Physics Questions

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Contents

1 Section Numbering

- If `numbering` $= 0$, there is no numbering.
- If `numbering` $\neq 0$, there is numbering.

$$\texttt{numbering} = 1$$

2 The Idea

Some of these questions may be simple, some may not be, but it is a good idea for a person to write down its quesitons so as not to forget them. Also, putting the questions up for public viewing may lead to an answer from some random reader.

3 Conceptual Questions

3.1 Energy and Mass

- **Concept of Energy**

  Energy is a quantity that characterizes particular motions and configurations of matter and fields (e.g., electromagnetic or gravitational fields) and relates how these motions and configurations can be converted into one another. In this conception, it is the matter and the fields that are physical, while the energy is an intangible property. In general relativity, energy is presented as a seemingly physical source of gravitation. How can we view energy in such a way to resolve this contradiction?

  One could view *everything* as particles, or fields/wavefunctions that have energies determined by their mass, frequency, velocity, etc.

3.2 Classical Mechanics

3.3 Electrodynamics

- **Electromagnetic Kinetic Energy**
  - In a static field, there is some momentum, so how much of the "electromagnetic energy" is "potential" and how much of it is "kinetic"?
  - Same question for a dynamic field.
- **Faraday's Law**

  What is the mechanism behind Faraday's law (in the case where there is no magnetic field at a loop of wire along the Faradayan loop.)?

3.4 Light (Electromagnetic Radiation) and Optics

- **Light and Electromagnetic Radiation**

  How true is it that light is electromagnetic radiation?
  - My understanding: Light that reaches the eye can be considered to be virtual photons, to some extent, and radiation, to some extent.
- **Huygen's Principle**

  To what degree is Huygen's principle true? If it were completely true one would never expect to see laser beams, since they should immediately disperse in different directions.
  - I have seen a beam from the sun (which came through a rectangular hole on one side of a room) reach the other side of the room, transformed into a more elliptical shape. How can one describe this behavior?

3.5 Quantum Mechanics

- **Spin**
  - Can spin momenta and other angular momenta be converted into each other?
  - When we talk about rotating a spinor by 360 degrees, what is it that is really being rotated? (with respect to real space?)
  - Why do we force the magnetic dipole moment vector operator to be parallel to the spin vector operator? ($\boldsymbol{\mu} = -\mu_p \mathbf{L} - g\mu_p \mathbf{S}$)
  - Are there higher multipoles of "spin"? (Spin is associated with a magnetic dipole moment; what about the possibility of internal or intrinsic magnetic quadrupoles, etc.?)
  - Why does (show how) the spin singlet state $|0,0\rangle = \frac{1}{\sqrt{2}}(|+-\rangle - |-+\rangle)$ yeild zero total spin while the $m = 0$ triplet state $|1,0\rangle = \frac{1}{\sqrt{2}}(|+-\rangle + |-+\rangle)$ yield non-zero ($s = 1$) spin?
- **Operator algebra**

  Why are commutation relations all you need to know to understand the properties of everything in quantum mechanics? What are the relevant concepts and the big picture?
- **Time / Viscosity**

  In my astronomy book rock was likened to silly putty - it breaks if it is pulled apart too quickly but stretches when pulled slowly enough. (Everything is fluid and has its own viscosity.) Here's the question: If I could move incredibly quickly, could I pick up a blob of water and mold it into some arbitrary shape like silly putty?
- **Units**

  Why are the mole and the candela not "derived units"? The mole, as it relates to Avagodro's number, seems to be an experimental constant rather than a fundamental unit. If we're measuring "amount of substance" by just counting the number of "elementary entities", then the number 1 seems to be a more fundamental unit to me. Other fundamental units are really arbitrarily defined, but a mole is not since it relates number of particles to another SI unit - that of mass (grams). Also, how does one measure luminous intensity? As I gather from the

Wikipedia article, it has to do with the perceived power of visible light by the human eye. (See the current SI unit definitions from NIST.)

- **Conventions**

  In quantum mechanics, is there a reason why a person might prefer the definition $\hbar\mathbf{J} = (\mathbf{r} \times \mathbf{p})$, so that $\mathbf{J}$ is a unitless operator? Does this somehow make the connection to classical mechanics more apparent at some point?

- **Stern-Gerlach**

  Why does the magnetic field in a Stern-Gerlach experiment have to be inhomogeneous? (Why is a moving magnetic dipole only deflected by inhomogeneous magnetic fields?)

  – Simple: we have $\mathbf{F} = -\boldsymbol{\nabla}U = -\boldsymbol{\nabla}(-\boldsymbol{\mu} \cdot \mathbf{B})$, and $\boldsymbol{\nabla}$ only applies to $\mathbf{B}$, so $\mathbf{B}$ must vary over space if there is to be a displacing force.

- **QM Operators**

  What is the difference between operators in quantum mechanics (QM) that correspond to measurements and ones that don't?

  – An operator that corresponds to an observable (and thus measurement), must be Hermitean to have real eigenvalues. Note that an operator that corresponds to an observable does not describe a transformation of the vector state it operates on. However, the physical act of measurement upon a (previously isolated) system does transform the system's state; linking a large, macroscopic system (measuring device) with a small, microscopic system will necessitate exchange of momentum, at least. You could either say that the microscopic system is no longer isolated or that the system under consideration has been enlarged to macroscopic proportions. Anyway, other operators that are not associated with observables could just so happen to be Hermitean (as in the case of reflection on even or odd parity states), but they must be unitary, to preserve the unitary probability (the unitary norm) of the vector state... No... this is wrong, because the raising and lowering operators are not unitary. Another nonunitary operator appears when we model the decay of a particle, in which case we allow an exponential decrease in the value of the norm of the state of that particular particle. These other operators do describe transformation of states of systems (although, transformations that result in simply multiplying a state by a complex number of unit magnitude are not directly observable). – (I need to look at time-symmetry and anti-unitarity again as well.)

- **Quantum Harmonic Oscillator**

  What is the physical significance of multiplying a state by zero? (Or, mathematically, what is that state?) Is it the vacuum/null/empty state? Does it matter that it's not normalizable? Does this relate to the vacuum state of quantum field theory?

3.6 Relativity

- **Length Contraction Trick**

  Could you keep a long object in a small container by causing it to move very fast so as to contract in length then sending it inside the container and have it whiz around in circles so as to remain length contracted?

- **General Relativity: Photon Gravitation**

  Is it possible to have enough energetic photons to create a photon star? (so that the photons are held together or localized by their self-gravitation?)

3.7 Historical

- **Historical**

  – How did people first explain mass (at the time conservation of momentum was discovered but before Newton's second law of motion, $\mathbf{F} = \mathrm{d}(m\mathbf{v})/\mathrm{d}t$)? It must have been related to weight and how heavy an object is. Did they not also relate this to "inertia" or "impetus"?

  – Who first called Newton's first law "the law of inertia"? Newton? (Shouldn't Newton's first and second laws together be called "the laws of inertia"? Has anyone given an authoritative, technical definition of inertia?

3.8 Bohr Magneton

We derive the electron orbit magnetic dipole moment and thereby define the Bohr magneton.

Using the Bohr assumptions, the electron circulates in a flat orbit of radius r, with quantized angular momentum $L = |\mathbf{r} \times \mathbf{p}| = mrv = n\hbar$ (it isn't $\hbar\sqrt{l(l+1)}$???), and

$$\mu = IA = \left(-e\frac{v}{2\pi r}\right)(\pi r^2) = -\frac{evr}{2} = -\frac{e}{2m}L = -\frac{e\hbar}{2m}\sqrt{l(l+1)} \equiv \mu_B\sqrt{l(l+1)}$$

(I got this from `http://hyperphysics.phy-astr.gsu.edu/hbase/quantum/orbmag.html`)

WAIT A MINUTE! ISN'T $L = n\hbar$ IN THE BOHR MODEL, NOT $L = \hbar\sqrt{l(l+1)}$???

4 Incorrect Hypotheses

- Why does Newton's particle theory of light predict that the velocity of light in water is greater than that in air? (The wave theory of light, using Huygen's principle predicts correctly that light's velocity is lower in water than in air. In 1850 the French physicist Jean Foucault performed an experiment to measure the speed of light in water and confirmed the wave-theory prediction, although by then the wave theory was already fully accepted.) [See Giancoli [1] pg 868]

5 Open Questions

5.1 Classical Mechanics

- Dirac entered physics at the end of this baroque period. One of his first papers was an attempt at a general theory of these unchanging quantities. This is a delicate problem in classical mechanics, not solved even now. `http://physicsweb.org/articles/world/11/2/9`

6 Applicational Questions

- How does a battery work? `http://www.av8n.com/physics/battery.htm`
- How does a the Earth's magnetic field flip?
- How much have people worked on trying to harness lightning power (or lengthening the duration of the charge transfer and safely utilizing it)?

7 Miscellaneous

- **Liouville's Theorem**

  Is it really related to the fundamental theorem of algebra?

  - There are multiple Liouville theorems, some of which are not related to the fundamental theorem of algebra.

References

[1] Douglas C. Giancoli: *Physics for Scientists & Engineers with Modern Physics, Third Edition*, Prentice Hall (2000)