Bank of England Museum

THE FUTURE OF MONEY

The Future of Money

PACK 1

What is money?

An education resource for students aged 11-14.

Contents

About the Future of Money exhibition

This resource collection is designed to accompany The Future of Money exhibition at the Bank of England Museum. The resources explore the links between the exhibition and a range of mathematical ideas, using a series of exhibition objects and themes as a starting point for discussion and mathematical problem-solving. These activities will work in the classroom or at home and are designed for students aged 11-14.

The resources contain supporting notes for teachers, images from the exhibition and student activity sheets. There are five resource packs, each focusing on a different exhibition theme:

Pack 1: What is Money?

Topics covered include: compound measures; units of measurement; problem solving; probability

Pack 2: Futureproofing Today's Systems

Topics include: data collection and questionnaires; analysing data; bar charts; pie charts.

Pack 3: Future Methods of Payment

Topics include: prime numbers and their properties; divisibility rules; sampling methods; calculating percentages

Pack 4: Education, Environment, Sustainability

Topics include: 3D shapes; adding, subtracting and dividing with decimals; problem solving

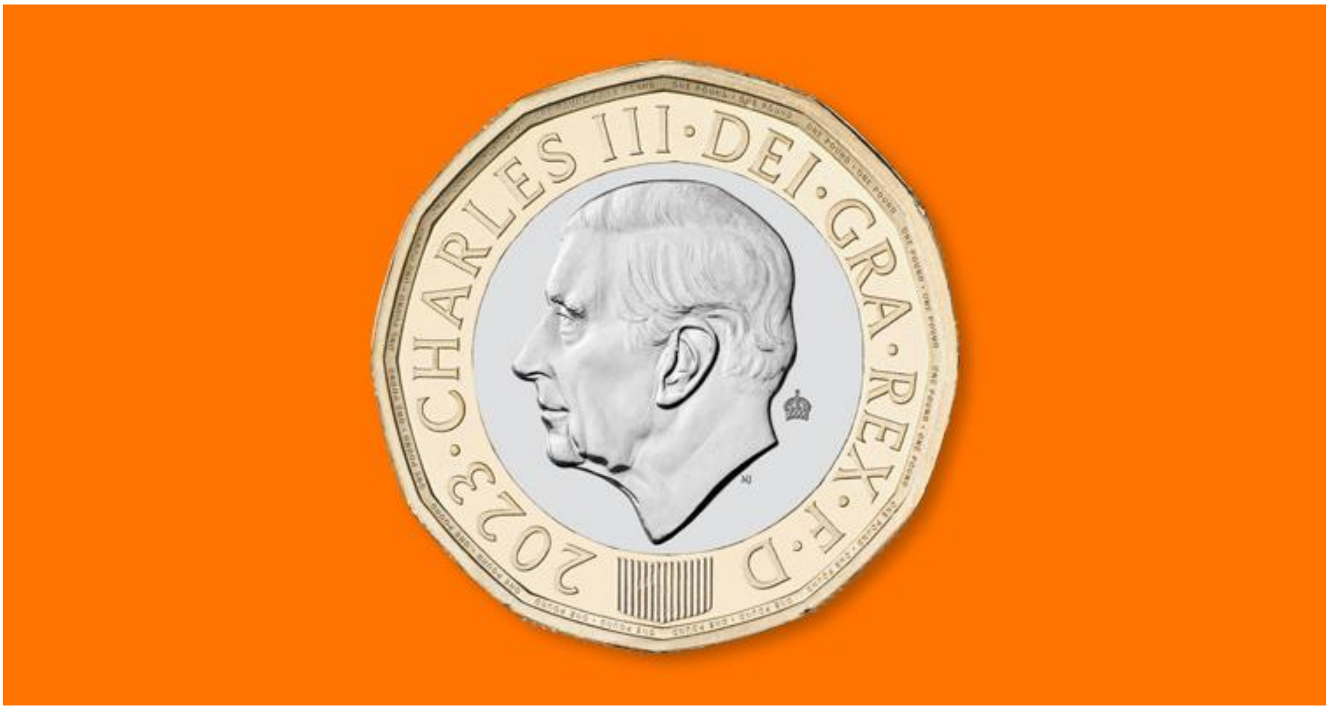
Pack 5: Data and Privacy

Topics include: sequences and patterns; problem solving; inverse operations; division with remainders

Whichever activities your students complete, we'd love to see the results, so please share them with @boemuseum **#TheFutureofMoney**

Object in focus: £1.00 coin

Mathematics curriculum topics: considering the relevance of different maths topics the subject of money



Credit: Royal Mint

The Bank of England issue UK banknotes and coins are issued by the Royal Mint. Both banknotes and coins have a number of features that make them easily recognisable and hard to counterfeit (fake). The Royal Mint was established in 886 and has been issuing coins ever since.
The Bank of England used to produce £1.00 banknotes, but these were gradually replaced by the £1.00 coin that was first issued by the Royal Mint in 1983. Originally the coin was round but replaced in 2017 by a 12-sided coin.

The newest £1.00 coin depicting HM King Charles III was produced in 2023.

Student activity 1: Maths and money

Question 1: What is money?

- What kinds of money can you think of?
- What does something need to be able to do to be considered ‘money’? What properties does it have?
- Does money need to be a real/ physical object?

Question 2: Why is maths relevant to money?

- Why might improving confidence in maths help you to manage your money?
- What maths topics have you experienced that might have some use related to finance or money?

Student activity 1: Supporting notes for teachers

Question 1: What is money?

Money needs to be:

- A unit of account - it needs to be measurable so that you can compare the amount that one person has with the amount that another person has and agree on the relative value of those amounts.
    - For example, money in the form of coins and notes can easily be counted and compared: if one pot has five one-pound coins in it and another has three, you know which pot contains the greatest value.
- A medium of exchange – money needs to be transferable between people or groups. For example, money in the form of coins and notes can be exchanged very easily, and most people would recognise that you were giving them something of value if you handed them a £10 note.
- Act as a store of wealth - when you receive some money, you need to be able to keep it somewhere until you want to retrieve it and use it (e.g. exchange it for a product or service).
    - For example, money in the form of coins and notes can be stored in a variety of places (in a pocket, or a money box, or a bank account) and then retrieved from these places when you want to go shopping.

Most importantly, we all need to trust that our money can do all of these things.

Some examples of money throughout history:

- Coins and notes (e.g. metal coins and paper or polymer notes) such as British Pound Sterling (£), American Dollars ($) and Euros (€).
- Livestock (e.g. sheep or cows) and plant produce (e.g. wheat).
- Clay tokens representing an amount of (e.g.) grain or barley.
- Valuable or rare objects such as cowrie shells and precious stones.

Question 2: Why is maths relevant to money?

- Some of the activities in this resource can help to illustrate the relevance of specific mathematical topics to money-related themes.
- Basic numeracy skills can help you keep track of the amount of money you spend and compare this to how much money you have.
- More specific skills can help you to understand things like interest and tax (percentages), risks and expected returns from investments (probability), and past performance of financial products (statistics).

Object in focus: Roman gold bar

Mathematics curriculum topics: Compound measures; units of measurement

Gold has been used as a store of wealth for a long time. It is rare (which makes it valuable) and because of its beauty, has often been a wearable store of wealth and display of status. As a material, it is one of the least reactive chemical elements, so it doesn’t tarnish or degrade. This gold bar was part of a hoard that was buried for 1,600 years.

Gold bars are still used as a way of storing wealth today, although the size, shape and mass of modern bars are different to this Roman bar. You can hold a modern gold bar at the Future of Money exhibition.

The high value of gold means that some people have tried to counterfeit gold bars. This might be done by plating (covering) a base metal with gold, or by mixing some gold with a cheaper metal. There are several ways to test a gold bar to see if it is solid gold. Some of these are destructive (i.e. you need to remove some of the gold and test it chemically) and others are non-destructive. A non-destructive test is to check its density.

Density is a compound measure. This means that it is a combination of other measures. Its units are “grams per centimetre cubed”, usually written as g/cm^3.

Grams are a measure of *mass* and centimetres cubed are a measure of *volume*, so *density* is a measure of how much *mass* there is in each unit of *volume*: If a substance has a density of 1 g/cm^3 this means that 1 cm^3 of that substance would have a mass of 1 g. In fact, this value is roughly the density of water.

Density cannot be measured directly; it is calculated using the following formula:

$$Density = \frac{mass}{volume}$$

Student activity 2: All that glitters

Task 1

10 bars need to be checked to see if they are made of gold. The mass and volume of these bars is provided in the table below. Use the information provided to calculate the density of each bar and decide which should be investigated further.

The density of pure gold is 19.3 g/cm^3.

Bar ID	Mass	Volume	Density (1dp)	Genuine gold (Y/N)
A	12,400g	642.49 cm^3		
B	12,200 g	632.12 cm^3		
C	12,800 g	1,132.74 cm^3		
D	10,300 g	1,320.51 cm^3		
E	15,600 g	1,752.81 cm^3		
F	9,100 g	471.50 cm^3		
G	13,500 g	1,588.24 cm^3		
H	12,000 g	621.76 cm^3		
I	13,100 g	678.76 cm^3		
J	12,400 g	5,166.67 cm^3		

Task 2

To detect forgeries, you need to use mathematical skills. London Good Delivery gold bars (like the one in the exhibition) have a standard mass of 12.4 kg, so forgers would try to replicate the same mass.

1. What volume would forged bars have if they have a mass of 12.4kg and are made out of the following materials?

i) Lead (density: 11.3 g/cm^3)

ii) Brass (density: 8.6 g/cm^3)

ii) Cast Iron (density: 7.3 g/cm^3)

Student activity 2: Answers and supporting notes for teachers

Task 1

Bar ID	Mass	Volume	Density (1dp)	Genuine gold (Y/N)
A	12,400g	642.49 cm^3	**19.3 g/cm^3**	Yes
B	12,200 g	632.12 cm^3	**19.3 g/cm^3**	Yes
C	12,800 g	1,132.74 cm^3	**11.3 g/cm^3**	No
D	10,300 g	1,320.51 cm^3	**7.8 g/cm^3**	No
E	15,600 g	1,752.81 cm^3	**8.9 g/cm^3**	No
F	9,100 g	471.50 cm^3	**19.3 g/cm^3**	Yes
G	13,500 g	1,588.24 cm^3	**8.5 g/cm^3**	No
H	12,000 g	621.76 cm^3	**19.3 g/cm^3**	Yes
I	13,100 g	678.76 cm^3	**19.3 g/cm^3**	Yes
J	12,400 g	5,166.67 cm^3	**2.4 g/cm^3**	No

Task 2

i) 12,400 / 11.3 = **1,097.35 cm^3**

ii) 12,400 / 8.6 = **1441.86 cm^3**

iii) 12,400 / 7.3 = **1698.63 cm^3**

Important note

The activity above is designed to illustrate one small aspect of gold bar forgery detection. Forging gold bars is a lot more complicated: rather than just being made to a standard mass, they are also made to other specifications relating to their size, shape and purity.

Extend this:

The specifications of a London Good Delivery gold bar, including dimensions, are available at: **https://www.lbma.org.uk/publications/good-delivery-rules/technical-specifications**

Object in focus: Polymer banknote

Mathematics curriculum topics: Problem solving; proportion; listing outcomes

The £10 polymer banknote was introduced in 2017. Polymer banknotes last much longer than paper ones and can be recycled once they are withdrawn from circulation.

Modern banknotes have a number of security features to help identify them as genuine, making it much harder for people to produce counterfeit notes and helping to build trust in banknotes.

Some of the security features are not visible in this image but you can explore them in an online video at **https://bankofengland.education/takeacloserlook/index.html**

Student activity 3: How many?

Each banknote has a unique serial number, but they all follow the same pattern: two letters followed by eight digits. The serial number on this note is **AA10 471840**.

Task 1

If:

- the two letters can be any capital letters from the standard A - Z alphabet (you can use the same letter twice), and
- the eight digits can be any combination of digits from 0 - 9 (you can use any digit more than once)

How many different serial numbers are possible?

Task 2

Polymer banknotes are expected to last at least 2.5 times as long as the previous paper banknotes.

i) Paper £20 notes used to last about 8 years before they needed to be taken out of circulation and replaced. How long are the new polymer £20 notes expected to last?

ii) New polymer £10 banknotes are expected to last around 5 years, so how long does this suggest that old paper £10 banknotes lasted?

Something to think about: Why do you think £20 notes last longer than £10 notes?

Student activity 3: Answers and supporting notes for teachers

Task 1

As there are 26 different letters to choose from and 10 digits, and no restrictions on how many times each can be chosen, there are:

26 × 26 × 10 × 10 × 10 × 10 × 10 × 10 × 10 × 10 = **67,600,000,000**

There are sixty seven billion, six hundred million possible serial numbers, therefore this many £10 polymer banknotes could enter circulation without any having the same serial number.

Task 2

i) Around **20 years**

ii) About **2 years**

Something to think about: lower-value notes tend to be used more than higher-value notes, so they are subject to greater wear-and-tear.

Object in focus: Payment device

Mathematics curriculum topics: Listing outcomes; probability

“Fintech” is a combination of the words “financial” and “technology” and refers to computer systems and devices used to manage money and make payments. Fintech has changed the way we pay for things and manage our money.

Electronic payments do not require any physical money to be exchanged. Instead, data is exchanged between banks. An important part of this data exchange is verifying that the people involved are who they say they are.

Payment devices like this card reader form part of that verification process: not only does the device read information stored on (for example) a debit or credit card, but it also requires the user to enter a Personal Identification Number (PIN).

PINs should be kept secret between the owner of a card and the bank that issued it and are one of a number of measures designed to reduce the possibility of somebody using the wrong card (either accidentally or on purpose) to make a payment.

Student activity 4: PIN and password security

Bank card PINs are made up of a string of four digits (the numbers 0 to 9). Preferably, these would be randomly generated. For example: 4127.

Task 1

i) How many different PINs can be chosen in this way?

Imagine you have a bank card with a randomly chosen PIN.

ii) If someone finds your bank card and tries to withdraw some money from your account, what is the probability that they choose the correct PIN first time?

Task 2

A lot of people choose something more memorable for their PINs, such as their date of birth, although this can make it easier for somebody to guess, so is not recommended.

One way in which someone might represent their birth date as a PIN is in the form DDMM, where DD is a two-digit number representing a date within a month, and MM is a two-digit number representing a month. For example, 1108 would represent the 11th day of the 08th month (August).

i) How many different PINs are there that follow this rule?

ii) If somebody knows that you have chosen your PIN in this way, but **does not** know what your date of birth is, what is the probability that they would choose the right one first time?

iii) How many times more likely is someone to guess a PIN that corresponds to a date than a PIN chosen randomly from all possible options?

Student activity 4: Supporting notes for teachers

Task 1

i) There are **10,000** (**ten thousand**) possible PINs to choose from.

ii) The probability of guessing a randomly chosen PIN first time is $\frac{1}{10{,}000}$, (**one ten thousandth**), or **0.0001**.

Something to think about:

ATMs allow you to make three attempts to enter the correct PIN, and if the third attempt is incorrect the machine keeps the card and notifies the bank and the owner of the card. Some students may wish to explore how this changes the probability of someone guessing a randomly chosen PIN.

Task 2

i) There are 366 different combinations of birth date in the form of ddmm (including February 29th!)

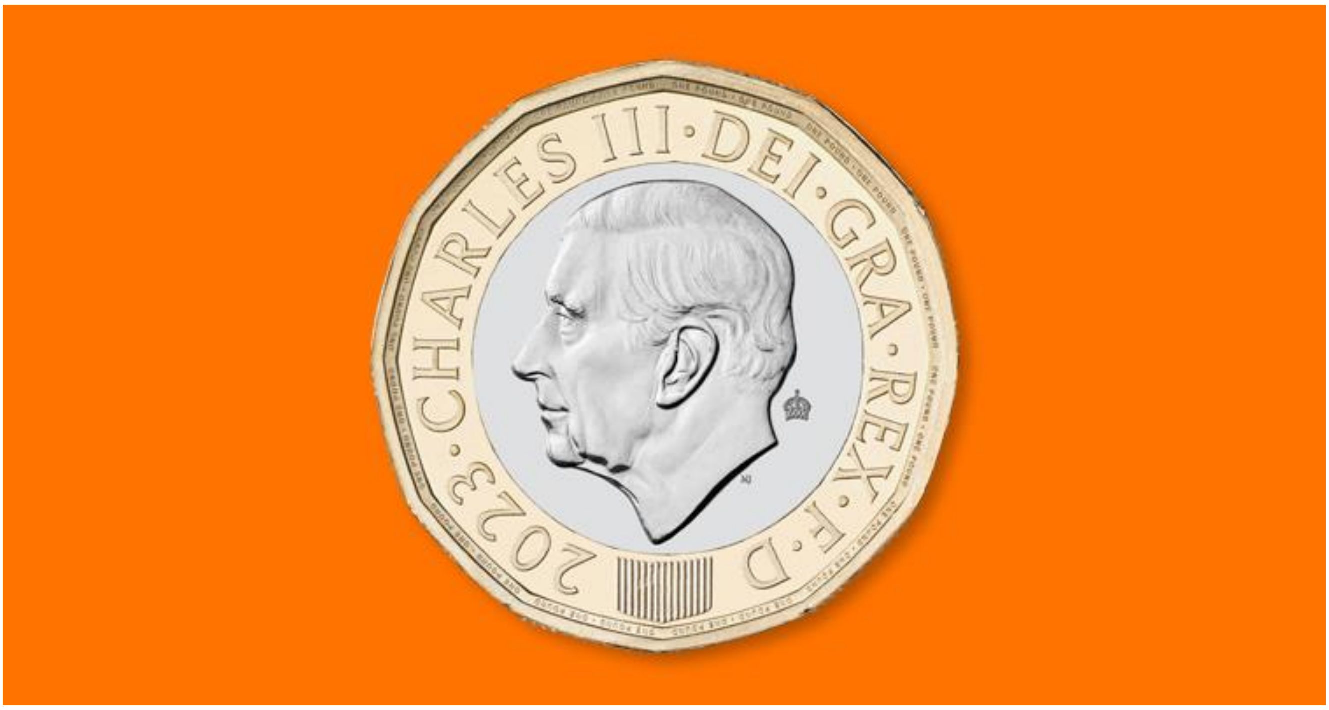
ii) The probability of guessing a randomly chosen date (and therefore PIN in the ddmm format) first time is $\frac{1}{366}$ (**one three-hundred-and-sixty-sixth**), or **0.0027 (2dp)**.

iii) $\frac{\frac{1}{366}}{\frac{1}{10{,}000}} = 27.3\ (1dp)$ or $\frac{0.0027}{0.0001}$ = 27

It is around 27 times easier to guess a PIN related to a date than it is to guess a randomly generated PIN.

Idea in focus: Earnings over time

Mathematics curriculum topics: Plotting and interpreting graphs



Credit: The Royal Mint

The Office for National Statistics (ONS) collects data about the UK’s economy, society and the population. The ONS is responsible for large-scale surveys such as the census, which is carried out every 10 years and looks at people and households across England and Wales.

The ONS also publish data related to the weekly earnings of people across the UK. The table on the following page lists the average weekly earnings for people in the UK from 2000 to 2003.

Year	Average Weekly Earnings
2000	£308.74
2001	£326.48
2002	£338.34
2003	£347.34
2004	£362.04
2005	£378.56
2006	£395.26
2007	£412.40
2008	£432.14
2009	£438.18
2010	£441.43
2011	£450.99
2012	£459.76
2013	£477.48
2014	£469.34
2015	£481.24
2016	£495.29
2017	£502.05
2018	£515.35
2019	£534.41
2020	£529.46
2021	£576.16
2022	£604.08
2023	£650.99

Source: Office for National Statistics (https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/earningsandworkinghours/datasets/averageweeklyearningsearn01

Student activity 5: Calculating earnings over time

Task 1

The table above lists the average weekly earnings for people in the UK from 2000 to 2023.

1. Draw a line graph for the data in the table:

- “Year” should be on the x-axis and “Average weekly earnings” should be on the y-axis
- Choose an appropriate scale for each, starting from 0
- Join each point that you plot to the next one with a straight line
- Don’t forget to label each axis and give your graph a title.

Task 2

Look at your line graph and answer the following questions:

a) What is the general trend for average weekly earnings between the year 2000 and 2023?

b) Does every year follow this trend? If there are any that don’t, can you suggest why this may be the case?

c) Can you make any other observations based on the data in the graph?

Task 3

Draw a line of best fit for your graph, and then answer the following questions:

a)

i) Which years’ data are closest to your line of best fit? Which are further away?

ii) Which sections of the graph most closely match the gradient (or slope) of your line of best fit? Which sections match it least well?

b) You might need to extend the axes of your graph for this one, and then continue your line of best fit beyond the points that you have plotted:

i) Can you use your line of best fit to estimate average weekly earnings for 2024? How about 2025?

ii) What year will you leave school? Can you use your line of best fit to estimate average weekly earnings for that year?

iii) How accurate do you think your predictions in parts (i) and (ii) will be?

Student activity 5: Supporting notes for teachers

Task 1

This is an example of what the final graph might look like:

Source: Office for National Statistics (https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/earningsandworkinghours/datasets/averageweeklyearningsearn01

Task 2

a) The general trend is that average weekly earnings rise over time.

b) Average weekly earnings fall from 2013 to 2014 and from 2019 to 2020. Some students might suggest that the pandemic might be at least part of the cause for the second fall.

c) Students may suggest that sections of the graph are close to straight lines (such as 2001 to 2008, and then 2008 to 2013). Another interesting feature is that 2020 onwards seem to follow a steeper trajectory than earlier years.

Task 3

a) Responses to these questions will depend on your students' specific lines of best fit, but they might be an interesting way to compare the choices they have made as to how and where to draw this line.

b) Again, answers to these questions will depend on the lines of best fit, but they will probably agree that future values will be higher than past values. Some may identify that it is possible that values go down at points, but in general average weekly earnings will be higher. Some might ask whether the seemingly steeper trend in the last few years might continue, and a few may even ask whether the trend is necessarily a linear one, and whether the pattern might break entirely in the future. These are all great points: projecting things into the future is very difficult, and the further into the future we try to predict values, the less accurate we are likely to be.