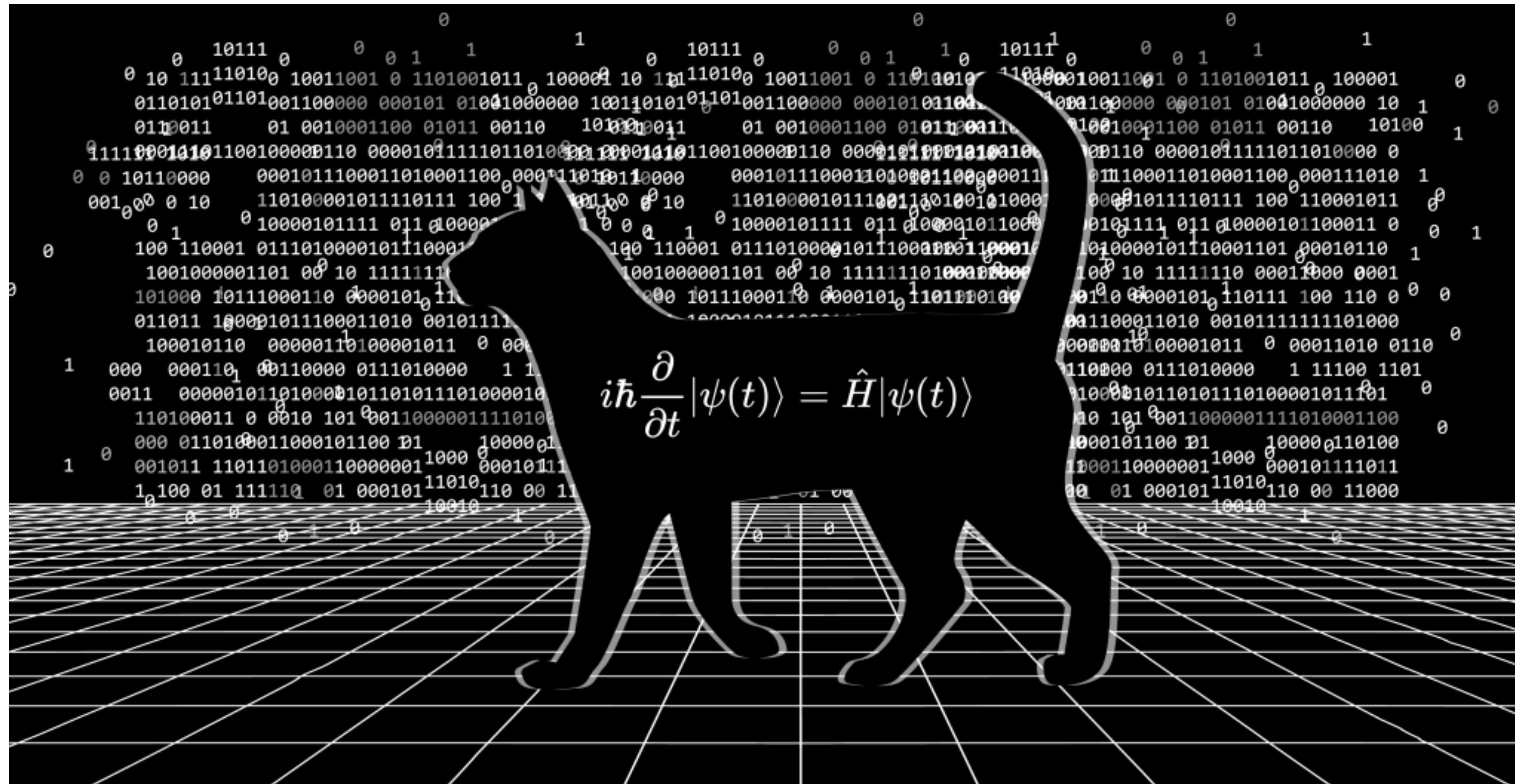


PHYS-344: QUANTUM MECHANICS FOR NON-PHYSICISTS

Prerequisites: working knowledge of complex numbers, linear algebra, calculus & differential equations.
Knowing a little physics helps but **not required**.



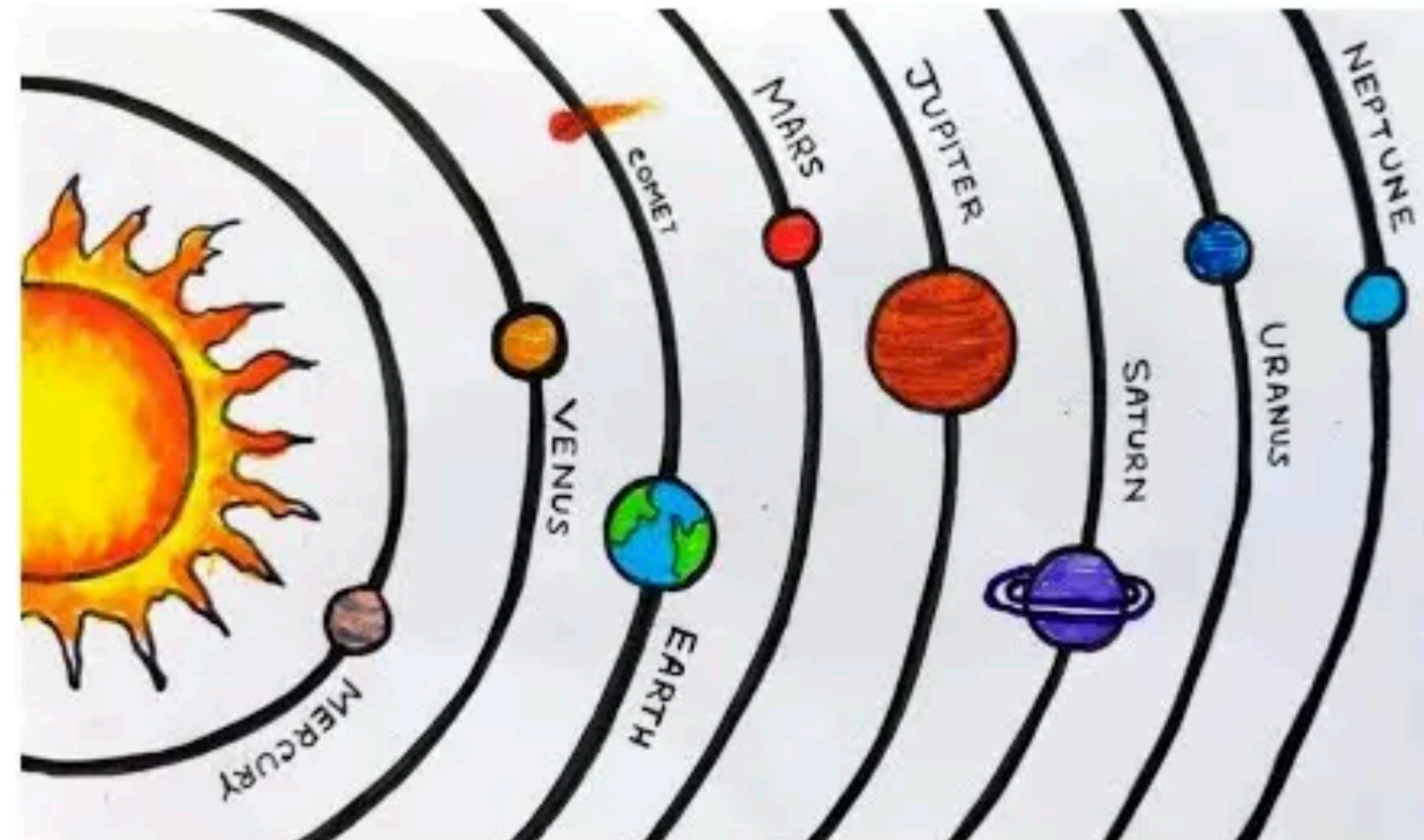
Mon 10-12
CM 4

Thu 10-12
INM 202

Instructor: Prof. Vladimir Manucharyan, head of SQIL

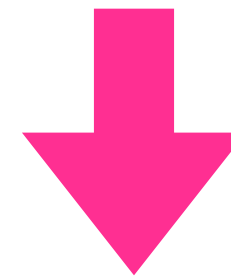
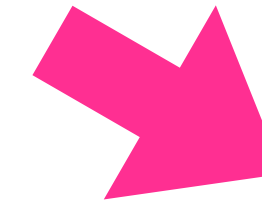
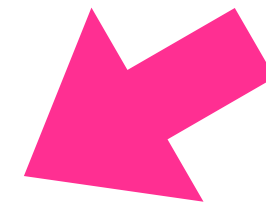
Classical vs quantum

Mechanics & thermodynamics

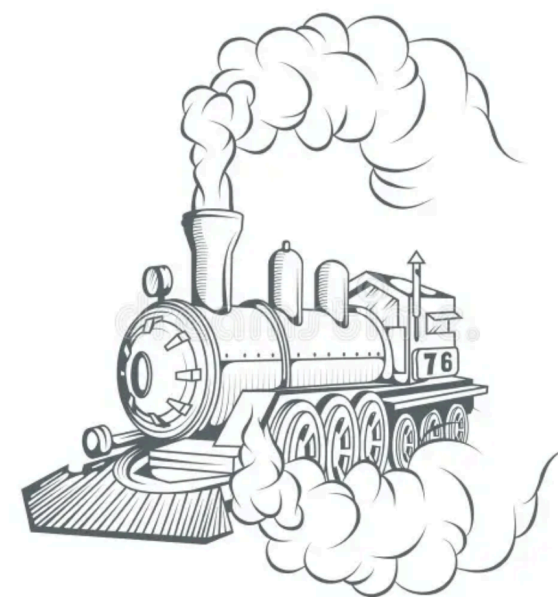


Planetary motion

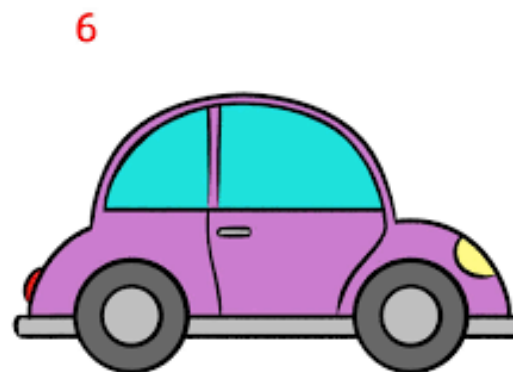
How bicycle works?



Buoyancy



Heat engines

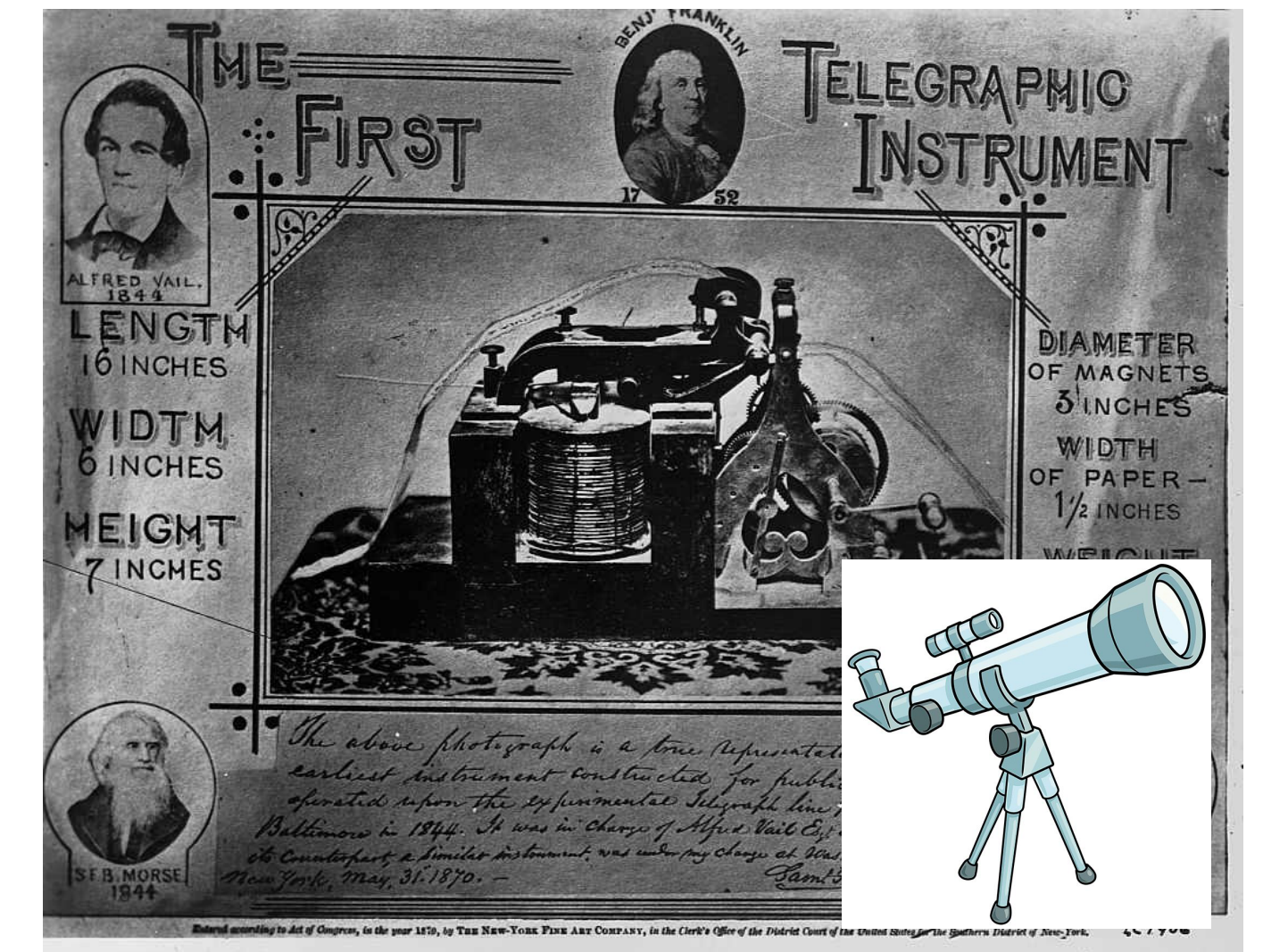


Air travel

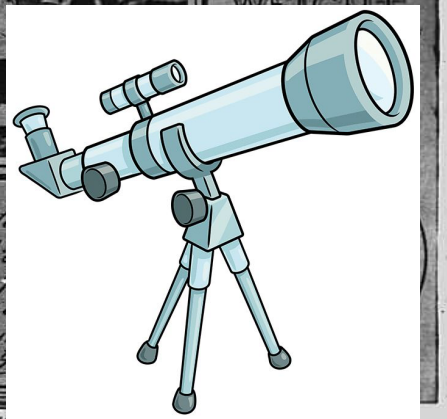


Reactive motion

Electromagnetism & optics



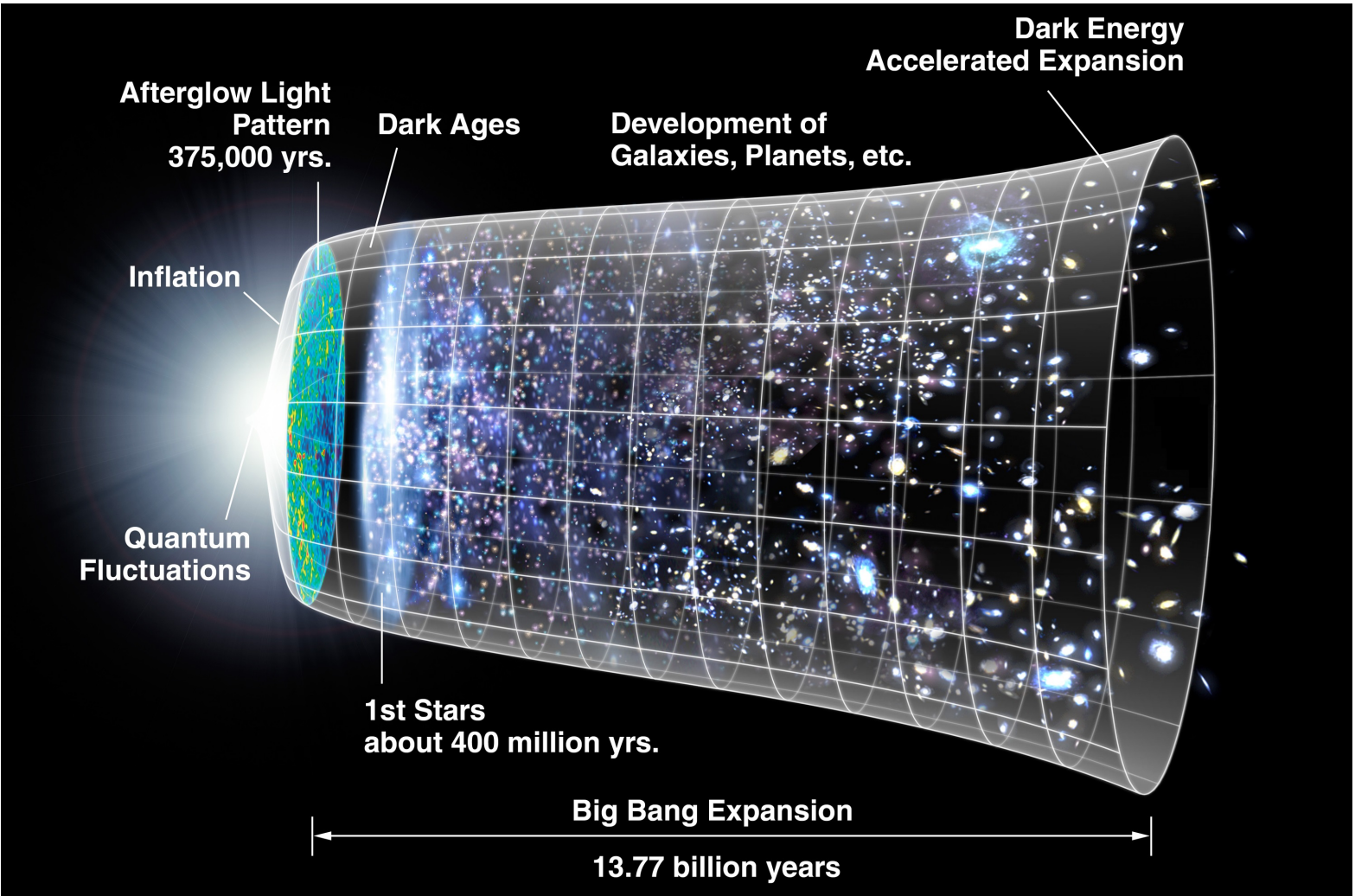
Telegraph



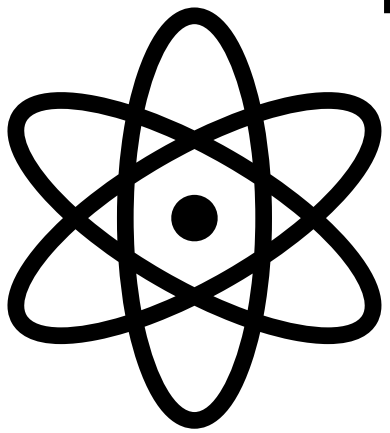
Telescope

Classical vs quantum

Big bang theory



How atom works?



Periodic table

Non-metal

Alkali metal

Alkaline earth metal

Transition metal

Metal

Metalloid

Halogen

Noble gas

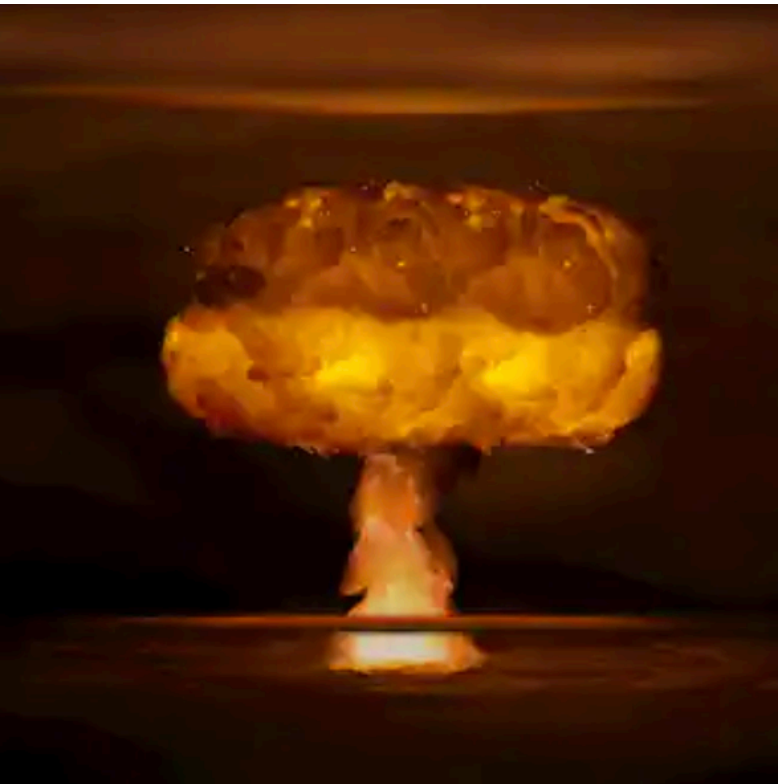
Lanthanide

Actinide

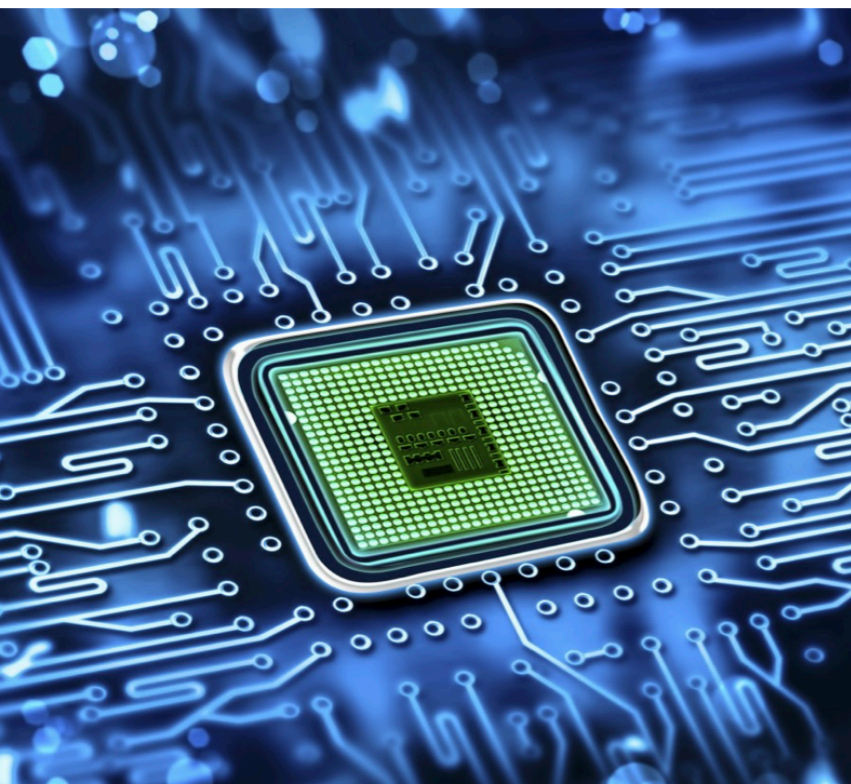
alamy

Image ID: M0P42F
www.alamy.com

Nuclear



Computers



Lasers



Magnetic Resonance Imaging

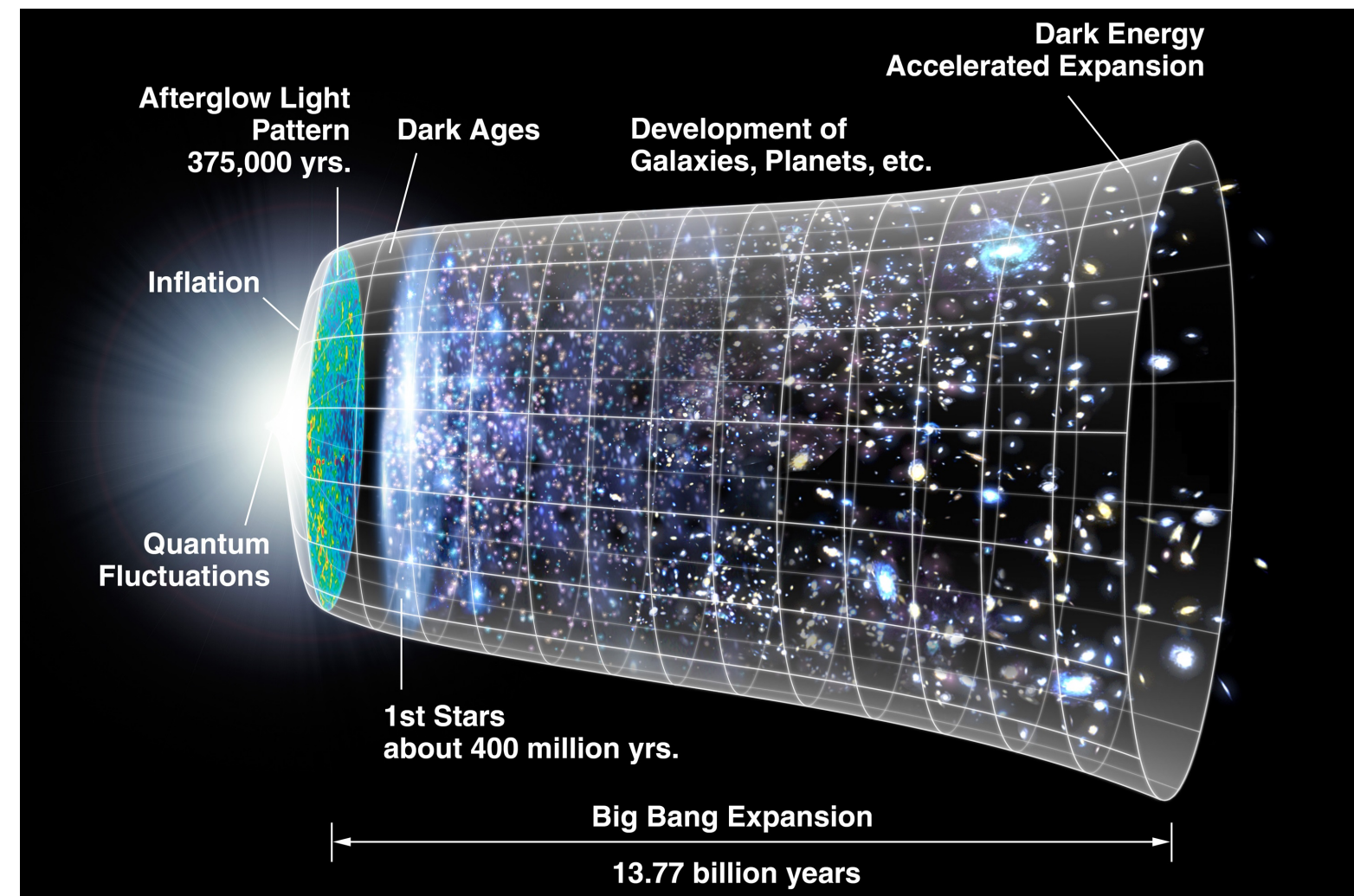


Atomic clocks and GPS

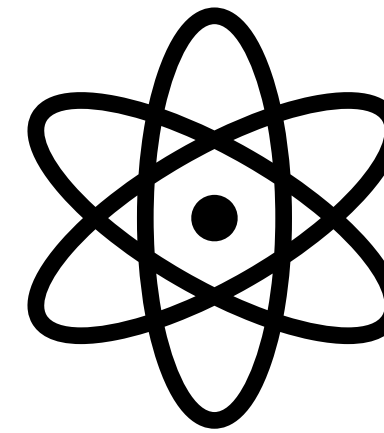


Classical vs quantum

Big bang theory



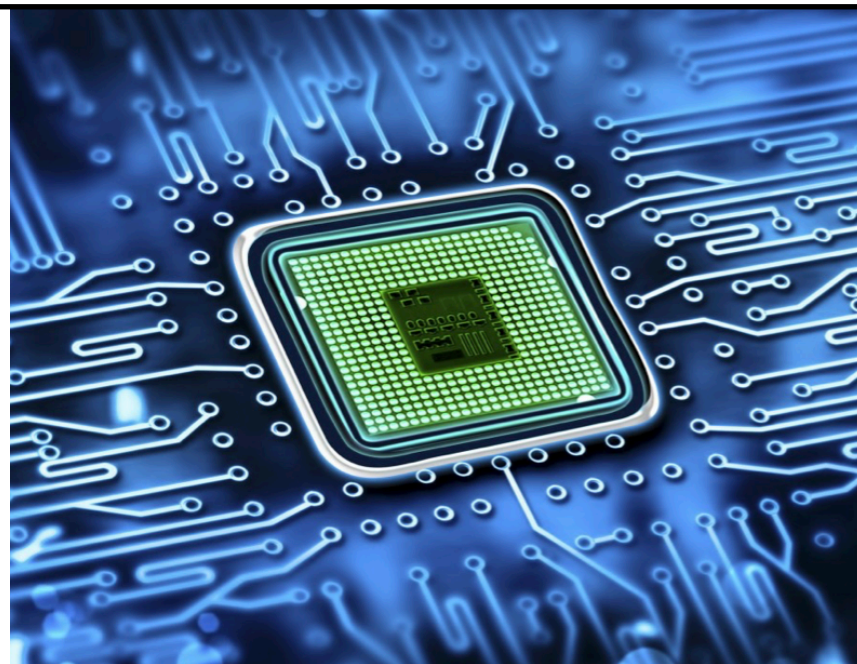
How atom works?



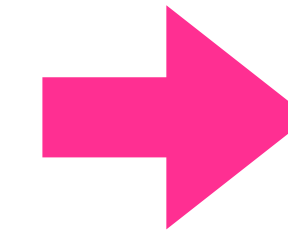
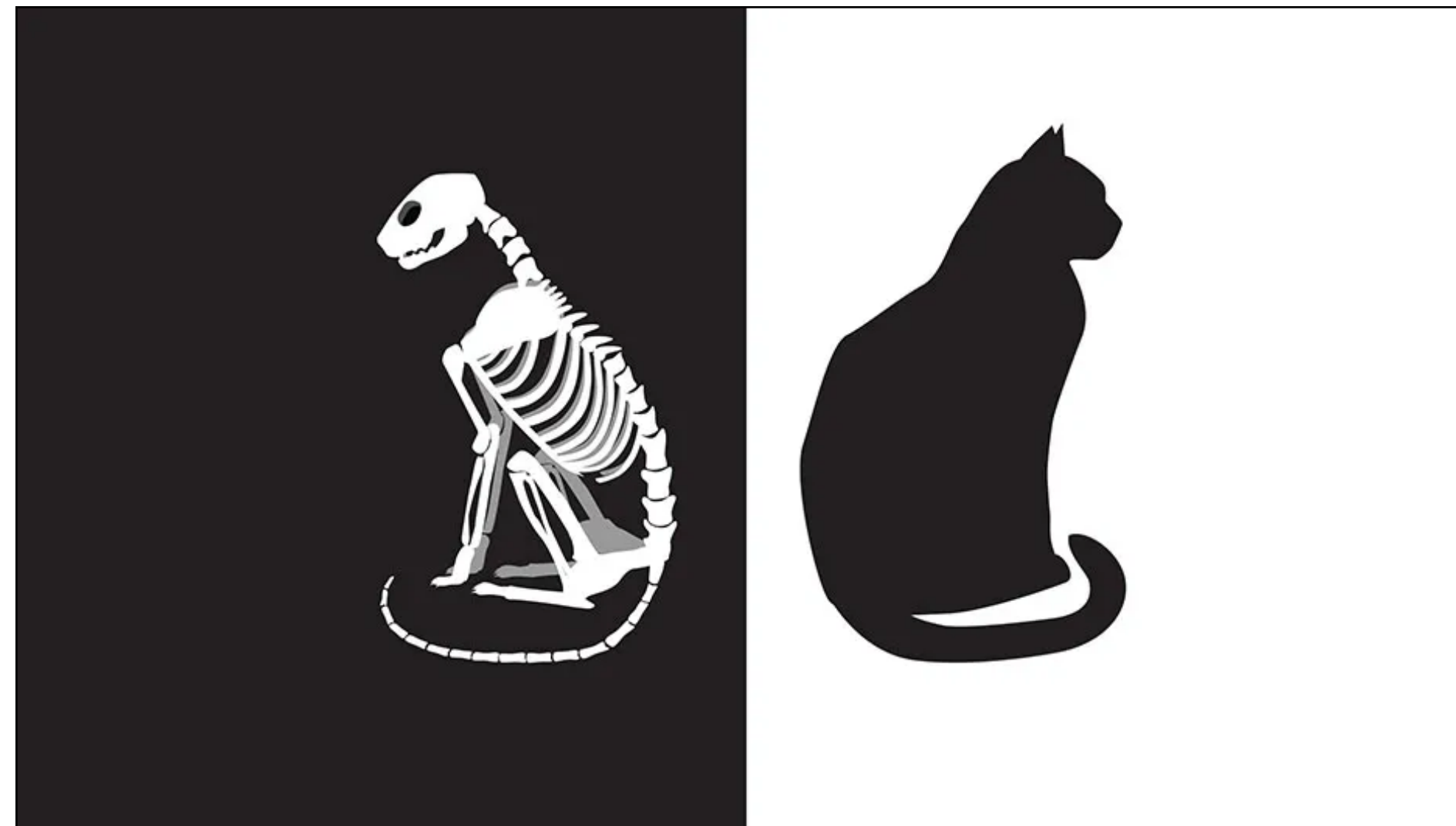
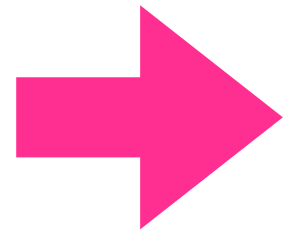
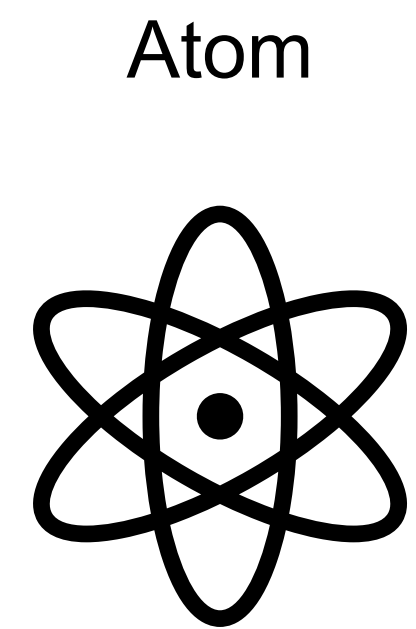
Periodic table

A standard periodic table of elements. Elements are color-coded by groups: Non-metal (grey), Alkali metal (orange), Alkaline earth metal (red), Transition metal (yellow), Metal (green), Metalloid (light green), Halogen (teal), Noble gas (blue), Lanthanide (purple), and Actinide (pink). The table includes element symbols, atomic numbers, and names. The Lanthanide and Actinide series are shown separately at the bottom.

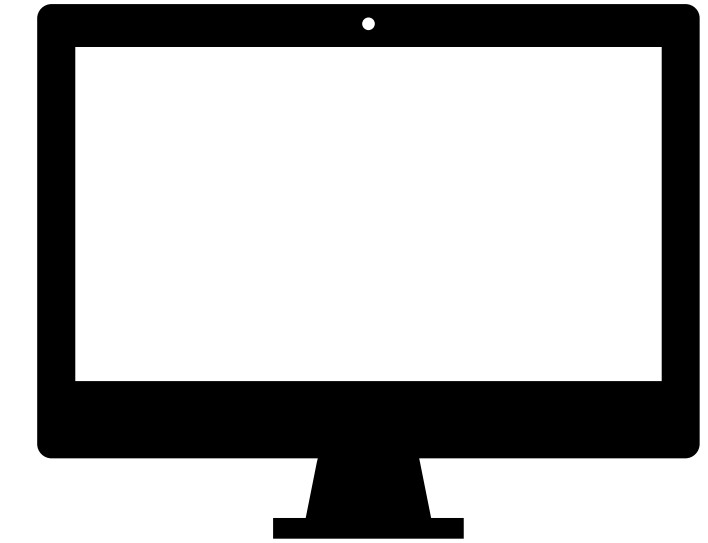
Only physics (considerations determining optimal parameters) is quantum!
The electrical signals in an Intel processor or light coming out of a laser pointer are still classical
Can a voltage in a circuit be as quantum as position of an electron in an atom?



Quantum 2.0



A more **efficient** way to process information?



Bit
(Classical Computing)

0



1

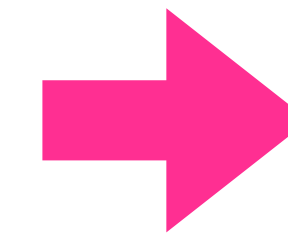
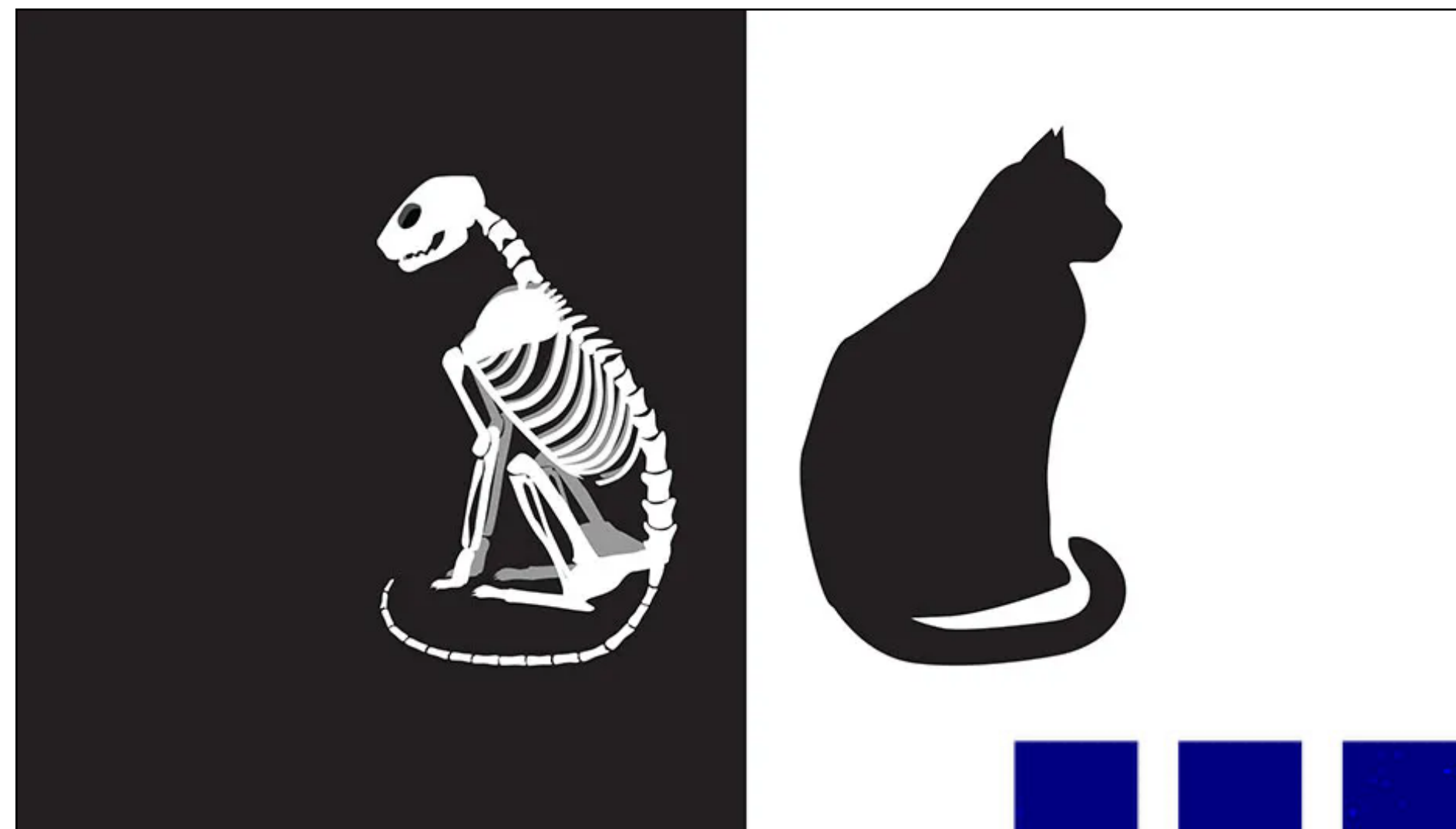
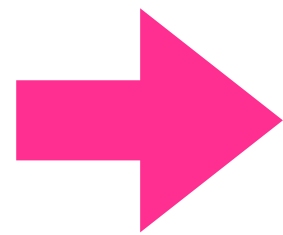
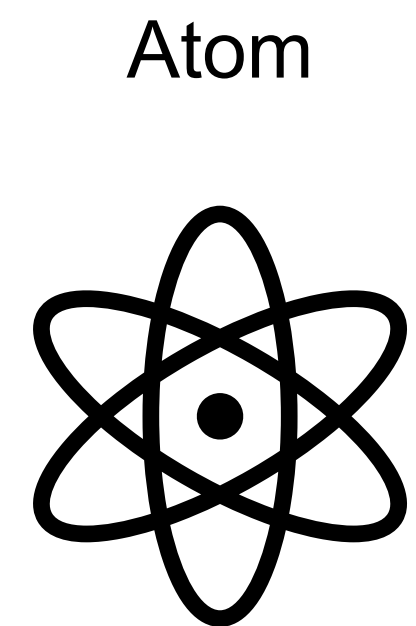
Qubit
(Quantum Computing)

0

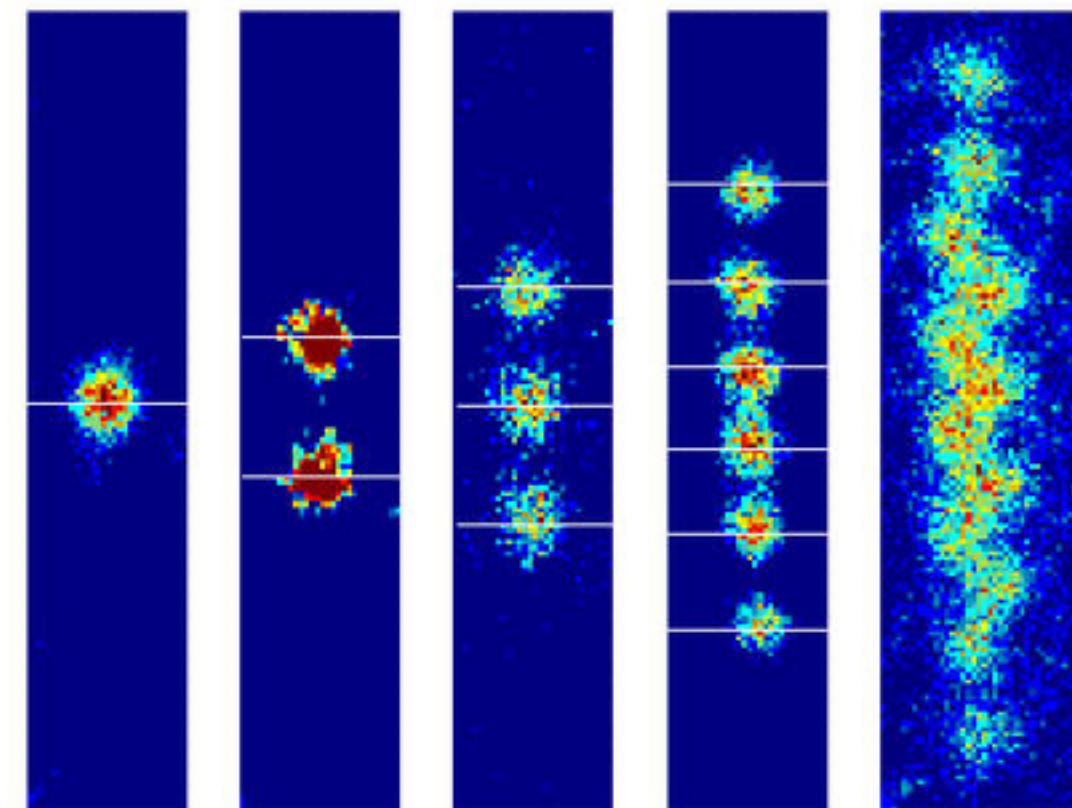


1

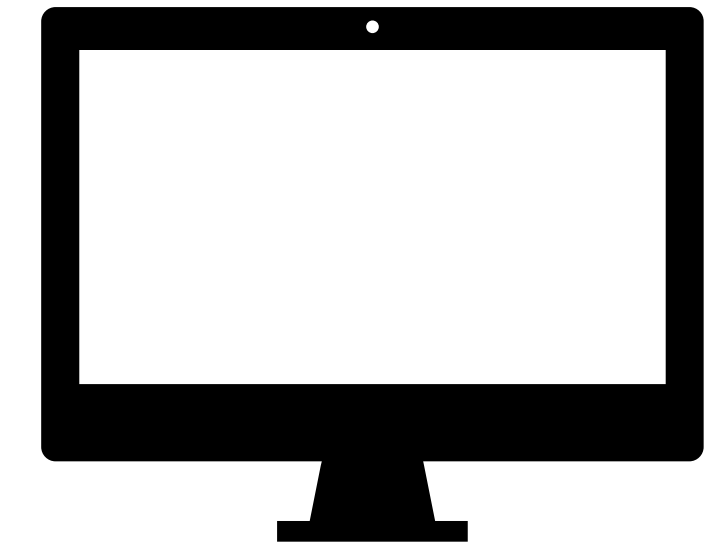
Quantum 2.0



Trapping and seeing (in a microscope)
1, 2, 3, 6, and 12 **individual**
magnesium ions



A more **efficient** way to process
information?



Bit
(Classical Computing)

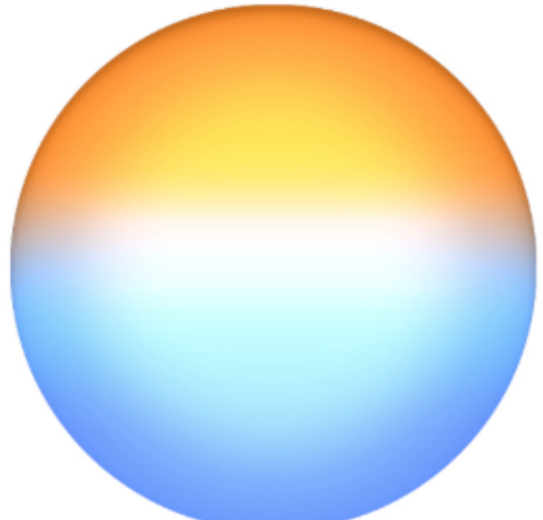
0



1

Qubit
(Quantum Computing)

0



1



Quantum computing

\$45B–\$131B

estimated market size by 2040

\$6.7B

invested
as of Dec 2023

261

start-ups
as of Dec 2023



~\$42B

total government
investment announced

Quantum communication

\$24B–\$36B

estimated market size by 2040

\$1.2B

invested
as of Dec 2023

96

start-ups
as of Dec 2023



Quantum sensing

\$1B–\$6B

estimated market size by 2040

\$0.7B

invested
as of Dec 2023

48

start-ups
as of Dec 2023

Potential economic value from
quantum computing

~\$0.9T–\$2T

across four industries by 2035: chemicals, life
sciences, finance, and mobility³

Quantum-capable talent



55

QT master's degree
programs



195

universities with QT
research groups

Scientific progress



4,763

QT-related patents
granted in 2022



42,155

QT-related publications
in 2023



Quantum computing

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estimated market size by 2040

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invested
as of Dec 2023

261

start-ups
as of Dec 2023



\$173B

potential quantum
market size by

367

start-ups in the ec



~\$42B total
invested

Potential economic value from
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start-ups
as of Dec 2023

I WANT YOU!

PHYS-344: QUANTUM MECHANICS FOR NON-PHYSICISTS

Course topics

1. Mathematics of quantum bits (qubits)
2. Two-qubit systems and entanglement
Homework 1 due ~ Oct 15

3. Quantum harmonic oscillator
4. Some qubit-like systems
Homework 2 due ~ Nov 15

5. Cavity QED (coupling a qubit to an oscillator)
6. Dissipation and decoherence
7. Quantum measurement
Homework 3 due ~ Dec 15

Course goals

Join the “Quantum Talent” pool!

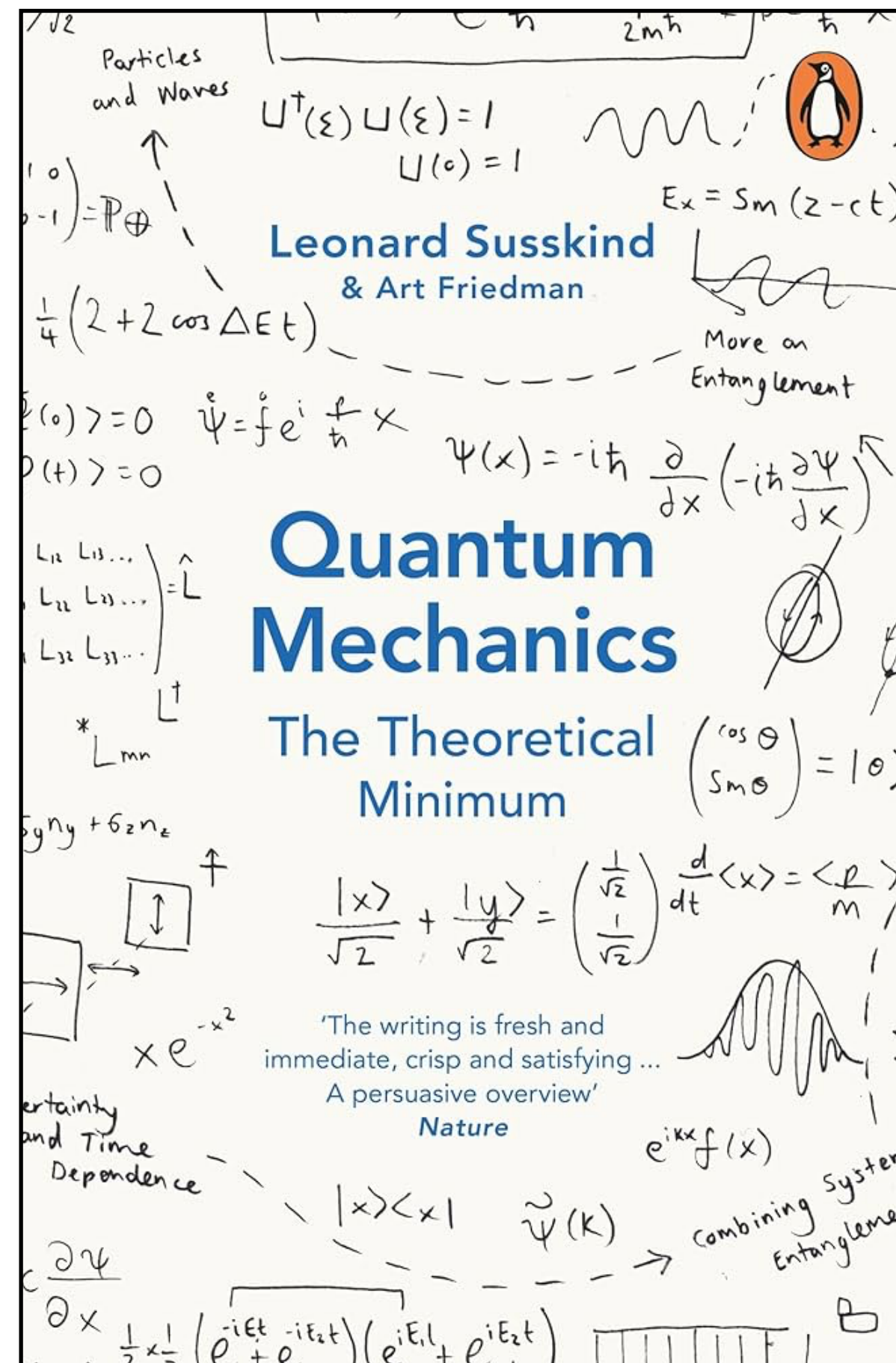
engage in Quantum projects
follow Q.I. textbooks & talks
take Q.I. courses

This is NOT a course on

Quantum computing
Quantum information
Quantum technology
Quantum communication

PHYS-344: QUANTUM MECHANICS FOR NON-PHYSICISTS

Reading



Slow modern intro for absolute beginners

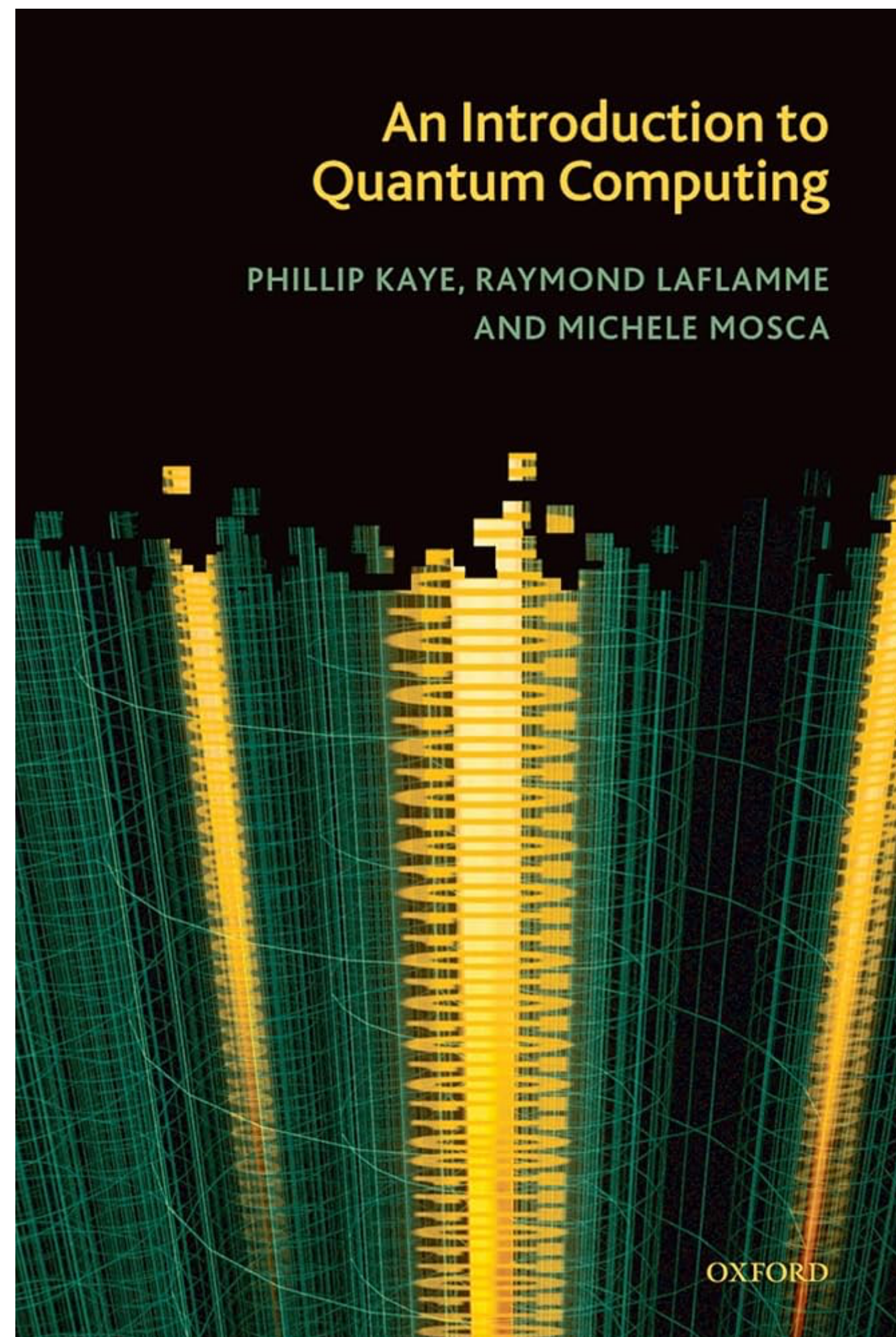
comes with free video lectures

<https://theoreticalminimum.com/courses/quantum-mechanics/2012/winter>

Sold for 10-20 CHF

PHYS-344: QUANTUM MECHANICS FOR NON-PHYSICISTS

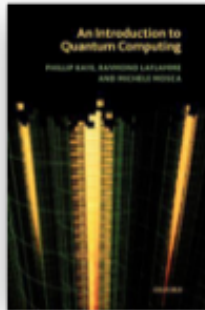
Reading



selected chapters

Concise intro of quantum formalism

2



BOOK

An introduction to quantum computing

Kaye, Phillip

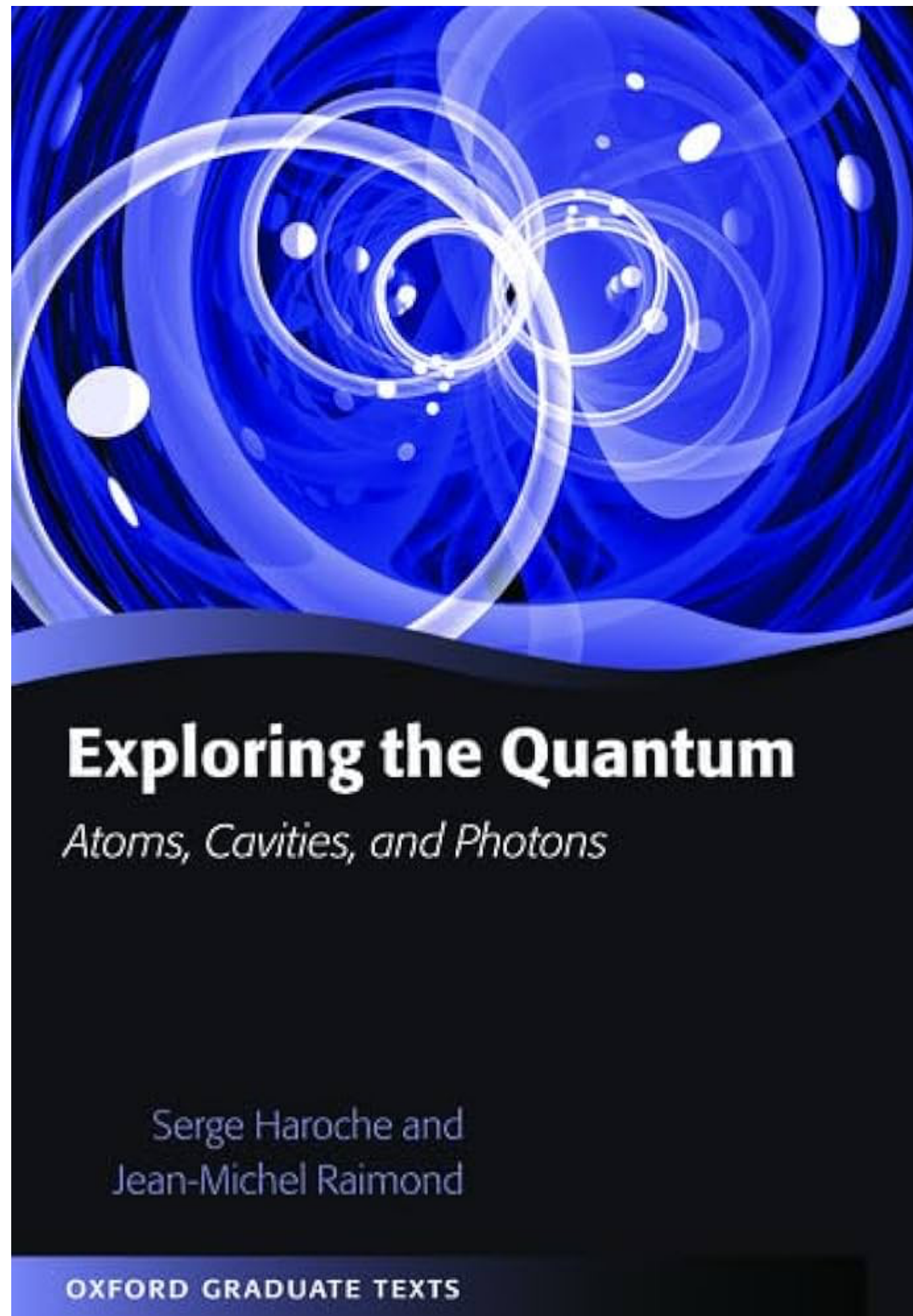
Oxford : Oxford University Press

1st ed.; 2007

[Available Online](#)  [>](#)

PHYS-344: QUANTUM MECHANICS FOR NON-PHYSICISTS

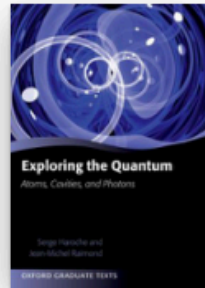
Reading



selected chapters

Modern physics-inclined text

2



BOOK

Exploring the quantum : atoms, cavities and photons

Haroche, S

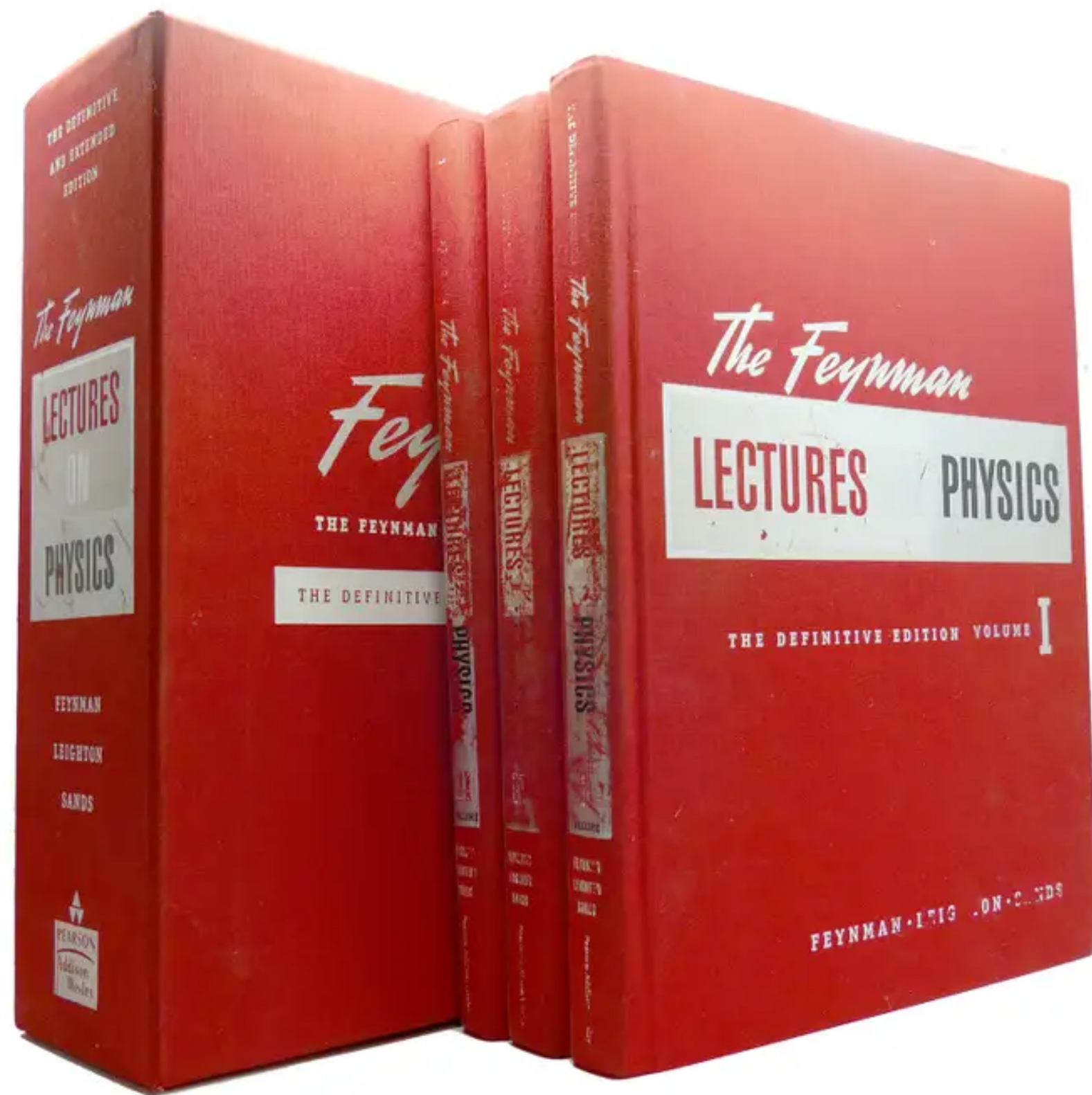
Oxford ; New York : Oxford University Press

1st ed.; 2006

[Available Online](#) >

PHYS-344: QUANTUM MECHANICS FOR NON-PHYSICISTS

Reading



Quick reference on anything Physics

PHYS-344: QUANTUM MECHANICS FOR NON-PHYSICISTS

Exercises based on QuTiP in Python

```
time_list = np.linspace(0, 11, 1001) # [ns] time points
f_q = 1 # [GHz] qubit frequency
f_d = 1 # [GHz] drive frequency
g = 0.3 # [GHz] coupling strength
epsilon = 1 # constant drive

omega_q = 2*np.pi*f_q
omega_d = 2*np.pi*f_d

# definition of the initial state
psi0 = basis(2,0) # ground state in 2 level system

# definition of the time-dependent hamiltonian
H = QobjEvo([-omega_q/2*sigmaz(),
            [sigmay(), lambda t: g*epsilon*np.sin(omega_d*t)]]])

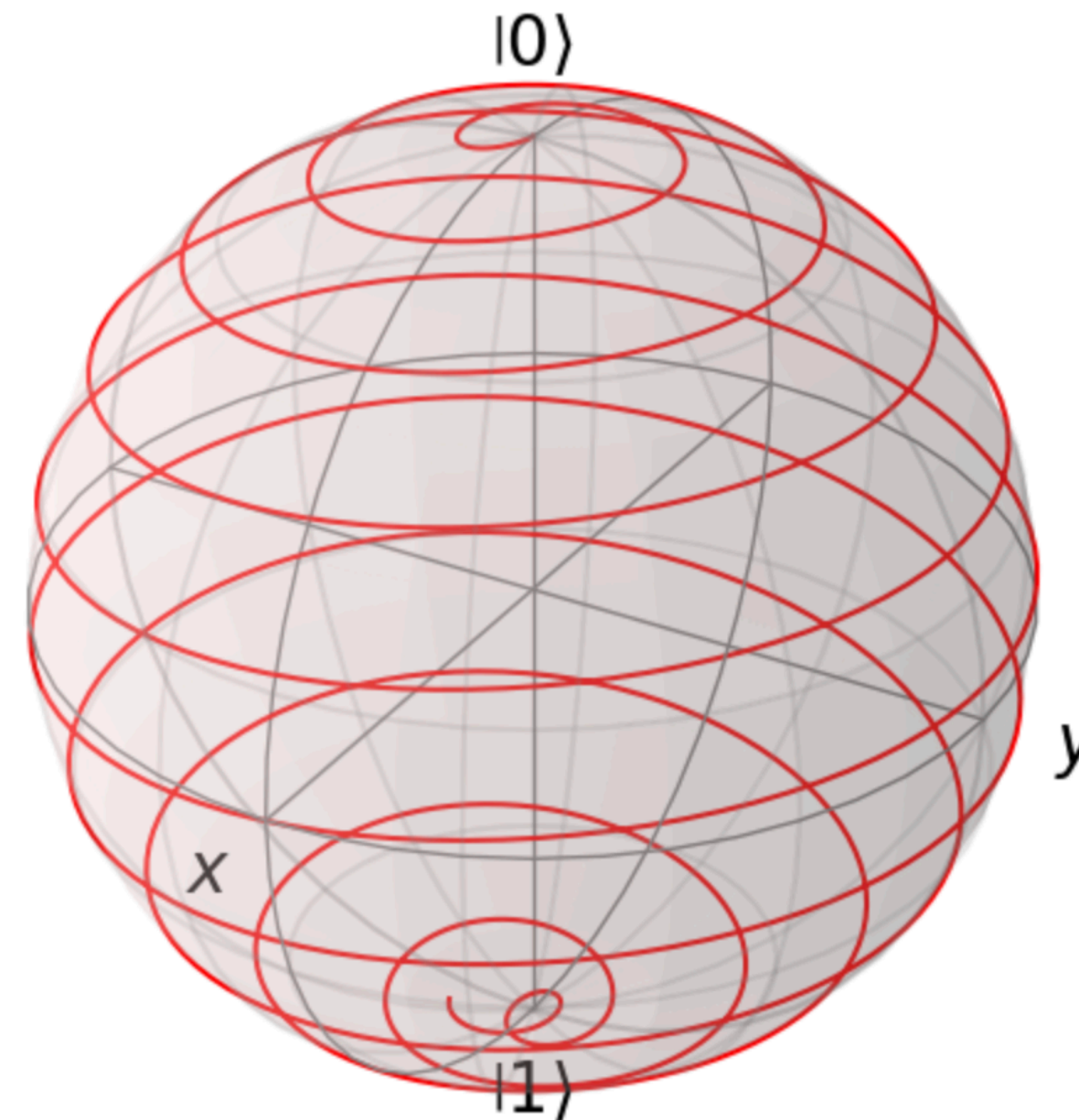
# solve the Schrodinger equation
output = mesolve(H, psi0, time_list, [], [sigmax(), sigmay(), sigmaz()])
```

```
# plot on Bloch sphere
b = Bloch()
b.make_sphere()

# settings of Bloch class
b.point_marker=["o"]
b.point_size=[25]

# plot the laboratory frame states (plot points)
b.add_points(output.expect, meth="l", colors="red")
b.render()
b.show()
```

Evolution of qubit's state
on Bloch sphere



Taketo Imaizumi



Don't miss
seminars on
Thursdays!

<https://qutip.org>

PHYS-344: **QUANTUM** MECHANICS FOR NON-PHYSICISTS

Scoring system

A) Three homework sets

- each exercise is graded 0 or 1
- most are Python-based
- about 1/2 are explained at seminars

50%

B) Oral exam - course project

- learn a new topic and teach it to your peers
- each student presents/Q&A 10 min/10min
- project choice finalised by ~ Oct 15 (TBD)

50%