\bar{a} = -g$

$g = 9.8\ m/s^2$

Experiment 1: ball floating



$F_{DRAG} = F_D = -b\,v_b$

$$b = 6\pi\eta r$$

Stokes' Law

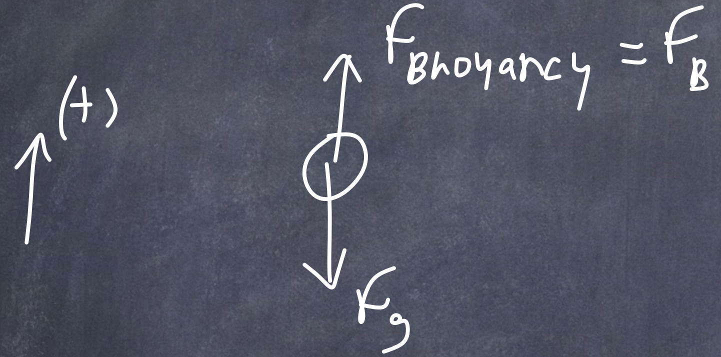
η: viscosity of fluid

r: radius of the ball

$$\Sigma F = F_b - F_g = m\cancel{a} = 0 \quad (a = 0 \text{ if not moving})$$

$$F_b = F_g$$

Experiment 2: buoyancy



when ball is suspended,

$$\Sigma F = F_B - F_g = m\cancel{a} = 0 \quad (a = 0 \text{ not moving})$$

$$F_B = F_g$$

F_B : weight of fluid being displaced by the ball

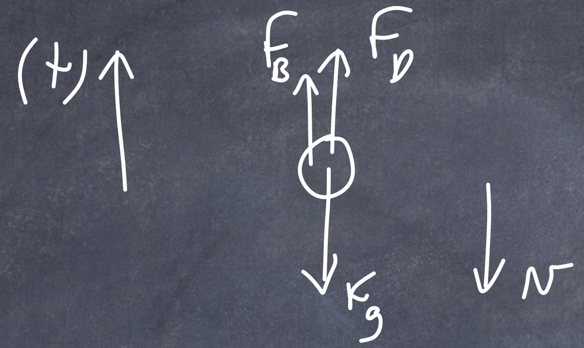
Archimedes' principle: There is a buoyant force (upward) on an object that is immersed in a fluid.

$$F_B = m_f g$$

density of fluid, $\sigma = \frac{m_f}{Volume}$

$m_f = \text{density} * \text{volume}$

Experiment 3: Buoyancy + drag force



Ball reaches a constant velocity (terminal velocity) when forces balance.

$$\Sigma F = F_B + F_D - F_g = m\cancel{a} = 0$$

($a = 0$: constant velocity)

ball: density $\rho = \dfrac{m}{V}$ $\quad m = \rho V$

$$F_g = mg = \rho V g = \rho\left(\tfrac{4}{3}\pi r^3\right)g$$

$$F_B = m_f g = \sigma V g = \sigma\left(\tfrac{4}{3}\pi r^3\right)g$$

(σ ← density of fluid)

$$F_D = bv = (6\pi\eta r)\, v_t$$

(v_t ← terminal velocity)

At equilibrium, $F_B + F_D - F_g = 0$

$$\sigma\left(\frac{4}{3}\pi r^3\right) + (6\pi\eta r)v_t - \rho\left(\frac{4}{3}\pi r^3\right)g = 0$$

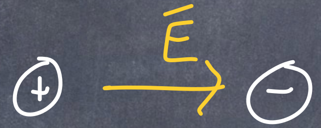
$$v_t = \frac{(\rho-\sigma)\left(\frac{4}{3}\pi r^{\cancel{3}\,2}\right)g}{6\pi\eta \cancel{r}}$$

we see : $v_t \propto r^2$

The bigger the ball, the faster

Experiment 4: add electricity

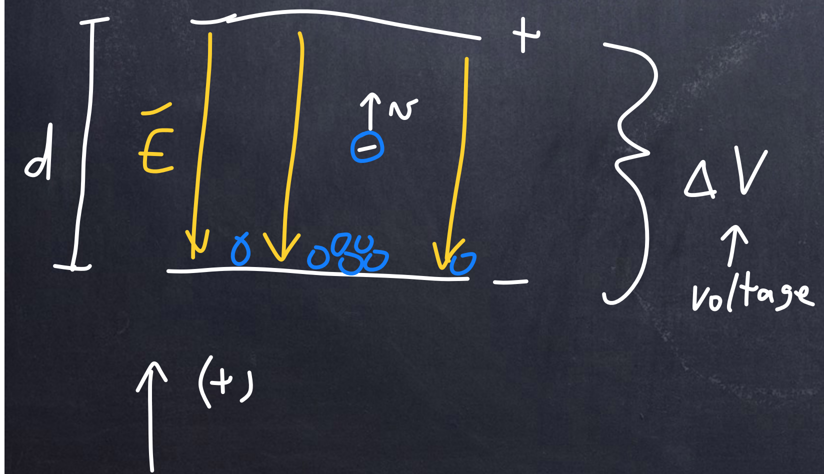
→ bubbles can be charged electrically with an electric potential, and there is an electric force, F_E



$\bar{E}$ points in the direction a positive charge would go.

$$\bar{F} = q\bar{E}$$

Experiment 5: tiny glass balls in an electric field filled with oil.

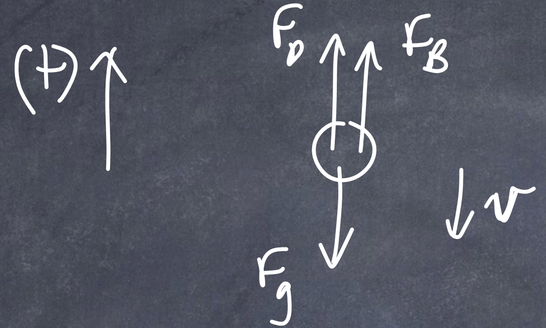


$$|\bar{E}| = \frac{\Delta V}{d}$$

$$\bar{F}_E = q\bar{E}$$

(−) charge * (−) direction → (+)

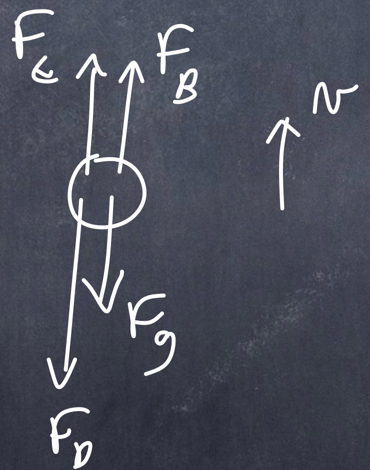
Case 1 : ball falling in fluid, no electric field



at equilibrium (no acceleration)
ball has terminal velocity (constant)

$$F_D + F_B - F_g = 0$$

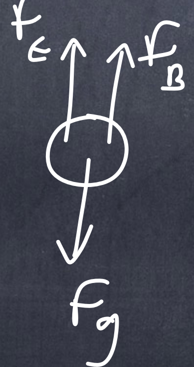
Case 2 : we have electric field, ball goes up.



$$\Sigma F = F_E + F_B - F_g - F_D = m\cancel{a}^{\,0} = 0$$

at constant velocity

Case 3 : ball suspended in an E-field.



$v = 0$, so no F_D

$$\Sigma F = F_E + F_B - F_g = m\cancel{a}^{\,0} = 0$$