RETURN CHOICES FOR PRESENTATION TOPIC BY WEDNESDAY.

FILL IN TA SURVEY

MIDTERM 1 GRADED

--> OVERALL GOOD JOB

NEED TO MAKE SURE YOU PRACTICE SOME PROBLEMS

GET COMFORTABLE WITH SOME BASIC MATH LIKE COMPARING TWO EQUATIONS.

THINK BEFORE YOU BLINDLY PLUG IN NUMBERS
### PHY100 Spring 2010 Midterm 1 grade distribution

<table>
<thead>
<tr>
<th>Entries</th>
<th>31</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>65.52</td>
</tr>
<tr>
<td>RMS</td>
<td>13.93</td>
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<tr>
<td>Median</td>
<td>66.00</td>
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</table>

**1. Is it possible to prove, for certain, that a scientific theory is false?**

- (a) Yes, by means of a single confirmed experiment that contradicts the theory
- (b) Yes, by taking a vote among all scientists who are experts concerning the theory
- (c) Yes, by performing a large number of experiments and finding that the outcomes that dispute the theory outnumber the outcomes that support the theory
- (d) No, because it is always possible that future experiments will agree with the theory
- (e) No, because science can never be certain of anything
**Time Dilation:**  $T = \gamma T'$

**Proper Time:** Measured on system that is moving, at rest on its Ref. Frame.

**Length Contraction:**  $L' = \gamma L$

**Proper Length**

$m \sim \gamma m'$  → That's why you cannot reach c if you are a massive object, because your mass appears as $\infty$ to an outside observer.

$\gamma = \frac{1}{\sqrt{1 - \left(\frac{v}{c}\right)^2}}$
\[ F_e = \frac{G M_e m}{R_e^2} = g_e \]

\[ F_J = \frac{G M_J m}{R_J^2} = g_J \]

**QUESTION:**

**\( g_J \) in terms of \( g_e \)?

1. \[ g_J = \frac{G M_J}{R_J^2} = G \frac{300 M_e}{(10 R_e)^2} = \frac{300}{100} \times \frac{G M_e}{R_e^2} = 3 \frac{G M_e}{R_e^2} = 3 g_e \]

2. \[ \frac{g_J}{g_e} = \frac{G M_J}{G M_e} \times \frac{R_e^2}{R_J^2} = \frac{M_J}{M_e} \times \frac{R_e^2}{R_J^2} = 300 \times \left( \frac{1}{10} \right)^2 = \frac{300}{100} = 3 \]

\[ \frac{M_J}{M_e} = 300 \]

\[ \frac{R_e}{R_J} = \frac{1}{10} \]
Visible light is only a tiny fraction of the total spectrum.

Visible light is the combination of many colors (red).
Light from many atoms (continuous spectrum)

Light from specific atoms (emission spectrum)

Cold and transparent cloud of gas absorbing some colors (absorption spectrum)
DIFFERENT
ATOMS

↓

DIFFERENT
DISCRETE PATTERN

↓

ATOMIC FINGERPRINTING
BOHR'S MODEL OF THE ATOM

- CIRCULAR ORBITS
- ELECTRIC ATTRACTION KEEPS ATOM STABLE
- DISCRETE ORBITS
  - DISCRETE RADI
  - DISCRETE ENERGIES

PHOTONS Emitted OR ABSORBED BY e⁻ MAKING TRANSITIONS BETWEEN ORBITS

ENERGY DIFFERENCE BETWEEN ORBITS = ENERGY OF PHOTON

THIS PICTURE IS NOT QUITE RIGHT
WE SHOULD THINK OF DE BROGLIE MATTER WAVE \( \lambda = \frac{h}{p} \) INTERFERING WITH ITSELF

\[ \text{DISCRETE ORBITS} \]
**Schrödinger Equation**

\[-\frac{\hbar^2}{2m} \frac{\partial^2 \psi(x)}{\partial x^2} + V \psi(x) = E \psi(x)\]

As important to Q.M. as Newton's laws to classical mechanics.

This eqn. describes the proper wave eq. for the electron.

But it is a general formulation for all matter waves.

**Prescription:**

1) Put e\(^{-}\) in spherical symmetry.

2) Put e\(^{-}\) in Schrödinger eqn. and solve it.

**Result:** Particular allowed spatial states for e\(^{-}\)

- Particular energies allowed.
Different quantum states where e⁻ is

different 3D shapes and energies

e⁻ is no longer in
defined circular orbits

but in “fuzzy” orbitals

These describe all atoms and their spectra

Solutions of Schrödinger equation for hydrogen

Figure 6.12. Probability density plots of some hydrogen atomic orbitals. The density of the dots represents the probability of finding the electron in that region.

© 1983 University Science Books, “Quantum Chemistry” by Donald A. McQuarrie
In fact, to understand chemistry:
you have to understand how e\textsuperscript{-} are arranged among available quantum states.

\[ \text{Electron density} \]

**Spin:** Spin is a fundamental property of nature like charge or mass.

Imagine e\textsuperscript{-} as a spinning ball of charge. Spinning charge creates a magnetic field.

Stern-Gerlach discovered that particles can act like little magnets: they have spin.
Otto Stern vowed in 1913:

"If this nonsense of Bohr should in the end prove to be right, we will quit physics!"

- Article in Physics Today, December 2003

**FOR CLASSICAL "SPINNING" PARTICLES: THE DEFLECTION BY THE INHOMOGENEOUS B FIELD IS RANDOM, EACH PARTICLE WILL BE DEFLECTED UP OR DOWN BY SOME AMOUNT \( \Rightarrow \) EVEN DISTRIBUTION ON SCREEN/DETECTOR.**

The fact that the atoms were deflected in two distinct directions (up by a fixed amount, or down by a fixed amount) means that spin is quantized and only has two possible values: "up" or "down."  

**Spin is quantized**

Think of particles as magnets of selected strengths \( \ldots \) multiple of \( \frac{1}{2} \) \( \Rightarrow \) value for e−

Spin: \( 0, \frac{1}{2}, 1, \frac{3}{2}, 2, \ldots \)
All particles are divided into:

**Bosons**: Integer spins (0, 1, 2, 3, ...)

**Fermions**: $\frac{1}{2}$ integer spins (1/2, 3/2, 5/2, ...)

Two bosons can occupy the same quantum state. Two fermions cannot.

**Energy**

- $n=3, l=2$
- $n=3, l=1$
- $n=3, l=0$
- $n=2, l=1$
- $n=2, l=0$
- $n=1, l=0$

Allowed energies: "Quantum states" from Schrödinger eqn.

Four quantum numbers determine one "state":

- $n =$ principal Q. number $\rightarrow E$
- $l =$ azimuthal Q. number $\rightarrow \text{shape}$
- $m_l =$ magnetic Q. number $\rightarrow \text{orientation}$
- $m_s =$ spin

$\text{e}^-$ can occupy only these Q. states.
<table>
<thead>
<tr>
<th>Atomic Number</th>
<th>Energy (n)</th>
<th>1</th>
<th>2</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>e</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
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<tr>
<td>1</td>
<td>H</td>
<td></td>
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<tr>
<td>2</td>
<td>He</td>
<td></td>
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<td>4</td>
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<td></td>
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</tr>
<tr>
<td>5</td>
<td>B</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>...</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Na</td>
<td></td>
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2 is the atomic number: number of protons in the nucleus.

As 2 increases, so does the number of e⁻.

Fill available quantum levels from lowest to highest.