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Conversations in Physics

Do We Understand Classical Mechanics?

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1. Introduction

It is often stated that quantum mechanics is inconsistent with 'common sense' and intuitive notions of reality. Wave-particle duality, quantum tunnelling, uncertainty principle, wave function collapse, measurement problem, non-locality, entanglement, quantum teleportation etc provide good examples that can be used to substantiate this argument. Richard Feynman in *The Character of Physical Law* says "I think I can safely say that nobody understands quantum mechanics." However, I would like to point out that there are several things in classical mechanics that are difficult to understand intuitively. Furthermore there are many apparent contradictions which are yet to be resolved fully. Let me explain this with a few examples.

2. Reflection of Light and Corpuscular Theory

Take the case of reflection of ordinary light. In Physics classrooms we state that to explain reflection we need only corpuscular theory of Newton, whereas to explain things such as interference or polarisation we need to invoke wave theory. But Sir Isaac Newton himself in his Opticks (Yes, that is the original spelling, not Optics!) explains that any simple models of reflection does not work.

Let us start with the case of reflection of a beam of light from, say, a metal surface. We will be tempted to assume that the corpuscles of light get just bounced off the surface as if it is like tennis balls getting reflected from a brick wall. Even the laws of reflections can be explained by this model. However as Newton himself points out, this simple model will not be sufficient to explain internal reflection. For example consider a beam of light travelling within a glass slab, surrounded by, say, air. In this case a ray within the material does not meet a hard wall at the boundary. But still at least a part of the light gets internally deflected. And if the angle of incidence is more than the critical angle the internal reflection is total.

So in the next step, we may change our model to say that for reflection, we don't need a hard wall, but a boundary is all that we need. We will realise soon that even this is insufficient. Consider the case of a beam of light travelling within a glass slab that is falling at an angle just above the critical angle. In this case, the light will undergo total internal reflection. Now think of pouring some water at the boundary. Note that the critical angle for the glass-water interface is less than that for the glass-air interface. So in this case part of

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the light escapes from the glass slab and part of this will get internally reflected. That is, in some sense the light that is falling on the boundary should 'know' what is on the other side. This can't be explained by our model.

We can now go a step beyond this to consider the case of reflection of light on the surface of a, say gold foil. If this is very thin - points out Isaac Newton - the light will go through the foil. But if we use a thick sheet of the same material,it will be opaque and most of the light will be reflected. How do we explain this with corpuscular theory? In this case the corpuscles should 'make a measurement of the thickness' before deciding whether to go through or return back.

3. Sailboat Moving Faster than the Wind

Another interesting fact is that many sailboats can actually travel faster than the wind that pushes it forward. This can be achieved by careful designing of the boats/sails and expertise in manoeuvring. When this is achieved and a rider moves faster than the wind, in the frame of reference of the rider the wind will be flowing against him/her. Though this sounds counter-intuitive this is true. Yet another astounding thing is that sailors can steer their sailboat against the direction of the wind by a technique called tacking. Actually the famous physicist and sailor, late V. Radhakrishnan of Raman Research Institute has published a lovely article in Current Science titled 'From square sails to wing sails: The Physics of sailing craft. BTW he was the son of C V Raman and cousin of S Chandrasekhar both Nobel Laureates. Recently Derek Muller has made a video and uploaded it on YouTube with the title 'Risking My Life to Settle a Physics Debate' and that is strongly recommended. *See the Video*

4. The Mpemba Effect

If you have not heard about Mpemba effect, just google it and you will get a lot of information on an interesting effect named after a Tanzanian school boy. This refers to an observation that warmer water freezes faster than cold water. Though many philosophers such as Rene Descartes (See Discourse on the method) have observed and tried to explain it even today many questions remain open as to why this happens.

5. Balancing a Bicycle

> Life is like riding a bicycle. To keep your balance you must keep moving.

We will all agree with this quotation of Albert Einstein. However if we are asked to explain the physics of the balancing act, it is not at all trivial. For example, we will be tempted to give an explanation by simply referring to the conservation of angular momentum. But this argument can be proved wrong by trying to ride a bicycle after locking the handle bar. You may also be refer to conservation of linear momentum. But this argument also fails to explain the fact that even if you give a knock to a ghost-riding bicycle it will continue to move with stability. If this sounds interesting see these videos by *minutephysics* or *veritasium*.

These will make you think that there is more to learn in classical mechanics.
