QUANTUM QUEST

Story by Brigid Sweeney, Khalak Mahadeviya,
Mark Mitchison, Saulo Moreira.
Illustrated by Brigid Sweeney

AMBER
Advancing Materials for Impact

Advanced Materials and BioEngineering Research (AMBER) Centre, hosted at Trinity College, Dublin is a multi-disciplinary, multi-university centre for world-class materials science research. The mission of our 300+ team members is to drive excellence in materials science research for people, planet and prosperity. A fundamental aspect of AMBER's work is our Education and Public Engagement (EPE) programme, which aims to inspire, facilitate and celebrate engagement between AMBER and the public to encourage authentic involvement in materials science and bioengineering research for societal improvement. We provide multiple inclusive pathways for the public to engage with AMBER's research, with particular attention given to underrepresented and underserved communities. We aim to foster young people's STEM identities, with the aim of enhancing their agency and active citizenship in a rapidly changing world.

FIGHTING WORDS
The write to right.

Fighting Words is a creative writing organisation that aims to help children and young people, and those who did not have this opportunity as children, discover and harness the power of their own imagination and creative writing skills, strengthening their ability to be resilient, creative and successful shapers of their own lives. It has twenty centres across the island of Ireland.

ASPECTS
aspects-quantum.com

Co-funded by
the European Union

Quantum Quest

Story by Brigid Sweeney, Khalak Mahadeviya,
Mark Mitchison, Saulo Moreira.
Illustrated by Brigid Sweeney

Preface

Quantum Quest was conceived and written through a partnership between Fighting Words and AMBER Centre. The project aimed to make complex science and STEM concepts more accessible to the public through the medium of creative writing. Through a series of four creative workshops, researchers from the School of Physics in Trinity College Dublin participating in the ASPECTS project, which is co-funded by the EU and UKRI, worked with Fighting Words facilitators to write this science story for children. Throughout the process we were struck by synergies between scientific thought and creative writing in their ability to evoke wonder and curiosity with both disciplines encouraging us to see the world afresh. We hope this playful approach to exploring the sciences will evoke the same curiosity and wonder in the reader.

Heartfelt thanks to AMBER researchers and collaborators Mark Mitchison, Khalak Mahadeviya, and Saulo Moreira for embarking on this creative quest with us with such enthusiasm and openness. We are greatly indebted to Philip Elliott and Brigid Sweeney, expert illustrators, storytellers and Fighting Words volunteers. Warm thanks also to proof-reader and Fighting Words volunteer, Lucy Taylor, for her eagle eye.

We hope you enjoy this Quantum Quest!

Dr Mairéad Holden, Education & Training Manager / Bainisteoir Oideachais & Oiliúna, AMBER, SFI Research Centre for Advanced Materials and BioEngineering Research, Trinity College, University of Dublin.

Nora Nic Con Ultaigh, Education Director/ Stiúrthóir Oideachais, Fighting Words.

When I was eleven, my uncle invited myself and my twin brother to Paris. It was 1967 and an important year for him because it marked the centenary of Marie Curie's birth. He worked in the museum named after Marie Curie, and he was excited to be opening up her chemistry laboratory to select visitors. We were selected, so we felt very important indeed.

We were to meet Uncle Pierre at 1, rue Pierre et Marie Curie! Yes, a street named after Marie and her beloved husband in the 5th arrondissement (the city of Paris is split into various districts called arrondissements).

We got there early. Uncle Pierre had not yet arrived to unlock the door for us. October was halfway through and already we could feel winter's icy breath in the morning air.

"Such a pity we can't walk through brick walls," laughed Bob.

"Or shrink so we could fit under the door," I added.

Just then, our uncle arrived with the keys. Under his hat I could see his famous blue eyes. They sparkled like sapphires in the sunlight. Uncle Pierre heard us talking and told us that thanks to Marie Curie and scientists like her, we might just be able to find a way to walk through walls. We might be able to shrink and fit under them too.

"Come inside, Alice. You too, Bob, and I'll show you," he said, grinning.

The inside of the museum looked like an old house. It smelled like Madame Gardot's house. She was my piano teacher, and she used a lot of floor polish and strong soap to keep her house free from germs.

We stopped in a corridor full of wooden cabinets displaying glass bottles all neatly arranged and labelled. There were at least half a dozen doors but they were closed. Bob and I were told to wait in the hall. Uncle Pierre would be back in a minute.

"Please try not to touch anything," he said and left us.

On a cabinet near the coat hooks was a curious apparatus. It had the look of a clock. Bob thought that

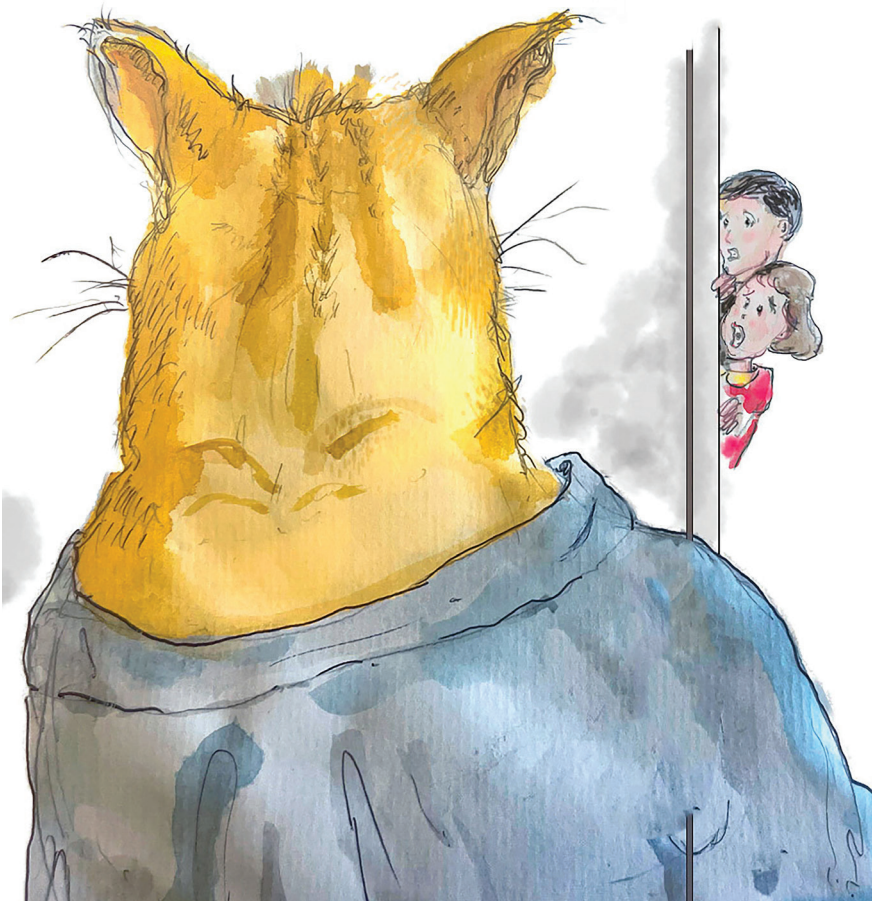
perhaps it was broken. He was the kind of boy who liked everything just so. And this clock did have a queer broken look to it. I suggested we wait until Uncle Pierre returned before we started to tinker.

But Bob was not a very patient person. The clock was under a glass cloche (a glass cover in the shape of a bell – 'cloche' is French for bell). He lifted it off and reached for the clock. At that very minute, he disappeared!

What had happened? I called for our uncle. I called again, louder. I was panicking. Then I thought perhaps Bob was playing a trick on me. I went over to the clock. I went to move it to see if Bob was hiding behind it.

Suddenly, I felt a whoosh of air below me (or was it above?). I was moving quickly like one does in a dream. Then thump! I was on the ground as if I had skidded off the edge of a slide having descended too quickly. Bob was standing above me looking as confused as I felt.

"Alice, what the…" was all he managed to say.



I got up and looked around. Where on earth were we? This place was very odd indeed. For starters, when I moved, my body looked different. So did Bob's. He put out his arm to help me up. Oddly, his arm looked as though it was in water, even though it wasn't. It seemed to ripple.

Maybe my eyes were blurry from the strange event that had just happened. The place we were in was not that different to the place from where we had come. But it felt very different.

Just then, we heard a noise that seemed to be coming from around the corner. We moved towards the sound. Slowly, we peered around the door. Two very remarkable things happened at that moment. First, the wooden door frame dissolved, allowing myself and my brother to walk right through. And a very large cat appeared.

"Bob," I managed to whisper, "that cat is bigger than the two of us. And he's wearing a lab coat."

"I can also speak," said the cat, grinning. He laughed. "I am Cat. I'll show you around," he said.

I suppose we were too shocked to be afraid. And Cat didn't seem too threatening.

He continued: "Welcome to the Quantum World. I suppose you are the type of creatures that don't care for rules. Otherwise you would not have touched the clock in the hallway. You see, it is a special clock. It is a portal to the Quantum World. That is where you are now. Although you are still in your world. It is just a part of your world

you cannot see... usually. You are now the size of an electron. You've heard of electrons haven't you?"

Our faces showed that we had not.

"You've surely heard of atoms?" Again, not.

Cat looked irritated. But he continued the lesson.

"Atoms are tiny particles that make up everything you see and touch in the regular world. Within an atom are even smaller particles called electrons, protons and neutrons. And that is the size you are now."

This was absurd! A giant talking cat telling us we were now smaller than the smallest particle. And it got more crazy. As Cat spoke, another cat started to speak. The second cat was identical to the first. It seemed like Cat had two bodies in two separate places, but only one voice.

"Not only are you in a world much smaller than where you came from, but here you can look as if you are in different places at the same time!"

And with that, Cat appeared in five places and kept talking.

"Like I said, you have entered the Quantum World through a portal in the Classical World. The portal is in the clock in the corridor," Cat continued. "You can have a lot of fun here as long as you accept that everything is different from what you are used to. Rules in the Classical World don't apply here. That is why you were able to walk through that door frame earlier."

Now the five cats were three. My mind was racing. Perhaps, I thought, I might divide myself into five as well?

But Cat was talking again. “It is probably best not to question any of it. Just enjoy it. It is really fun here. Listen to me…” Cat started reciting a poem about an old man talking in his sleep. As he did so, his voice changed. He sounded like a girl now.

“Would you like a tour?” she asked.

Bob looked at me. Our curiosity was piqued.

“Yes please!” We said together.

Cat brought us down the corridor which was not unlike the hall in the Madame Curie Museum. Then she stopped at a closed door and looked very, very serious.

“We NEVER go inside this room,” she said.

“Why not? “I asked.

“This is the Observation Room,” said Cat. “All I know is that if you go in there, you will lose all your new powers. And then you will disappear.”

“Disappear to where?” asked Bob.

Cat did not answer, but continued looking stern. Then she warned, “Do not enter under any circumstances.”

“How long have you been here?” asked Bob.

Cat answered simply, “Well, I’ve been here since I arrived.”

This was a lot to consider. Bob looked worried.

“Do you think Uncle Pierre has noticed us missing?” he whispered to me. “Perhaps Cat could show us how to

return to the Classical World. You know, in case we need to."

But Cat was disappearing through a wall.

"I'll be back soon. Read the book on the table!" And with that, they were gone.

A very large book sat on a table by the window.

"It's called Quanpendium," said Bob, taking it into his hands. "Your Guidebook to the Quantum World."

He opened the volume. To our dismay, there were hundreds and hundreds of pages with very small writing.

It was all very scientific and difficult to understand.

"What is The Theory of Quantum Chrom-o-dynamics, and how do I pronounce it?" I asked. "This is not going to help us!"

And with that I slammed the book shut. I wanted to walk through walls again.

"C'mon, Bob! Let's play! Cat told us it was fun here. Let's have fun!"

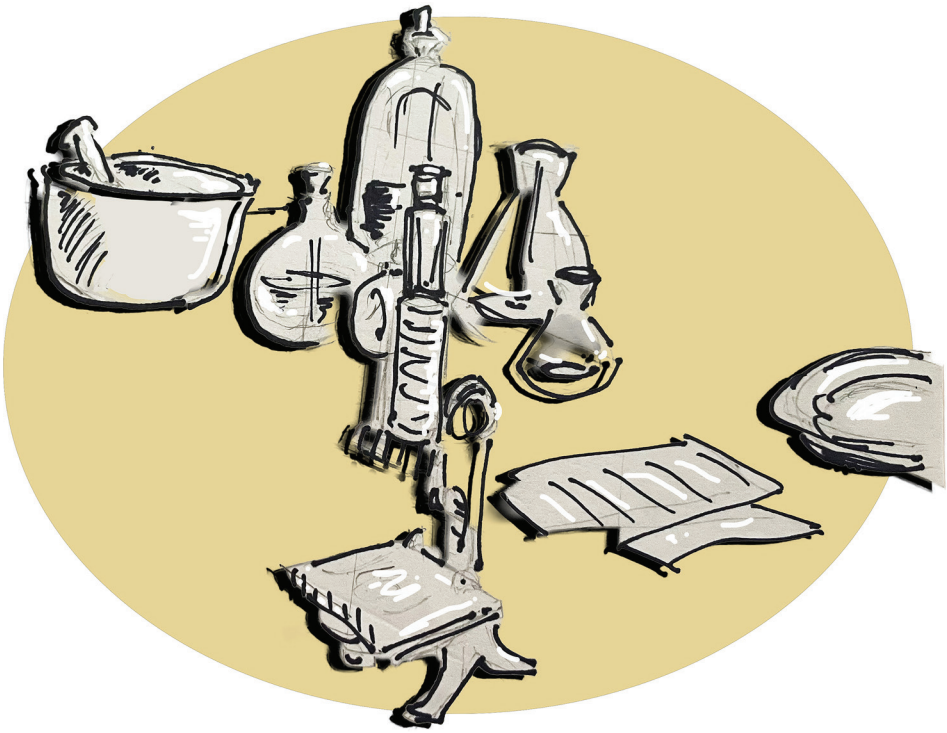
Bob was opening the book again. He looked uncomfortable. But my mind was racing. Imagine walking through walls as if they were made of air. Imagine being in two places at the same time. What else could we do here in this Quantum World?

"Come ON!" I cried, looking at my rather nervous brother. "Let's explore."

And with that, I whooshed through the wall! Now I was in a room full of shelves on top of which were funny bottles and jars of all sizes. There were rubber pipes and burners on the counter tops. I knew better than to touch anything here.

The walls were lined with glass shelves. I didn't want to knock down the bottles and I supposed I could use the door, but what fun would that be?

Whoosh! I found myself in a room with lots of books and folders. I didn't recognise any of the titles. Most of them were names: Thomas Young, Isaac Newton and someone called Huygens. It looked like a school room.



“Boring!” I yelled out and whooshed through another wall.

I was in another lab. More jars and pipes and notebooks. I wondered who else lived here. I also wondered whether walking through walls was only one of many new tricks we were able to perform in the Quantum World. Could I double myself like Cat did? I started to think… perhaps I could change other things.

My hair was very dark. It had a slight curl and fell to my

shoulders. There had been a girl in my last class at school with beautiful long hair, the colour of rust in afternoon sunlight. She always had it tied neatly into two plaits. I concentrated on having her hair. I felt a sensation in my whole body. My skin was tingling.

There was no mirror but I was just about to make out my reflection in the glass cupboards. My hair looked longer! I was able to pull it around my shoulders and it was … it was orange. Not rust, but it was different. I did it! However, looking down at my arms, I noticed they had turned a very light pink. Extraordinary!

I had to find Bob.

"Bob!" I called out. There was no response. I repeated myself. "Bob!".

I decided to retrace my steps. I wooshed through the walls. I found him still looking through the Quanpendium. He stared at me.

"Alice!" he exclaimed. "Alice, don't be alarmed but your hair is orange!"

I laughed. "I know! Isn't it fun? Let's explore," I suggested.

"How did your hair change colour?" asked my brother.

"I just, I don't know, willed it to change." I said. "You can too."

Bob looked thoughtful. "But I don't want orange hair."

I laughed, "I think you can change anything you want, Bob!"

Bob looked very serious. “Look, we really ought to examine this guidebook.”

“Oh, you are never any fun!” I said, glaring at him. “Who wants to read that old book. We don’t even understand the big words in it! Please come and explore with me. I promise we can read that boring book later. I want to find Cat and see who else lives here.”

“Alright,” said Bob hesitatingly. Then he started laughing. “Your hair is awful!” he teased and ran through the wall.

I followed him to one of the labs. Bob was looking more serious. His eyes were closed. He was concentrating. I watched as his appearance started to change. But I wasn’t sure he’d like it very much. Bob opened his eyes.

“Oh, no,” he groaned, looking at himself. Bob was wearing a frilly dress! “I was trying to change into long trousers. Now this!” he said. He concentrated again. Poor Bob changed three or four times, but none was right. Riding Jodhpurs, lederhosen

and a suit that was very much too big for him.

"What am I doing wrong?" he cried.

Now he was wearing a pink and green polka dot dress.

"I give up," he said, ignoring my giggles.

We were exploring the house when we got back to the room Cat had warned us not to enter.

OBSERVATION ROOM was signposted above the door.

"We can't go in there," Bob said. "Cat told us it was forbidden. She said not to enter under any circumstances."

"Yes", I added. "Cat said we'd lose all our powers and disappear. But maybe it's called 'Observation Room' because it is fun to observe things. We should definitely try."

I started towards the room. Bob followed me.

"No, Alice. We should definitely NOT try!"

With that, he came towards me and grabbed my arm.

At that moment a very curious thing happened. The instant Bob's hand touched my arm, it seemed to melt. Or rather, melt into my arm. Then, my arm and his arm seemed to fuse

together! I realised that our whole beings were becoming garbled together. A strange feeling came over me. Not a good feeling.

I started to walk toward the Observation Room. But I could feel Bob pulling me back, and there was nothing I could do to stop him since we were somehow merged like conjoined twins.

"Trouble?" We heard Cat's voice. "Thank goodness," I thought. "Cat will know how to undo this mess."

"Obviously…" continued Cat, "you did not read the guide book. It explicitly tells you that if you connect with someone else, you will become 'entangled'. This is another phenomenon of the Quantum World. This can have distinct advantages, but in your case, maybe not."

Cat was smirking. "By the way, it is a fascinating place you have found yourselves in. But it can be … messy."

Messy? Bob and I were seemingly fused together! I was trying to make out what was left of his polka dot dress when all of a sudden he was gone. He was still with me, but I couldn't see him.

"Oh, dear," Cat was looking at us, at me. Was I still Alice? Or was I Bob? Perhaps I was Bobice, Balice or Aliob.

"As I was saying, the two of you have become what we call 'entangled'. When particles come in contact with one another, they are no longer independent of each other."

I looked at Cat doubtfully.

“I don’t know if I am still completely me, if I am Alice,” I said.

“I’m afraid,” said Cat, “that your brother could be anywhere, anywhere in the world.”

“The Quantum World?” I asked.

“The world. It’s all one,” replied Cat.

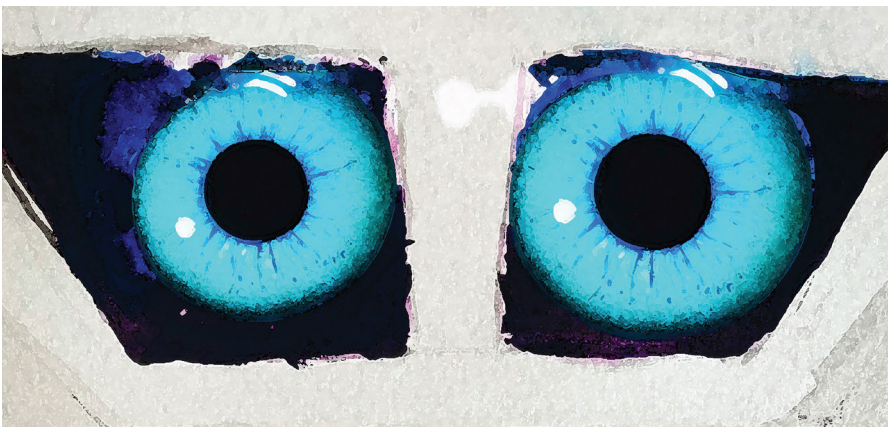
“Well,” I hesitated. “How do Bob and I become disentangled?”

“I think you might have to go into the Observation Room after all if you want to disentangle,” said Cat.

I didn’t need to be told twice. I started towards the door.

“Alice,” warned Cat. “You will become disentangled, but you will lose all your new powers, and you could both disappear completely. It is a risk.”

I could suddenly sense Bob pulling me towards the door. We were definitely in agreement on taking this risk.



We whooshed through the wall. The Observation Room was not that different to other labs we'd seen... until we looked up. Two giant glass convex bowls seemed to fill the ceiling. It was very strange indeed.

Nothing happened for a long time. Then, there seemed to be movement in the glass. What looked like two enormous eyeballs moved and even blinked. Then the eyes seemed to see us looking up at them. They were an extraordinary shade of sapphire blue, much like Uncle Pierre's eyes. At that instant we found ourselves being whooshed away. Suddenly, Bob and I were back in the familiar corridor of the Madame Curie Museum.

We were in front of the clock and no longer conjoined! We were disentangled. Bob was back in his short trousers and I assumed my hair was no longer orange.

There was a noise from a room down the hall. We followed the sound to a laboratory where we discovered Uncle Pierre staring into a microscope.

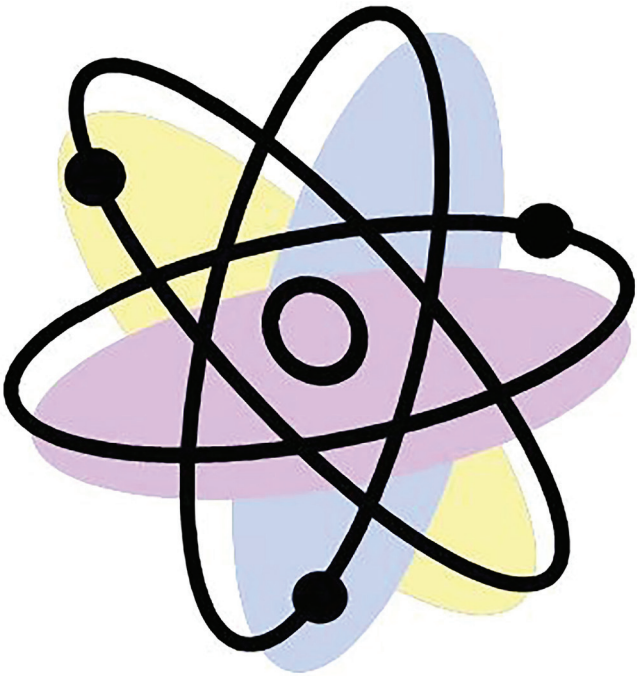
"Children," he cried. "There you are! I wondered where you'd got to." He gazed at us for what seemed like a very long minute. Then he shook his head. "You wouldn't believe... never mind."

Bob and I looked at each other. An orange cat strolled into the lab, purring. It jumped onto Uncle Pierre's lap. We didn't tell our uncle what had happened. He most likely would not have believed us anyway.

Years passed. I studied physics and moved to America to work for the NASA space programme. Then I retired back to France where I now live with my cat.

Bob also studied physics. He became a leading quantum physicist and taught at the Sorbonne (an important university in Paris). Then, one day he paid a visit to the Marie Curie Museum.

He hasn't been seen since.



Khalak Mahadeviya
Khalak first encountered quantum physics at the beginning of her undergraduate degree, and she found it all very confusing. It wasn't until later when it started making sense to her and she made peace with the strange world of quantum physics. Now she is midway through her PhD in theoretical physics at Trinity college Dublin, and she loves exploring the quantum world. Khalak finds cooking very therapeutic and enjoys listening to (and sometimes dancing to) folk music from her home region, Gujarat.

Saulo Moreira
Saulo is a Brazilian post-doctoral researcher at Trinity College Dublin. As a child, he wanted to be a vet, but he was also very intrigued by light and colourful periodic tables of elements. This curiosity led him to become a researcher in quantum physics. He loves playing with his cat Rainy Day, watching old movies and sunbathing.

Mark Mitchison
Mark is a theoretical physicist who works at Trinity College Dublin. He first got interested in quantum physics when his Dad showed him a beautiful illustration of an atom during bathtime when he was six years old. He has spent the last thirty years learning why the illustration was completely inaccurate. When he is not thinking about quantum particles he is listening to loud dance music, playing computer games or cycling in the Wicklow mountains.

Brigid Sweeney
Brigid is a facilitator, teacher, actor, (art) historian and illustrator. She loves trying to realise creative potential in any project or person- even Quantum Physicists! Brigid is a regular volunteer illustrator, mentor and facilitator at Fighting Words, an organisation she holds dear since she brought her own children in the early naughties.

Definitions from our story

Tunnelling:
Imagine you are playing with a toy car and want to send it across a hill, but its battery is too weak to climb up the hill. In the quantum world, this car could end up on the other side of the hill without actually climbing it. It's like the quantum car finds a hidden tunnel through the hill. This amazing trick is called "quantum tunnelling." The strange and wonderful laws of quantum physics allow tiny particles like electrons to pass through barriers that seem impossible to cross.

Superposition:
If you flip a coin, it can either be heads or tails. In the quantum realm, a coin could be heads, tails, or neither heads nor tails. When the quantum coin is neither heads nor tails, we say that it is in a "superposition". A superposition is something in between heads and tails that only exists in the quantum world. We don't encounter them in everyday life because superpositions are very delicate and fragile: simply by observing them, we can destroy them and force the quantum coin into being heads OR tails in a random way. There is no way of directly observing a superposition, but quantum systems can give indirect signs of being in a superposition and those can be observed in cleverly designed experiments.

Entanglement:
When two objects in superposition come into contact with each other, they lose their individual identities. We say that the objects are "entangled", which means they are in a superposition together. For example, two entangled coins are in a superposition: they are neither heads nor tails. But when they are observed, one is always found to be heads, and the other one is always tails. This means that the coins are connected, or correlated, in a way that seems almost magical. How do the coins always end up in opposite states from each other if they don't have a definite state (heads or tails) beforehand? This question has been debated by physicists and philosophers for 100 years, but everyone has a different answer!

In the autumn of 1967, eleven-year-old twins Alice and Bob are invited to Paris by their Uncle Pierre, a curator at the Marie Curie Museum. After tinkering with a mysterious clock, the twins find themselves transported to the Quantum World, where they experience bizarre phenomena like walking through walls and shape-shifting. They are guided by a talking cat. Despite warnings, the twins' curiosity gets the better of them. Discover how Alice and Bob save themselves from danger and unlock a few quantum mysteries along the way.

AMBER
Advancing Materials for Impact

FIGHTING WORDS
The write to right.