

PHY 127

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.

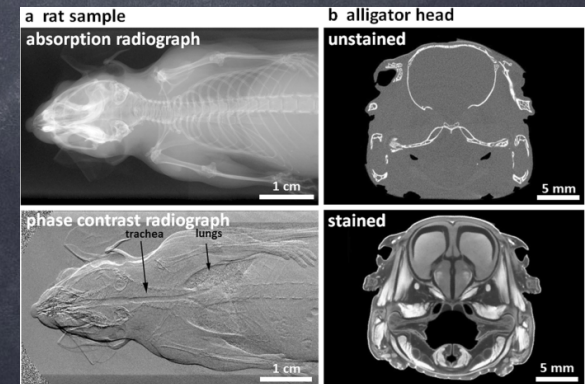
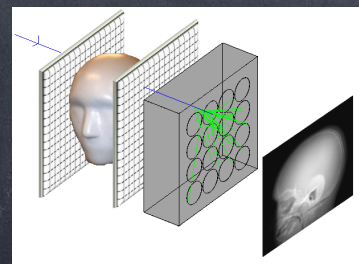
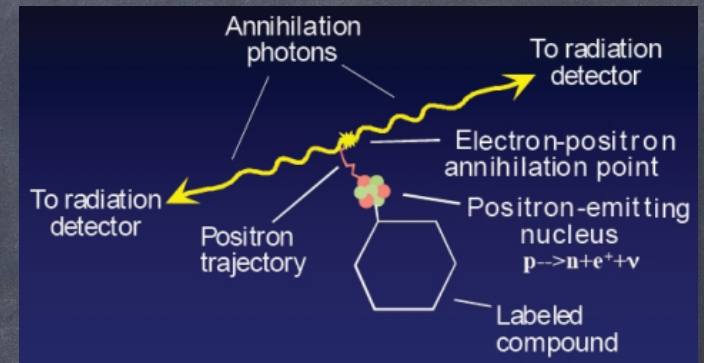
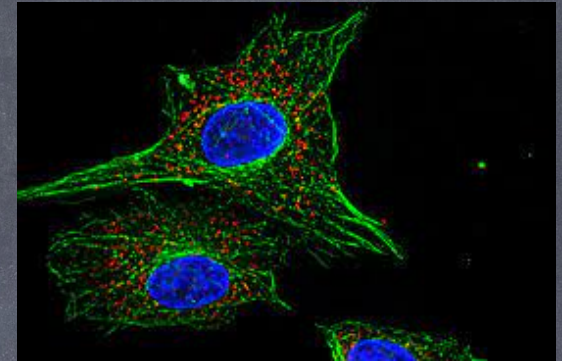
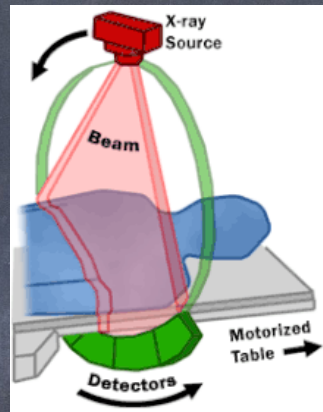
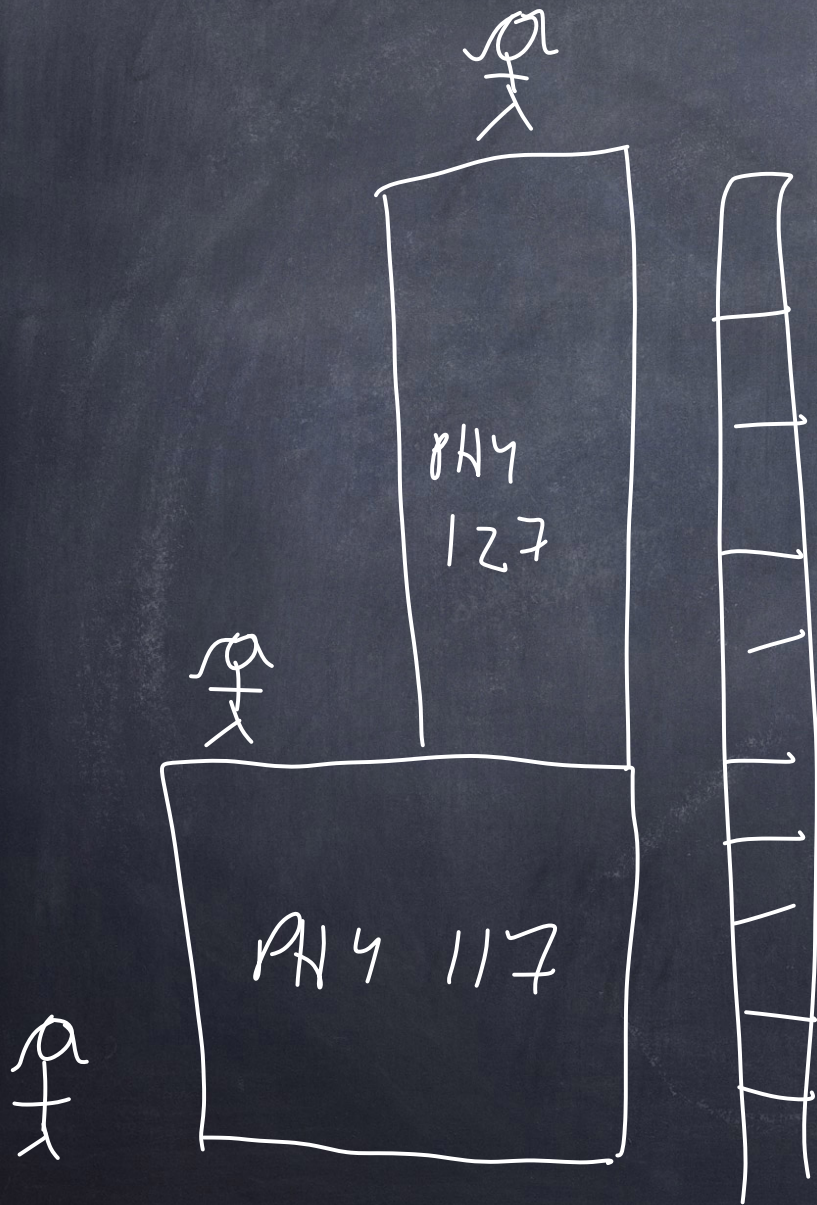
physics

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



bio-med

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



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
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Maximino	Adrover	maximino.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



Physik-Institut

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[PHY110 Vertiefung zu Physik I](#)[PHY111 Physik I](#)[PHY112 Praktikum zu Physik I](#)[PHY120 Vertiefung zu Physik II](#)[PHY121 Physik II](#)[PHY122 Praktikum zu Physik II](#)[PHY131 Physik III](#)[PHY139 Physik III für Studierende des
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Physics I](#)[PHY321 Elektrodynamik](#)[PHY322 Mathematical Methods of
Physics II](#)[PHY331 Quantenmechanik I](#)[PHY341 Thermodynamik](#)[PHY351 Quantenmechanik II](#)[PHY391 Proseminar Theoretische Physik](#)[PHY401 Condensed Matter Physics](#)[PHY411 Condensed Matter Theory](#)

PHY127, Physics for Life Sciences 2

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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](mailto: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 I](#), [↓ Kilminster-IntroPhysics I-PHY 111-Script \(PDF, 5 MB\)](#)

PHY411 Condensed Matter Theory

PHY420 Electron Spectroscopy

PHY432 Physik mit Myonen: Von der Atomphysik zur Festkörperphysik

PHY451 Elementary Particle Physics

PHY452 Elementary Particle Theory

PHY461 Experimental Methods in Particle Physics

PHY465 Experimental Astroparticle Physics

PHY511 General Relativity

PHY519 Applications of General Relativity

PHY551 Quantum Field Theory I

PHY552 Quantum Field Theory II

PHY563 Standard Model of Electroweak Interactions

PHY571 Physics beyond the Standard Model

PHY568 Flavour Physics

PHY572 Advanced Field Theory

PHY573 Quantum Field Theory III

PHY575 Introduction to Contemporary Quantum Matter Physics

PHY576 Understanding Topological Phases of Matter from Toy Models

PHY578 Effective Field Theories for Particle Physics

PHY585 Principles of Non-Relativistic Scattering Applications to Quantum Matter

AST241 Introduction to Astrophysics

SPI301 Computergestütztes Experimentieren I

SPI302 Computergestütztes Experimentieren II

PHY1010 Physik für Human-, Zahn- und Veterinärmedizin

PHY1030 Physikpraktikum für Physik für Human-, Zahn- und Veterinärmedizin

PHY116 Physik I für Nebenfachstudierende

PHY117 Physik für Life Sciences

PHY118 Physik I für Naturwissenschaften

PHY119 Ergänzungen Physik I für Chemie

PHY124 Physik für die Biomedizin

PHY126 Physik II für Nebenfachstudierende

PHY127 Physik für Life Sciences II

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FS2022

- 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 :

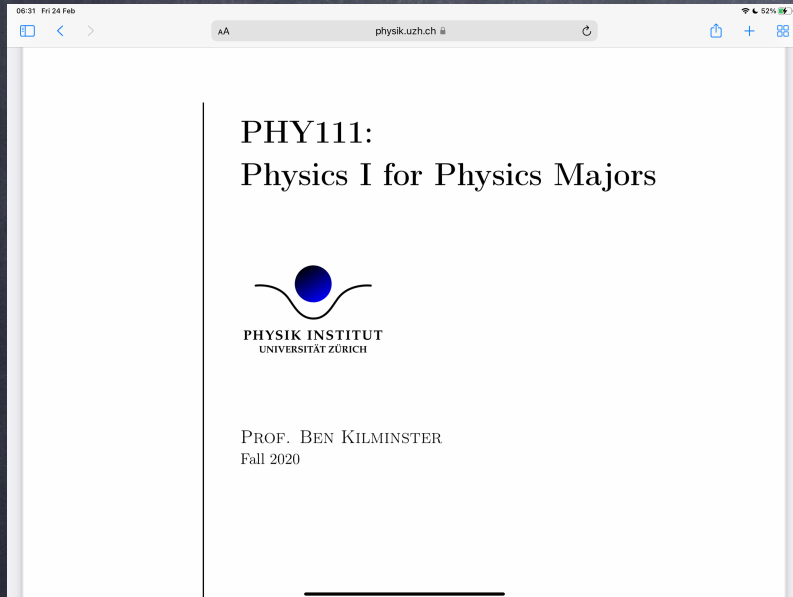
- 100% final examination

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



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PHY121:
Physics II for Physics Majors



PHYSIK INSTITUT
UNIVERSITÄT ZÜRICH

PROF. BEN KILMINSTER
Spring 2020

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Mathematische Hilfsmittel zur Physik I und II

mit ergänzenden Beispielen und Korrekturen, 15. Februar 2013

Physik - Institut Universität Zürich

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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.

- $y = a \dots \dots \dots y' = 0$
- $y = ax \dots \dots \dots y' = a$
- $y = ax^p \dots \dots \dots y' = apx^{p-1}$, wobei $p \neq 0$
- $y = \sqrt{x} = x^{\frac{1}{2}} \dots \dots \dots y' = \frac{1}{2}x^{-\frac{1}{2}} = \frac{1}{2\sqrt{x}}$
- $y = 1/x = x^{-1} \dots \dots \dots y' = (-1)x^{-2} = -1/x^2$
- $y = e^x \dots \dots \dots y' = e^x$ also: $f(x) = f'(x)$
- $y = \ln x \dots \dots \dots y' = 1/x$ (durch Umkehrfunktion)
- $y = \sin x \dots \dots \dots y' = \cos x$
- 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: $y = f_1(x)f_2(x) \dots \dots \dots \frac{dy}{dx} = \frac{df_1}{dx}f_2 + \frac{df_2}{dx}f_1$

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PHY124 Physik für die Biomedizin

PHY126 Physik II für
Nebenfachstudierende

PHY127 Physik für Life Sciences II

FS2022

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FS2020

PHY128 Physik II für
NaturwissenschaftenPHY129 Ergänzungen Physik II für
Chemie

FS2022

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, Schrodinger 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		

Week 4 (Mar. 17, 2023)			
Week 5 (Mar. 24, 2023)	Wave-particle duality, wave packets, uncertainty principle, Schrodinger 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.		
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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.		

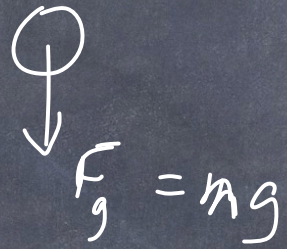
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physical quantity (SI base units in blue) (radiation physics units)	Deutsch	Symbol	SI unit	Simplified Formula to help with units	in other SI units	typical units in radiation physics	conversions
Length	Länge	l	meter = m				
time	Zeit	t	second = s				
velocity	Geschwindigkeit	v	m/s			$c \approx 3E8$ 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	$1e = 1.602E-19C$
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	$F=BI/l$	$1T=1N/(A*m)$		
Resistance	Elektrischer Widerstand	R	Ohms = Ω	$V = IR$	$1\Omega = 1V/A$		
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_r	Gray = Gy		$m^2/s^2 = J/kg$		
Equivalent dose	Äquivalentdosis	H_r	Sievert = Sv		$m^2/s^2 = J/kg$		

Newton's second law: $\Sigma \vec{F} = m\vec{a}$

(+) \uparrow



$$\Sigma \vec{F} = -F_g = -mg = m\vec{a}$$

$$-mg = m\vec{a}$$

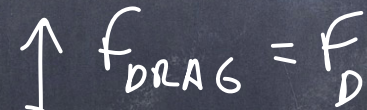
$$\vec{a} = -g$$

$$g = 9.8 \text{ m/s}^2$$

Experiment 1: ball floating

(+) \uparrow

\vec{v}_f
velocity \uparrow



wind
fluid = air \uparrow

$$F_{\text{DRAG}} = F_p = -b\vec{v}_b$$

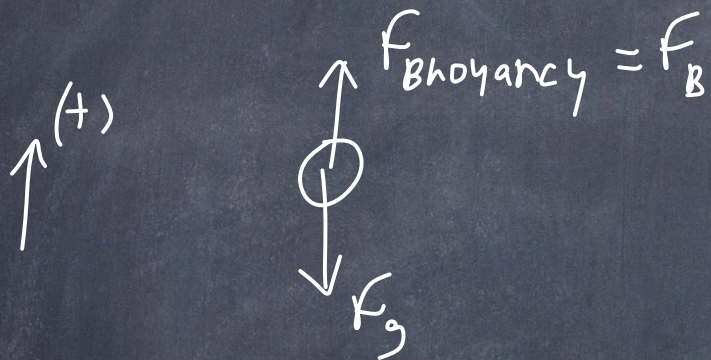
$$b = 6\pi\eta r$$

\uparrow
viscosity
of fluid

Stokes' Law
radius
of the
ball

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

Experiment 2: buoyancy



when ball is suspended,

$$\Sigma F = F_B - F_g = m \overset{0 \text{ not moving}}{a} = 0$$

$$F_B = F_g$$

F_B : weight of fluid being displaced by the ball

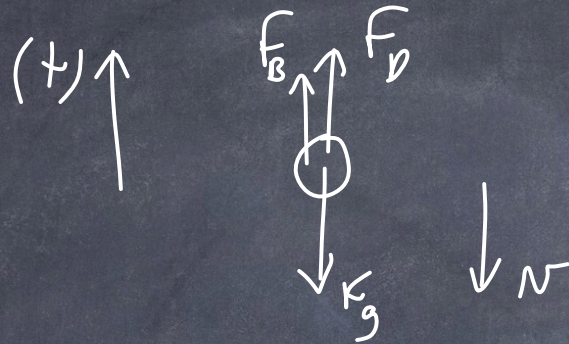
Archimedes' principle: There is a buoyant force (upward) on an object that is immersed in a fluid.

$$F_B = m_f g$$

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

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

Experiment 3: Buoyancy + drag force



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

$$\Sigma F = F_B + F_D - F_g = m \overset{\text{constant velocity}}{a} = 0$$

ball: density $\rho = \frac{m}{V}$ $m = \rho V$

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

$$F_B = m_f g = \overset{\substack{\uparrow \\ \text{density} \\ \text{of fluid}}}{\sigma} V g = \sigma \left(\frac{4}{3} \pi r^3 \right) g$$

$$F_D = b v = (6 \pi \eta r) v_t \leftarrow \text{terminal velocity}$$

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

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

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

We see : $N_t \propto r^2$

The bigger the ball, the faster

Experiment 4: add electricity

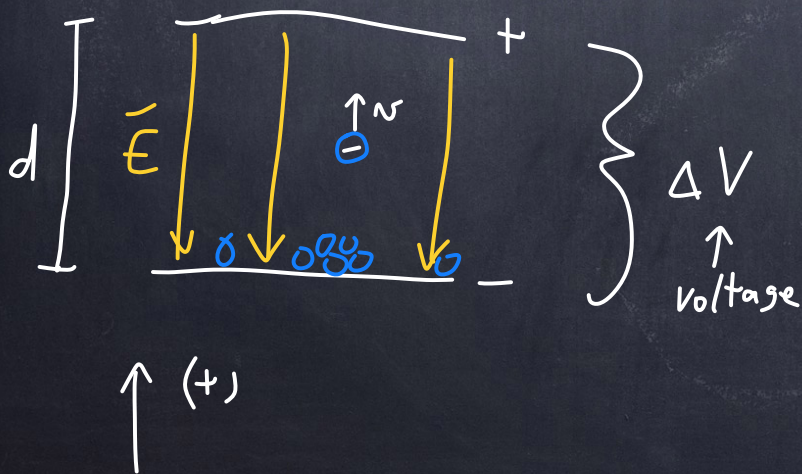
→ bubbles can be charged electrically with an electric potential, and there is an electric force, F_E



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

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

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

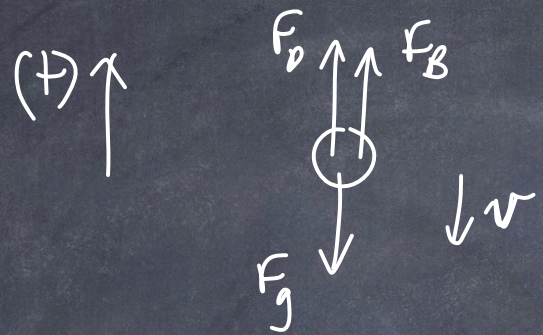


$$|\vec{E}| = \frac{\Delta V}{d}$$

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

↑ ↑
(-) charge → (+)
direction

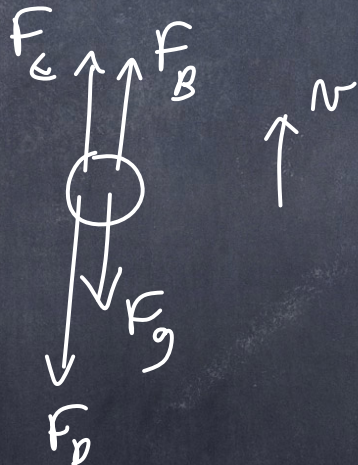
Case 1: ball falling in fluid, no electric field



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.



Case 3: ball suspended in an E-field.



$v=0$, so no F_D

$$\Sigma F = F_E + F_B - F_g = m\vec{a} = 0$$

$$\Sigma F = F_E + F_B - F_g - F_D = m\vec{a} = 0 \text{ at constant velocity}$$