

# Quantum Mechanics I

## Phys. 362

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## Books

▶ **The Physics of Quantum Mechanics**

by James Binney And David Skinner

▶ **Nonclassical Physics**

by Randy Harris.

▶ **Quantum Mechanics demystified (تبسيط)** by David McMahon

▶ <http://scholar.cu.edu.eg/?q=badawysarhan/classes>

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**Schrodinger equation and principle of quantum mechanics (application)**

Matter waves

Quantum states

Quantum amplitudes and measurements

Dirac notation

Vector spaces and their adjoints

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## ► Operators, measurement and time evolution

Operators

Functions of operators

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Evolution in time

Evolution of expectation values

The position representation

Wavefunction for well defined momentum

The uncertainty principle

Probability current



## ► Particle wave propagation

Properties of matter waves

Phase velocity

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Mathematical bases of uncertainty principle



# Application

## ► **Bound states:**

Particle in a Box in one-dimension (The infinite well).

The finite well.

The simple harmonic Oscillator in one dimension.

## ► **Unbound states:**

Potential step

Potential Barriers



## The Evaluation

60 : final Exam.

20 : Mid-term Exam.

5 : Attendance the Lectures.

5 : Homework.

10 : Presentation

# Introduction

## ► How we learn?

By experiment:

Eye, ear,....



## Aim of the Physics

- ▶ Find the laws that govern any phenomena in our universe, these laws enable us from:
- ▶ Predict the future.
- ▶ Increase our

## How we build a theory (The law that govern a phenomena)

- ▶ First we propose an idea to explain the experimental data
- ▶ If we succeed to explain the data we extend it to another data, if it fail at any stage we have to modify it until it succeed. If we succeed we apply it to all the available experimental data. If we succeed than our theory is correct and we accept it. If a new data is appear and the theory does not agree with it. Then we have to think ?

Any idea or any theory give results, one can not confirm from it experimentally, then it is not useful form the physics point of view.

# What questions the physics can answer ? and what questions the physics can not answer ?

- ▶ The physics answer How the phenomena occurs.
- ▶ The physics can not answer why the phenomena obeys the given law not other.

Why two charges obeys Coulombs law ?why this form not other form ?

Why we need to eat why we are not like plants do our food ourselves.

# language

- ▶ It is a tool, by it we understand each other.
- ▶ الموسيقى لها لغة-في الغالب نحن لا نفهم النوتة الموسيقية الا اذا درسنا لغة الموسيقى.
- ▶ عندما تقع في يد شخص نوتة موسيقية ثم لا يفهم منها شيئاً هل هذا معناه انه غبي ؟ ام انه فقط لم يتعلم لغة هذا العلم.
- ▶ عندما نذهب الى الصين و لا نفهم ماذا يقول الناس نقول يجب علينا تعلم اللغة.
- ▶ عندما يستشكل عليك امر تأكد تماما ان المشكلة تكمن في اللغة.
- ▶ علينا ان نستوعب لغة أي علم لكي نفهم هذا العلم

# Our universe: up to today knowledge

- ▶ Matter : it is energy  $E=mc^2$
- ▶ Energy (EM Waves):  $E=hf$

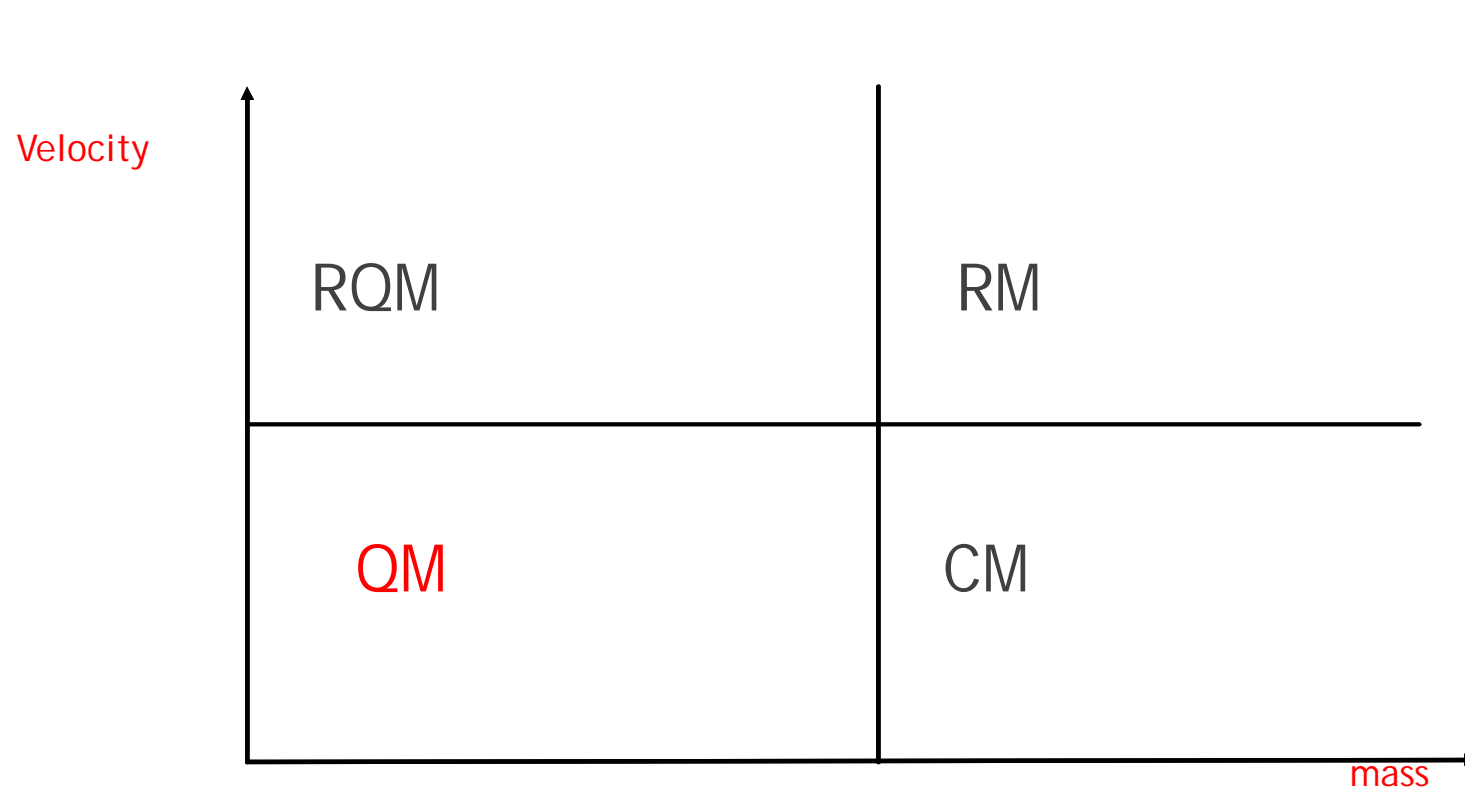
(energy is the mechanism behind an activity)

The mass of a body is a measure of this resistance to change; “dark matter.” This invisible material does not affect light and can be detected only through its gravitational effects. Its detailed nature has yet to be determined

## mass

- ▶ satisfactory grand unified theory (GUT) has yet to be derived, one component, the electroweak theory of Sheldon Glashow, Abdus Salam, and Steven Weinberg (who shared the 1979 Nobel Prize for Physics for this work) predicted that an elementary subatomic particle known as the Higgs boson imparts mass to all known elementary particles. After years of experiments using the most powerful particle accelerators available, scientists finally announced in 2012 the likely discovery of the Higgs boson.





All laws we obtain has some conditions or limitations  
this related to **the limitation of the ability of the  
mankind.**

## According to classical mechanics

- ▶ Wave {amplitude, frequency, wavelength, make interference, can not have momentum}

Energy of the wave distributed continuously a long a broad wave front

The intensity proportional to the square of the amplitude.

- ▶ Matter {mass, momentum, can not make interference(superposition)}

## According to Quantum mechanics

- ▶ Light is quantized, the quanta of the light called photon ( $E=hf$ )
- ▶ Things may behave as waves or as discrete particle depending on the situation. (light has momentum  $p=h/\text{wavelength}$ , can make a collision, matter can make interference)

Matter and wave can change from matter to waves and vice versa according to the situation

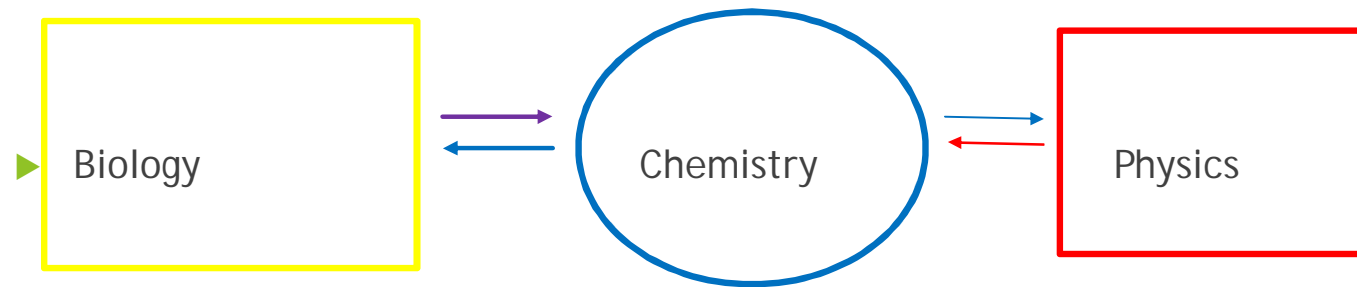
## Why we study Quantum Mechanics ?

- ▶ Transistor
- ▶ Computers, TV, cell phone
- ▶ Solar energy
- ▶ Laser
- ▶ Nuclear energy
- ▶ Nano-technology
- ▶ Quantum computing

Effect of QM on our life is hidden



## Can improve medicine and effect on the biology



- ▶ Hiroshi Amano" **When I was a child, I could not understand why I should study"**

The Nobel Prize in Physics 2014 was awarded jointly to Isamu Akasaki, Hiroshi Amano and Shuji Nakamura *"for the invention of efficient blue light-emitting diodes which has enabled bright and energy-saving white light sources"*.

## Effect of the science on our life

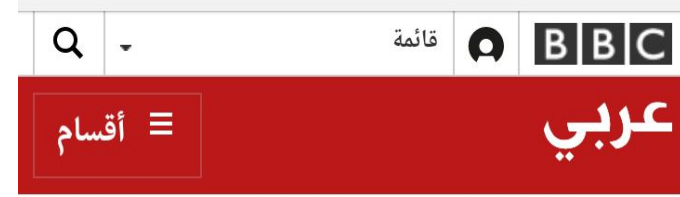
What is the job allowed for you ?

Most the good jobs will be related to science and technology

# Effect of the science on our life

- ▶ On our culture:
- ▶ Cloning
- ▶ Charles Darwin:  
On the Origin of Species by Means of Natural Selection.

اندماج الانسان مع الآلة  
ما يميز الانسان هو قدرته على  
التعاون و التعارف  
هل يفقد الانسان هذه القدرة



## تكوين أجنة بشرية بدون بويضات "يلوح في الأفق"

جيمس غالغر

محرر شؤون الصحة والعلوم - بي بي سي

شارك

14 سبتمبر / أيلول 2016

قال علماء ان تجارب أولية تشم الى احتمال تكوين أجنة

- ▶ Quantum Mechanics built as any other theory
- ▶ I am here to teach you the language of Quantum Mechanics theory and to teach you how to use it.

عندما يستشكل عليك امر تأكد تماما ان المشكلة تكمن في اللغة.

**وظيفتك ان تتقن هذه اللغة و تتقن استخدامها**

# Aim of Mechanics

- ▶ Predict the body position (trajectory) as a function of time.  $\Psi(x, y, z, p_x, p_y, p_z)$

- ▶ Newton's law  
matter

Maxwell's equations  
EM waves

## Classical Mechanics: build determinism (الاحتمية)

### Quantum Mechanics: Destroy determinism

- ▶ Essential feature of Newton's second law that, given the initial coordinate and velocity of a particle and knowing all the forces on the particle, the orbit is uniquely determined as a function of time. The same holds for a system of particles. This is the essence of determinism.
- ▶ **Determinism:** the doctrine (دستور) that all events, including human action, are ultimately determined by causes (الاسباب) regarded as external to the will. Some philosophers have taken determinism to imply that individual human beings have no free will and cannot be held morally responsible for their actions.
- ▶ Quantum mechanics was to bring down the walls of determinism. The instrument of destruction was the Heisenberg uncertainty principle.

# Probability

- ▶ Probability is a concept which enables us to quantify and manipulate uncertainties.  
▶ الاحتمال مفهوم ادخل ليتمكننا من قياس و التحكم في عدم اليقين.
- ▶ Probability enters physics in two ways: **uncertain data and random influences**.
- ▶ QM rather than making firm predictions, it unable us to calculate probabilities.
- ▶ The scale of atoms is the scale on which the probabilistic aspect is predominant. This means, there is no such thing as an isolated atom, and we can not build measuring instruments of arbitrary delicacy.

# The laws of probability

$$p_a = \frac{n_a}{N}$$

$$P(a \text{ and } b) = P_a P_b \quad (\text{independent events})$$

event (a) can not effect event (b).

$$P(a \text{ or } b) = P_a + P_b$$

apperance of a prevent the apperance of b.

With just N mutually exculsive outcomes

$$\sum_{i=1}^N P_i = 1$$

if all outcomes are equally likely

$$P_i = \frac{1}{N}$$

# Expectation values and uncertainty

- Consider only discrete values

$$\langle x \rangle = \sum_i P_i x_i$$

$$\Delta x = \left[ \sum_i P_i (x_i - \langle x \rangle)^2 \right]^{1/2}$$

# Probability amplitude

- ▶ How we calculate probability in quantum mechanics ?

$$P = |\Psi|^2$$

the complex number  $\Psi$  is called probability amplitude

- ▶ Quantum mechanics is the only branch of science that calculate the probability by this method.

- In Quantum mechanics we add amplitudes not probabilities:

Suppose we have two mutually exclusive events T and S,  
has probability amplitude  $\Psi(T)$  and  $\Psi(S)$ .

So the probability amplitude for both T and S is

$$\Psi(T + S) = \Psi(T) + \Psi(S)$$

The probability of finding T and S is

$$P(T + S) = |\Psi(T + S)|^2 = |\Psi(T) + \Psi(S)|^2 \\ = |\Psi(T)|^2 + |\Psi(S)|^2 + 2\text{Re}[\Psi(T)\Psi(S)^*]$$

هذه القاعدة تحل محل قاعدة جمع الاحتمالات

► احتمالية حدوث حدث ما ليست فقط مجموع احتمال الحدثين في المسارين المحتملين و لكن هناك حد إضافي. هذا الحد ليس له تناظر في نظرية الاحتمالات المعروفة لدينا. انه يتعارض مع القوانين التي نعرفها.

- ▶ It depend on the phase of the amplitudes. This term responsible for the Quantum interference.

Quantum mechanics is the branch of science that learn us How we calculate the probability amplitude

في الميكانيكا الكلاسيكية يمكننا معرفة حالة أي نظام مع يقين و حالة الجسم الديناميكية تكون معروفة عن طريق معرفة إحدائياته و سرعته و طاقته.  
مقابل كل قيمه في الميكانيكا الكلاسيكية يناظرها مجموعه من القيم في ميكانيكا الكم يقال لها spectrum .

**a single number in classical mechanics replaced by  
a whole set of quantum amplitude in Quantum mechanics.**

**In Quantum mechanics we do not determine a single value for any observable  
but we determine a spectrum.**