Technology is everywhere!
Technology is everywhere!
Technology is everywhere!
Technology is everywhere!
Technology is everywhere!
Technology is everywhere!
Technology is everywhere!
Technology is everywhere!
Technology is everywhere!
Technology is everywhere!
Technology is everywhere!
Technology is everywhere!
Technology is everywhere!
Day-runners transported important messages in ancient Greece
Why didn’t they have radios?

“People listening to a radio in ancient Greece” as imagined by a stable diffusion model
Bracelet with gold wire
4th-3rd century BC [source]
Bracelet with gold wire
4th-3rd century BC [source]

Bronze water vessel
7th-6th century BC [source]
Bracelet with gold wire
4th-3rd century BC [source]

Bronze water vessel
7th-6th century BC [source]

Glass amphora
2nd-1st century BC
Bracelet with gold wire
4th-3rd century BC [source]

Bronze water vessel
7th-6th century BC [source]

Glass amphora
2nd-1st century BC

Induction coil
(Ca. 1900)
Wire wound around wooden post
Bracelet with gold wire
4th-3rd century BC [source]

Bronze water vessel
7th-6th century BC [source]

Glass amphora
2nd-1st century BC

Induction coil
(Ca. 1900)
Wire wound around wooden post

Ball coherer
(1899)
Metal balls in glass tube
Bracelet with gold wire
4th-3rd century BC [source]

Bronze water vessel
7th-6th century BC [source]

Glass amphora
2nd-1st century BC

Induction coil
(Ca. 1900)
Wire wound around wooden post

Metal balls in glass tube

Electrical machine
(Ca. 1719)
Spinning glass globe

Ball coherer
(1899)
Metal balls in glass tube

Wire wound around wooden post

Induction coil
(Ca. 1900)
Wire wound around wooden post

Metal balls in glass tube

Electrical machine
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(Ca. 1900)
Wire wound around wooden post

Metal balls in glass tube

Electrical machine
(Ca. 1719)
Spinning glass globe

Ball coherer
(1899)
Metal balls in glass tube

Wire wound around wooden post
Why didn’t the ancient Greeks pioneer radio communication?
Technology is everywhere!

—how did we learn to manipulate nature around us?
My attempt at an answer in eight lectures:
My attempt at an answer in eight lectures:

HOW FUNDAMENTAL SCIENCE HAS CHANGED THE WORLD
My attempt at an answer in eight lectures:

HOW FUNDAMENTAL SCIENCE HAS CHANGED THE WORLD

A STORY OF INVENTION AND DISCOVERY
My attempt at an answer in eight lectures:

How did scientific discoveries come about?

And how did they pave the way for technological progress?
My attempt at an answer in eight lectures:

“How did we get here?”
The program for today:

“Where are we now?”
The program for today:

“Where are we now?”

“How did we roughly get here?”
The program for today:

“Where are we now?”

“How did we roughly get here?”

Next week: the real story begins
The program for today:

“Where are we now?”

“How did we roughly get here?”

Next week: the real story begins
Technology is everywhere!
—let's get a taste
Where does electricity come from?
Where does electricity come from?

Your TV remote control
(or your cellphone)
Where does electricity come from?

- Your TV remote control (or your cellphone)
- My computer
Where does electricity come from?

A source of electricity

Your TV remote control (or your cellphone)

My computer
Where does electricity come from?

A source of electricity

Your TV remote control (or your cellphone)

Not a source of electricity

My computer
Where does electricity come from?

A source of electricity

Your TV remote control
(or your cellphone)

Not a source of electricity

My computer
Where does electricity come from?

Towards power station

"Transformer"

To house

Not a source of electricity

My computer
Where does electricity come from?

Towards power station

"Transformer"

To house

Not a source of electricity

My computer
Where does electricity come from?

Towards power station

"Transformer"

To house

Not a source of electricity

My computer
Where does electricity come from?

Towards power station

“Transformer”

To house
Where does electricity come from?

Towards power station

“Transformer”

To house
Where does electricity come from?

Byron generating station
Where does electricity come from?

Byron generating station
Where does electricity come from?

Byron generating station
Where does electricity come from?

Byron generating station
Where does electricity come from?
Where does electricity come from?
Where does electricity come from?

The wires are not connected to anything!!

*They just pass by a rotating magnet*
Where does electricity come from?

Voltage

Time

“120 V / 60 Hz”
Where does electricity come from?

- Voltage vs. Time
- "120 V / 60 Hz"
Where does electricity come from?

“120 V / 60 Hz”

Hertz

1/60th of a second
Where does electricity come from?

120 V / 60 Hz

Volt

Hertz

“120 V / 60 Hz”

Voltage

1/60th of a second

Time

120 V

[Diagram with voltage and time graph]
Where does electricity come from?

“1.5 V”

Volt

“120 V / 60 Hz”

Hertz
Where does electricity come from?

“1.5 V”
Where does electricity come from?

“1.5 V”

No spinning magnets inside!
Where does electricity come from?

“1.5 V”

No spinning magnets inside!
Where does electricity come from?
Where does electricity come from?

What makes the magnet turn?

"Generator"
Where does electricity come from?

What makes the magnet turn?

Steam turbine

“Generator”
Where does electricity come from?

What makes the magnet turn?

Steam turbine

“Generator”
Where does electricity come from?

What makes the magnet turn?

Steam turbine

“Generator”
Where does the steam come from?
Where does the steam come from?

Pool of (boiling) water
Why does the water start boiling?
Why does the water start boiling?

[Southern Nuclear]
Why does the water start boiling?

More fuel elements

“Fuel element”

Pool of (boiling) water

[Southern Nuclear]
Why does the water start boiling?

- Fuel element
  - More fuel elements
- Pool of (boiling) water

[Southern Nuclear]
Why does the water start boiling?

Fuel element

Fuel pellets

Pool of (boiling) water

“Fuel element”

More fuel elements
Why does the water start boiling?

Because the fuel pellets get hot!

Fuel element

Fuel pellets

Pool of (boiling) water

More fuel elements

“Fuel element”
Why do the fuel pellets get hot?

Fuel pellets

Atom
Why do the fuel pellets get hot?

Fuel pellets

Atom
Why do the fuel pellets get hot?
Why do the fuel pellets get hot?

Fuel pellets

Atom

“Neutron”
Why do the fuel pellets get hot?

Fuel pellets

Atom

“Neutron”
Why do the fuel pellets get hot?

Fuel pellets

Atom

“Neutron”
Why do the fuel pellets get hot?

Fuel pellets

Atom

“Neutron”
This is where electricity comes from!
This is where electricity comes from!
This is where electricity comes from!
This is where electricity comes from!
This is where electricity comes from!
This is where electricity comes from!
This is where electricity comes from!
This is where electricity comes from!
This is where electricity comes from!
This is where electricity comes from!
This is where electricity comes from!
Technology is everywhere!
What happens when you call your friend?

Bob
(In San Diego)

Alice
(In London)
What happens when you call your friend?

Bob
(In San Diego)

Cellphone tower

Alice
(In London)
What happens when you call your friend?

Bob
(In San Diego)

Cellphone tower

Alice
(In London)
What happens when you call your friend?

Bob  
(In San Diego)

Cellphone tower

Alice  
(In London)
What happens when you call your friend?

Bob (In San Diego)

Cellphone tower

Alice (In London)

Radio signal
What happens when you call your friend?

Bob
(In San Diego)

Cellphone tower

Radio signal

Alice
(In London)

Cellphone tower

Radio signal
What happens when you call your friend?

Bob
(In San Diego)

Alice
(In London)

Cellphone tower

Radio signal
Where does the radio signal come from?
Where does the radio signal come from?

[Image of cellular phone with an antenna]
Where does the radio signal come from?

It is produced by the antenna in the cellphone!
How does the antenna work?
How does the antenna work?

The antenna is just a piece of thin wire!
How does the antenna work?

The antenna is just a piece of thin wire!
The first antenna ever constructed

- 4 ft
The first antenna ever constructed
The first antenna ever constructed
The first antenna ever constructed
The first antenna ever constructed

- 4 ft

1 billionth of a second
The first antenna ever constructed

Not 60 Hz, but 1 billion Hz!
The first antenna ever constructed

Not 60 Hz, but 1 billion Hz!
Identical, yet different?

Voltage

60 Hz

Time

1 billion Hz

Voltage

Time
Today, we know a lot about how the world works
Today, we know a lot about how the world works

“Electricity flows easily through thin metallic wires.”
Today, we know a lot about how the world works

“Electricity flows easily through thin metallic wires.”

“Rapidly oscillating electricity produces radio waves.”
Today, we know a lot about how the world works

“Electricity flows easily through thin metallic wires.”

“Rapidly oscillating electricity produces radio waves.”

Our world works because we know a lot about it
Today, we know a lot about how the world works

“Electricity flows easily through thin metallic wires.”

“Rapidly oscillating electricity produces radio waves.”

Our world works because we know a lot about it

“Without electricity, trains, planes, phones, elevators, A/Cs are impossible!”
Today, we know a lot about how the world works

“Electricity flows easily through thin metallic wires.”

“Rapidly oscillating electricity produces radio waves.”

Our world works because we know a lot about it

“Without electricity, trains, planes, phones, elevators, A/Cs are impossible!”

That’s why the ancient Greeks did not have radios!
Today, we know a lot about how the world works

“Electricity flows easily through thin metallic wires.”

“Rapidly oscillating electricity produces radio waves.”

Our world works because we know a lot about it

“Without electricity, trains, planes, phones, elevators, A/Cs are impossible!”

That’s why the ancient Greeks did not have radios!

They did not even know radios were possible!
None of this is obvious!
None of this is obvious!
None of this is obvious!
None of this is obvious!

How wild is that?!
None of this is obvious!

How wild is that?!
None of this is obvious!

How wild is that?!

Fridge magnet

Hair dryer
None of this is obvious!

How wild is that?!

Fridge magnet

Hair dryer

Thin metal wires

Thick wooden pole
None of this is obvious!
None of this is obvious!
None of this is obvious!

Thin metal wires

Air
None of this is obvious!
None of this is obvious!

Black “rocks”

Heat

Thin metal wires

Air
Everything was discovered!
Everything was discovered!

“120 V / 60 Hz”

Voltage

Time

1/60th of a second

Hertz
Everything was discovered!

Heinrich Hertz (1880s)

“120 V / 60 Hz”
Everything was discovered!

Heinrich Hertz (1880s)
Everything was discovered!

Heinrich Hertz (1880s)

Time

Hertz

1/60th of a second

Voltage

Heinrich Hertz (1880s)
Everything was discovered!

Heinrich Hertz (1880s)

120 V / 60 Hz

Hertz

1/60th of a second
Everything was discovered!

Heinrich Hertz (1880s)

Hertz

1/60th of a second

120 V / 60 Hz

Time
Everything was discovered!

Volt

“1.5 V”
Everything was discovered!

Volt

“1.5 V”

Alessandro Volta (1800)
Everything was discovered!

Volt

“1.5 V”

Alessandro Volta (1800)
Everything was discovered!

Alessandro Volta (1800)
Everything was discovered!

Luigi Galvani (1790s)

Alessandro Volta (1800)
Discoveries didn’t come out of nowhere
Discoveries didn’t come out of nowhere

Heinrich Hertz (1880s)
Discoveries didn’t come out of nowhere

Heinrich Hertz (1880s)

Alessandro Volta (1800)
Discoveries didn’t come out of nowhere

Heinrich Hertz (1880s)

Alessandro Volta (1800)

Luigi Galvani (1790s)
Today: science mixes with technology
Today: science mixes with technology

“Where does electricity come from?”
Today: science mixes with technology

“Where does electricity come from?”

“It is generated by atoms of Uranium the size of a millionth-billionth of a foot.”
Today: science mixes with technology

“Where does electricity come from?”

“It is generated by atoms of Uranium the size of a millionth-billionth of a foot.”
Today: science mixes with technology

“Where does electricity come from?”

“It is generated by atoms of Uranium the size of a millionth-billionth of a foot.”
“Today: science mixes with technology”

“Where does electricity come from?”

“It is generated by atoms of Uranium the size of a millionth-billionth of a foot.”
Today: science mixes with technology

"Where does electricity come from?"

"It is generated by atoms of Uranium the size of a millionth-billionth of a foot."
All of this once was cutting-edge science
All of this once was cutting-edge science

“How many kinds of electricity are there?”
All of this once was cutting-edge science

“How many kinds of electricity are there?”

“If uranium is made of atoms, what are the atoms of electricity that flow through the wire?”
All of this once was cutting-edge science
All of this once was cutting-edge science

“What are radio waves made of?”
All of this once was cutting-edge science

“What are radio waves made of?”

“What changes when cold water is made hot?”
This is how we *roughly* got here
This is how we *roughly* got here

Heinrich Hertz *(1880s)*
This is how we *roughly* got here.
This is how we *roughly* got here

Heinrich Hertz (1880s)

Alessandro Volta (1800)
This is how we *roughly* got here

Without a stable source of electricity, Hertz's discovery would not have been possible!
This is how we *roughly* got here

Without a stable source of electricity, Hertz’s discovery would not have been possible!
This is how we *roughly* got here

Science

Engineering
This is how we *roughly* got here
This is how we *roughly* got here

Science

Volta discovers battery

Engineering

Hertz uses battery
This is how we *roughly* got here

Science

Volta discovers battery

Hertz discovers “radio waves”

Engineering

Hertz uses battery
This is how we *roughly* got here

Science

Volta discovers battery

Engineering

Hertz discovers “radio waves”

Hertz uses battery

Today we have mobile phones
This is how we *roughly* got here

Science

Engineering

Understanding of new natural phenomena

New scientific instruments

New technologies
This is how we *roughly* got here

We can understand *something* without having to understand *everything*.

“What changes when cold water is made hot?”

“If a large complicated thing seems mysterious, open it up and see if its parts are less mysterious.”
This is how we *roughly* got here

We can understand *something* without having to understand *everything*

“If a large complicated thing seems mysterious, open it up and see if its parts are less mysterious”
This is how we *roughly* got here

We can understand *something* without having to understand *everything*

“If a large complicated thing seems mysterious, open it up and see if its parts are less mysterious”
HOW FUNDAMENTAL SCIENCE HAS CHANGED THE WORLD
A STORY OF INVENTION AND DISCOVERY
For the next seven lectures ...

See the world through the eyes of the scientists and engineers of the past, searching answers to three fundamental questions.
For the next seven lectures ...

Part I:
“What is the nature of heat?”
“How to use the power of fire?”
For the next seven lectures . . .

Part I:
“What is the nature of heat?”
“How to use the power of fire?”
For the next seven lectures ...

Part I:
“What is the nature of heat?”
“How to use the power of fire?”
For the next seven lectures ... 

Part I: 
“What is the nature of heat?” 
“How to use the power of fire?”
For the next seven lectures …

Part I:
“What is the nature of heat?”
“How to use the power of fire?”
For the next seven lectures ... 

Part I:
“What is the nature of heat?”
“How to use the power of fire?”
For the next seven lectures ...

Part I:
“What is the nature of heat?”
“How to use the power of fire?”
For the next seven lectures ...

Part I:

“What is the nature of heat?”

“How to use the power of fire?”
For the next seven lectures . . .

Part II:
“What is the nature of electricity?”
“How to communicate without a wire?”
For the next seven lectures …

Part II:
“What is the nature of electricity?”
“How to communicate without a wire?”
For the next seven lectures ... 

Part II:

“What is the nature of electricity?”
“How to communicate without a wire?”
For the next seven lectures …

Part II:

“What is the nature of electricity?”
“How to communicate without a wire?”
For the next seven lectures ...  

Part II:  
“What is the nature of electricity?”  
“How to communicate without a wire?”
For the next seven lectures …

Part II:
“What is the nature of electricity?”
“How to communicate without a wire?”
For the next seven lectures …

Part II:
“What is the nature of electricity?”
“How to communicate without a wire?”
For the next seven lectures …

Part II:
“What is the nature of electricity?”
“How to communicate without a wire?”
For the next seven lectures ...

Part II:

“What is the nature of electricity?”

“How to communicate without a wire?”
For the next seven lectures . . .

Part III:

“What is the nature of matter?”

“How to treat cancer with subatomic particles?”
For the next seven lectures ... 

Part III:

“What is the nature of matter?”

“How to treat cancer with subatomic particles?”
For the next seven lectures ...

Part III:
“What is the nature of matter?”
“How to treat cancer with subatomic particles?”
For the next seven lectures ... 

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“What is the nature of matter?”
“How to treat cancer with subatomic particles?”
For the next seven lectures ...

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“How to treat cancer with subatomic particles?”
For the next seven lectures ... 

Part III:
“What is the nature of matter?”
“How to treat cancer with subatomic particles?”
For the next seven lectures ... 

Part III:

“What is the nature of matter?”

“How to treat cancer with subatomic particles?”
For the next seven lectures ...

Part III:

“What is the nature of matter?”

“How to treat cancer with subatomic particles?”
For the next seven lectures ...

Part III:

“What is the nature of matter?”

“How to treat cancer with subatomic particles?”
For the next seven lectures …

Part III: "What is the nature of matter?"
"How to treat cancer with subatomic particles?"
For the next seven lectures ...
HOW FUNDAMENTAL SCIENCE HAS CHANGED THE WORLD
A STORY OF INVENTION AND DISCOVERY
This is also my story!

Grein, Austria
This is also my story!
This is also my story!

2007–2011: Fell in love with electronics during high school

Home-made electronics (from scratch) in my parents’ basement
This is also my story!
This is also my story!

2013–2016: Studying physics in Vienna
This is also my story!

2013–2016: Studying physics in Vienna

Learned about radio waves → measured Schumann resonances of the Earth

[Wikimedia commons]

Ionosphere
Earth
Fundamental mode (7.83 Hz)
Second order (14.1 Hz)
Third order (20.3 Hz)
This is also my story!

**2013–2016: Studying physics in Vienna**

Learned about radio waves
→ measured Schumann resonances of the Earth
This is also my story!

2013–2016: Studying physics in Vienna

Learned about radio waves
→ measured Schumann resonances of the Earth
This is also my story!

2013–2016: Studying physics in Vienna

Learned about radio waves
→ measured Schumann resonances of the Earth
This is also my story!

2013–2016: Studying physics in Vienna
This is also my story!

2013–2016: Studying physics in Vienna

Learned about plasma physics and nuclear fusion
→ built a simple nuclear fusion reactor at home ("Farnsworth-Hirsch fusor")
This is also my story!

2013–2016: Studying physics in Vienna

Learned about plasma physics and nuclear fusion
→ built a simple nuclear fusion reactor at home
   (“Farnsworth-Hirsch fusor”)
This is also my story!

2013–2016: Studying physics in Vienna

Learned about plasma physics and nuclear fusion
→ built a simple nuclear fusion reactor at home
("Farnsworth-Hirsch fusor")
This is also my story!

2013–2016: Studying physics in Vienna

Learned about plasma physics and nuclear fusion
→ built a simple nuclear fusion reactor at home ("Farnsworth-Hirsch fusor")

Convincing mum that it's safe wasn't easy …
This is also my story!


Learned a lot about theoretical physics: from the very large to the very small
This is also my story!

2018–2022: PhD at Oxford, with long stays at CERN in Geneva: back to experiment!
This is also my story!

2018–2022: PhD at Oxford, with long stays at CERN in Geneva: back to experiment!
This is also my story!

2018–2022: PhD at Oxford, with long stays at CERN in Geneva: back to experiment!
This is also my story!

Since September 2022:
Postdoc at the Enrico Fermi Institute

Studying the laws of the microcosm, and particles from outer space.
How did we get that far?
Right outside this lecture hall

Until 6:00 pm today