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Quantum Jungles

Next morning Mr Tompkins was dozing in bed, when he became aware of somebody's presence in the room. Looking round, he discovered that his old friend the professor was sitting in the armchair, absorbed in the study of a map spread on his knee.

'Are you coming along?' asked the professor, lifting his head.

'Coming where?' said Mr Tompkins, still wondering how the professor had got into his room.

'To see the elephants, of course, and the rest of the animals of the quantum jungle. The owner of the billiard room we visited recently told me his secret about the place where the ivory for his billiard-balls came from. You see this region which I've marked with red pencil on the map? It seems that everything within it is subject to quantum laws with a very large quantum constant. The natives think that all this part of the country is populated by devils, and I am afraid it will hardly be possible for us to find a guide. But if you want to come along, you had better hurry up. The boat is sailing in an hour's time and we still have to pick up Sir Richard on our way.'

'Who is Sir Richard?' asked Mr Tompkins.

'Haven't you ever heard about him?' The professor was evidently surprised. 'He is a famous tiger-hunter, and decided to go with us, when I promised him some interesting shooting.'

They came to the docks just in time to see the loading of a number of long boxes containing Sir Richard's rifles and the special bullets made from lead which the professor had obtained from the lead mines near the quantum jungle. While Mr Tompkins was arranging his baggage in the cabin, the steady vibrations of the boat told him that they were off. The sea journey was nothing remarkable, and Mr Tompkins scarcely noticed the time until they came ashore in a fascinating oriental city, the nearest populated place to the mysterious quantum regions.

'Now,' said the professor, 'we have to buy an elephant for our journey inland. As I do not think any of the natives will agree to go with us, we shall have to drive the elephant ourselves, and you, my dear Tompkins, will have to learn the job. I shall be too busy with my scientific observations and Sir Richard will have to handle the firearms.'

Mr Tompkins was rather unhappy when, coming to the elephant market on the outskirts of the city, he saw the huge animals, one of which he would have to handle. Sir Richard, who knew a lot about elephants, picked out a nice big animal and asked the owner what price it was.

'Hrup hanweck 'o hobot hum. Hagori ho, haraham oh Hohohohi,' said the native, showing his shining teeth.

'He wants quite a lot of money for it,' translated Sir Richard, 'but says that this is an elephant from the quantum jungle and it is therefore more expensive. Shall we take it?'

'By all means,' explained the professor. 'I heard on the boat that sometimes elephants come from the quantum lands and are caught by the natives. They are much better than the elephants from other regions, and in our case we shall have quite an advantage because this animal will feel at home in the jungle.'

Mr Tompkins inspected the elephant from all sides; it was a very beautiful, large animal, but there was no marked difference in its behaviour from the elephants he had seen in the Zoo. He turned to the professor—'You said that this was a quantum elephant, but it looks just like an ordinary elephant to me, and does not behave in a funny way, like the billiard-balls made from the tusks of some of its relatives. Why doesn't it spread out in all directions?'

'You show a peculiar slowness of comprehension,' said the professor. 'It is because of its very large mass. I told you some time ago that all the uncertainty in position and velocity depends on the mass; the larger the mass, the smaller the uncertainty. That is why the quantum laws have not been observed in the ordinary world even for such light bodies as particles of dust, but become quite important for electrons, which are billions of billions of times lighter. Now, in the quantum jungle, the quantum constant is rather large, but still not large enough to produce striking effects in the behaviour of such a heavy animal as an elephant. The uncertainty of the position of a quantum elephant can be noticed only by close inspection of its contours. You may have noticed that the surface of its skin is not quite definite and seems to be slightly fuzzy. In course of time this uncertainty increases very slowly, and I think this is the origin of the native legend that very old elephants from the quantum jungle possess long fur. But I expect that all smaller animals will show very remarkable quantum effects.'

'Isn't it nice,' thought Mr Tompkins, 'that we are not doing this expedition on horseback? If that were the case, I should probably never know whether my horse was between my knees or in the next valley.'

After the professor and Sir Richard with his rifles had climbed into the basket fastened on to the elephant's back, and Mr Tompkins, in his new capacity of mahout, had taken his position on the elephant's neck, clutching the goad in one hand, they started towards the mysterious jungle.

The people in the city told them that it would take about an hour to get there, and Mr Tompkins, trying to keep his balance between the elephant's ears, decided to make use of the time by learning more about quantum phenomena from the professor.

'Can you tell me, please,' he asked, turning to the professor, '*why* do bodies with small mass behave so peculiarly, and what is the commonsense meaning of this quantum constant that you are always talking about?'

'Oh, it is not so difficult to understand,' said the professor. 'The funny behaviour of all objects you observe in the quantum world is just due to the fact that you are looking at them.'

'Are they so shy?' smiled Mr Tompkins.

'"Shy" is an unsuitable word,' said the professor bleakly. 'The point is, however, that in making any observation of the motion you will necessarily disturb this motion. In fact, if you learn something about the motion of a body, this means that the moving body delivered some action on your senses or the apparatus you are using. Owing to the equality of action and reaction we must conclude that your measuring apparatus also acted on the body and, so to speak, "spoiled" its motion, introducing an uncertainty in its position and velocity.'

'Well,' said Mr Tompkins, 'if I had touched that ball in the billiard room with my finger I should certainly have disturbed its motion. But I was just looking at it; does that disturb it?'

'Of course it does. You cannot see the ball in darkness, but if you put on the light, the light-rays reflected from the ball and making it visible will act on the ball—light-pressure we call it—and "spoil" its motion.'

'But suppose I used very fine and sensitive instruments, can't I make the action of my instruments on the moving body so small as to be negligible?'

'That is just what we thought in classical physics, before the *quantum of action* was discovered. At the beginning of this century it became clear that the *action* on any object cannot be brought below a certain limit which is called the quantum constant and usually denoted by the symbol "h". In the ordinary world the quantum of action is very small; in customary units it is expressed by a number with twenty-seven zeros after the decimal point, and is of importance only for such light particles as electrons which, owing to their very small mass, will be influenced by very small actions. In the quantum jungle we are now approaching, the quantum of action is very big. This is a rough world where no gentle action is possible. If a person in such a world tried to pet a kitten, it would either not feel anything at all, or its neck would be broken by the first quantum of caress.'

'This is all very well,' said Mr Tompkins thoughtfully, 'but when nobody is looking, do the bodies behave properly, I mean, in the way we are accustomed to think?'

'When nobody is looking,' said the professor, 'nobody can know how they do behave, and thus your question has no physical sense.'

'Well, well,' exclaimed Mr Tompkins, 'it certainly looks like philosophy to me!'

'You can call it philosophy if you like'—the professor was evidently offended—'but as a matter of fact, this is the fundamental principle of modern physics—*never to speak about the things you cannot know*. All modern physical theory is based on this principle, whereas the philosophers usually overlook it. For example, the famous German philosopher KANT spent quite a lot of time reflecting about the properties of bodies not as they "appear to us", but as they "are in themselves". For the modern physicist only the so-called "observables" (i.e. principally, observable properties) have any significance, and all modern physics is based on their mutual relation. The things which cannot be observed are good only for idle thinking—you have no restrictions in inventing them, and no possibility of checking their existence, or of making any use of them. I should say....'

At this moment a terrible roar filled the air and their elephant jerked so violently that Mr Tompkins almost fell off. A large pack of tigers was attacking their elephant, jumping simultaneously from all sides. Sir Richard grabbed his rifle and pulled the trigger, aiming right between the eyes of the tiger nearest to him. The next moment Mr Tompkins heard him mutter a strong expression common among hunters; he shot right through the tiger's head without causing any damage to the animal.

'Shoot more!' shouted the professor. 'Scatter your fire all round and don't mind about precise aiming! There is only one tiger, but it is spread around our elephant and our only hope is to raise the Hamiltonian.'

The professor grabbed another rifle and the cannonade of shooting became mixed up with the roar of the quantum tiger. An eternity passed, so it seemed to Mr Tompkins, before all was over. One of the bullets 'hit the spot' and, to his great surprise, the tiger, which became suddenly one, was vigorously hurled away, its dead body describing an arc in the air, and landing somewhere behind the distant palm grove.

'Who is this Hamiltonian?' asked Mr Tompkins after things had quietened down. 'Is he some famous hunter you wanted to raise from the grave to help us?'

'Oh!' said the professor, 'I am so sorry. In the excitement of battle I started to use scientific language—which you cannot understand! Hamiltonian is a mathematical expression describing the quantum interaction between two bodies. It is named after an Irish mathematician, HAMILTON, who first used this mathematical form. I just wanted to say that by shooting more quantum bullets we increase the probability of the interaction between the bullet and the body of the tiger. In the quantum world, you see, one cannot aim precisely and be sure of a hit. Owing to the spreading out of the bullet, and of the aim itself, there is always only a finite chance of hitting, never a certainty. In our case we fired at least thirty bullets before we actually hit the tiger; and then the action of the bullet on the tiger was so violent that it hurled its body far away. The same things are happening in our world at home but on a much smaller scale. As I have already mentioned, in the ordinary world one has to investigate the behaviour of such small particles as electrons in order to notice anything. You may have heard that each atom consists of a comparatively heavy nucleus and a number of electrons rotating round it. One used to think, at first, that the motion of electrons round the nucleus is quite analogous to the motion of planets round the sun, but deeper analysis has shown that ordinary notions concerning the motion are too rough for such a miniature system as that of the atom. The actions which play an important role inside an atom are of the same order of

A large pack of fuzzy-looking tigers was attacking their elephant magnitude as the elementary quantum of action and thus the whole picture is largely spread out. The motion of the electron round the atomic nucleus is in many respects analogous to the motion of our tiger, which seemed to be all round the elephant.'

'And does somebody shoot at the electron as we did the tiger?' asked Mr Tompkins.

'Oh yes, of course, the nucleus itself sometimes emits very energetic light quanta or elementary action-units of light. You can also shoot at the electron from outside the atom, by illuminating it with a beam of light. And it all happens there just as with our tiger here: many light quanta pass through the location of the electron without affecting it, until presently one of them acts on the electron and throws it out of the atom. The quantum system cannot be affected slightly; it is either not affected at all, or else changed a lot.'

'Just as with the poor kitten which cannot be petted in the quantum world without being killed,' concluded Mr Tompkins.

'Look! gazelles, and lots of them!' exclaimed Sir Richard, raising his rifle. In fact a big herd of gazelles was emerging from the bamboo grove.

'Trained gazelles,' thought Mr Tompkins. 'They run in as regular formation as soldiers on parade. I wonder if this is also some quantum effect.'

The group of gazelles which was approaching their elephant was moving rapidly and Sir Richard was ready to shoot, when the professor stopped him.

'Do not waste your cartridges,' he said, 'there is very little chance of hitting an animal when it is moving in a diffraction pattern.'

'What do you mean by "*an*" animal?' exclaimed Sir Richard. 'There are at least several dozens of them!'

'Oh no! There is only one little gazelle which, because it is scared of something, is running through the bamboo grove. Now, the "spread-out" of all bodies possesses a property analogous to that of ordinary light; and, passing through a regular sequence of

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openings, for instance between the separate bamboo trunks in the grove, it shows the phenomena of diffraction about which you might have heard at school. We speak therefore about the wave-character of matter.'

But neither Sir Richard nor Mr Tompkins could think at all what this mysterious word 'diffraction' might mean, and the conversation stopped at this point.

Passing farther through the quantum land our travellers met quite a lot of other interesting phenomena, such as quantum mosquitoes, which could scarcely be located at all, owing to their small mass, and some very amusing quantum monkeys. Now they were approaching something which looked very much like a native village.

'I did not know,' said the professor, 'that there was a human population in these regions. Judging by the noise, I suppose they are having some sort of festival. Listen to this incessant noise of bells.'

It was very difficult to distinguish the separate figures of natives who were evidently dancing a wild dance round the big fire. Brown hands with bells of all sizes were constantly rising from among the crowd. As they approached still closer, everything, including the huts and surrounding big trees, began to spread out, and the ringing of the bells became unbearable to Mr Tompkins's ears. He stretched his hand out, grabbed something, and then threw it away. The alarm clock hit the glass of water standing on his night-table and the cold stream of water brought him to his senses. He jumped up, and started to dress rapidly. In half an hour he must be at the bank.