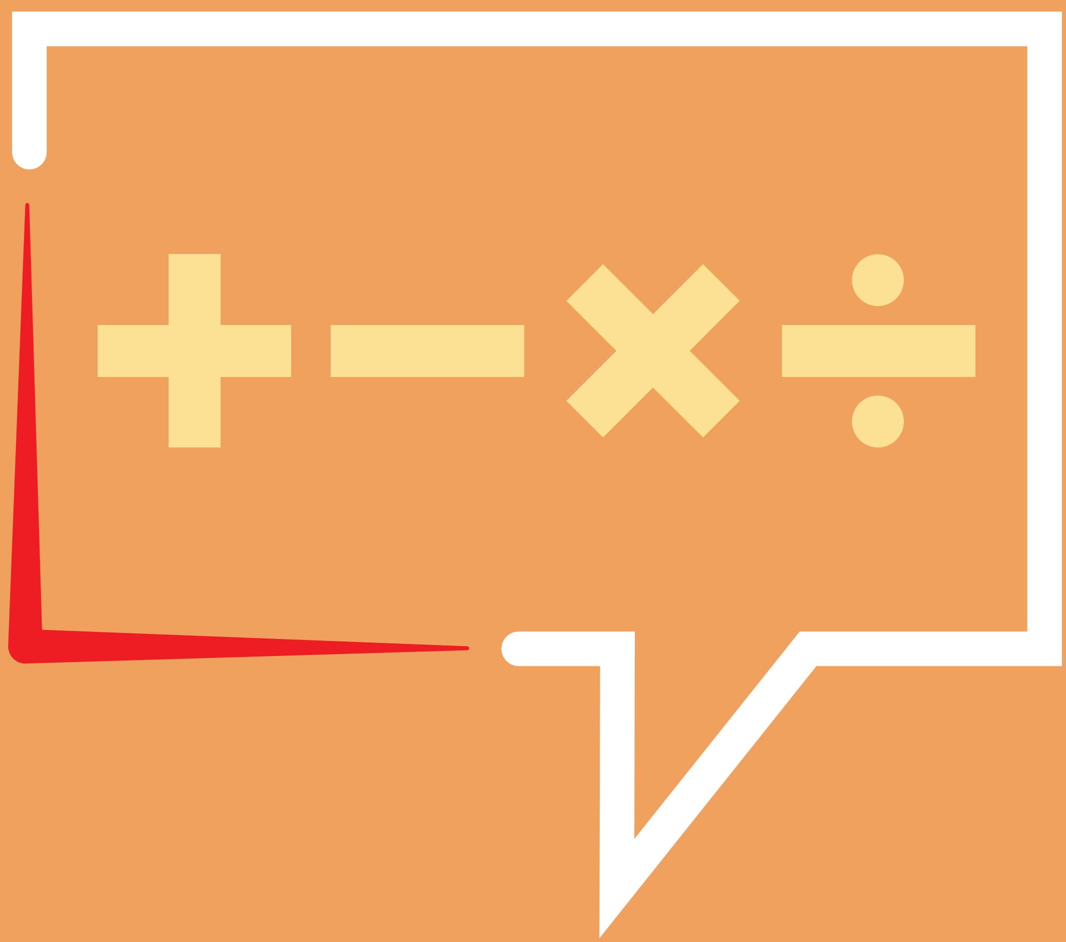
ICAEW
LESSON PLANS



Multiplicative Reasoning

MATHEMATICS KEY STAGE 4

icaew.com/ICAEWmaths

Introduction

SUMMARY:

Use compound measures to understand how savings and loans work.

STRUCTURE:

The content is divided into two (approximately) 60 minute lessons.

PRESENTATION:

Italicised text are suggested scripts for the teacher to say. There are explanatory notes to aid quick understanding of some of the finance material.

GCSE ASSESSMENT OBJECTIVES ADDRESSED IN THE LESSON[1]

The mathematical content specifications in this presentation are those used in the Mathematics GCSE Subject content and assessment objectives and are identified in red.

R1: change freely between related standard units (eg, time, length, area, volume/capacity, mass) and compound units (eg, speed, rates of pay, prices, density, pressure) in numerical and algebraic contexts

R6: express a multiplicative relationship between two quantities as a ratio or a fraction

R16: set up, solve and interpret the answers in growth and decay problems, including compound interest and work with general iterative processes

[1] The expectation is that:

- All pupils will develop confidence and competence with the content identified by standard type
- All pupils will be assessed on the content identified by the standard and the underlined type; more highly attaining pupils will develop confidence and competence with all of this content
- Only the more highly attaining pupils will be assessed on the content identified by **bold** type. The highest attaining pupils will develop confidence and competence with the bold content.

Before lesson 1

HOMEWORK A FOR THE PUPILS

Imagine that you want to save some money for a car. Let's say that the car would cost £5,000 and that you already have savings of £1,500.

Using the website below, answer all the following questions:

1. Using interest rates of 1%, 3% and 5%, find out how long it will take you to save the amount needed for the car by saving £50 each month.
2. Using interest rates of 1%, 3% and 5%, find out how much you would need to save if you needed to buy the car in two years.

The website is: **https://www.moneyadviceservice.org.uk/en/tools/savings-calculator**

FOR THE TEACHER

The website is from the Money Advice Service, a body set up by the government. The two questions correspond to the two calculation links that the pupils will see on the first page after they click on the link.

The objective of the task is to give the pupils a reality check on the interest rates available. Interest rates are very low and are likely to be less than 1% and, so, this will increase the amount of time required to save for the car (for the first question) and increase the amount of money needed to be put aside (for the second question).

Review the submitted homework before the lesson and select one or two to discuss in class (detailed in an activity below).

Lesson time

GENERAL NOTES

The associated powerpoint presentation has supporting script notes to help you. These can best be viewed by clicking 'View/Notes Page' in powerpoint. Items in *italics* are a proposed script for you to say. The content of the lesson plan follows closely the notes contained in the powerpoint.

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Teaching and activities

CLASS DISCUSSION: INTRODUCE DISCUSSION ON THE HOMEWORK

Ask for volunteers to say or present their homework results to the class. (How this is tackled by the teacher will vary depending on how willing the class is to present their ideas). It may be preferable to have group ideas presented or to choose one or two pieces of homework for the teacher to present.

EXPLANATORY NOTES

A key skill being developed is using financial websites confidently and discovering that there is useful information and web content available.

HOMEWORK FOR THE PUPILS: THE FOLLOWING WORK TO BE SET BEFORE THE LESSON:

Imagine that you want to save some money for a car. Let's say that the car would cost £5,000 and that you already have savings of £1,500.

Using the website below, answer all the following questions:

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The website is: https://www.moneyadviceservice.org.uk/en/tools/savings-calculator

POINTS FOR THE TEACHER TO WATCH-OUT FOR:

1. Interest accumulation on savings (and loans for that matter) is determined, in a large way, by the amount of time that savings are held. While there are changes to the answers to question 1 as interest rates change, you will see that interest rates have a smaller and smaller effect as the length of time of the savings period is reduced. Perhaps this could be demonstrated to pupils in class. The essential mathematical idea is that compounding needs compounding periods to have a big effect (unless interest rates are unrealistically high).
2. Interest rates on savings are very low. While 1% is achievable, 3% and certainly 5% are not. Also, the interest rates used do not take account of tax (they are gross rates without tax being deducted). Interest on savings accounts (unless you are a child) have tax deducted at 20%. This is likely to be an important factor for a person buying a car who will almost certainly be working – and a taxpayer – in order to buy the car and pay for its running costs.

THE ANSWERS TO THE QUESTIONS ARE:

Question 1

1% 5 years 7 months

2% 5 years 1 month

5% 4 years 8 months

Question 2

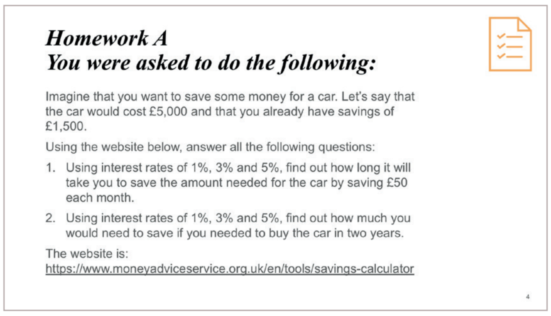
1% £150

2% £145

5% £140

REFERENCE SLIDES

Slide 2



Slide 4

Slide 5

INTRODUCE THE CLASS TOPIC

Meet Maya and her family. Maya lives with her parents and her brother, Rohan. Maya is wondering whether it is the right time to open a bank account. She is keen to understand how savings and loans work and has read that interest received and paid is key to understanding both. She wants to know how interest is calculated and how it can affect her. Her great aunt has told her to be aware of credit cards because of the high interest charges. Maya particularly feels that she should understand these, too.

REFERENCE SLIDE

Slide 6

Task 1

CLASS PROBLEM: INTRODUCE TASK 1

Present task 1 for the pupils to answer

EXPLANATORY NOTES

Part of the key here is to ensure that the motives for spending borrowed money have to be first considered. This will answer the question about whether a loan is necessary. Only then will questions about the cost of the loan be considered.

REFERENCE SLIDE

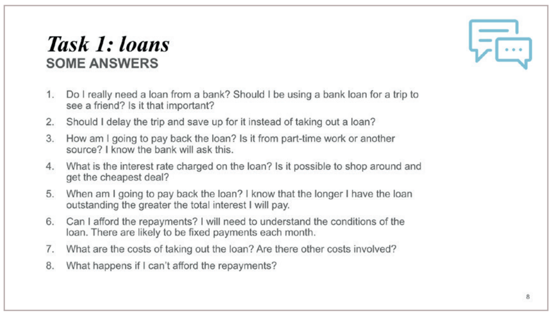
Slide 7

PUPILS ARE ANSWERING TASK 1

EXPLANATORY NOTES

1. The first question to ask is whether a loan is necessary. Is the trip that important? Other factors should then naturally arise about the ability to repay the loan and finding out the detail of the monthly payments schedule.
2. Shopping around is an important idea and various websites are available to indicate availability and cost of loans.
3. There are other costs typically associated with loans such as arrangement fees. Also, fixed interest loans are available which are generally low interest but these are normally associated with penalty charges if repaid before the end of the agreed period of the loan.
4. Finally, pupils should be encouraged to think about contingency arrangements if they can't afford to repay the loan. It might be worthwhile asking a class question about what they would do. Hopefully, some of the more thoughtful answers would indicate a consideration of the risk associated with the loan and judgements about how to manage it. For example, some pupils may say that they have a secure, part-time job to help repay the loan. It is the idea of a relatively secure income that reflects judgement about one way to mitigate this risk.

REFERENCE SLIDE



Slide 8

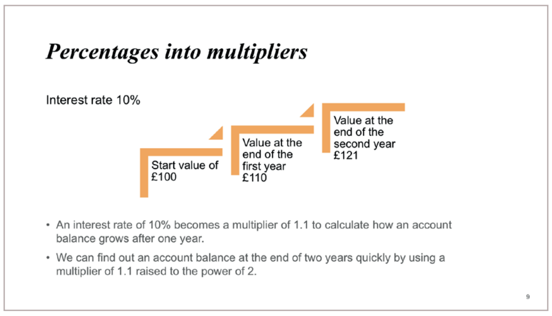
INTRODUCTORY TEACHING

This is a review of assumed prior knowledge about growth and decay. The example is of growth and links in to the development of work relating to compound interest. Be sure to explain the expression of percentages as factors to multiply balances; for example, 5% would become a 1.05 factor. This idea is then developed in the next slide using a bank account.

We can use multipliers to work out account balances for any period. So, for 10 years the multiplier would be 1.1^{10}

If the interest rate was 15% instead of 10% then the 10 year multiplier would become 1.15^{10}

REFERENCE SLIDE



Slide 9

Task 2

CLASS PROBLEM: INTRODUCE TASK 2

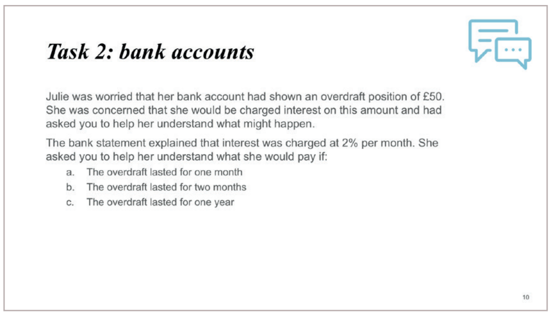
An initial explanation of the relationship percentage change and its related multiplier will be needed using the previous slide as an illustration and perhaps this might be elaborated with different examples, using different rates and different compounding periods.

The task relating to the annual interest cost will require pupils to identify the need to use powers or indices to efficiently complete the task. It has been assumed that index operations have been dealt with in earlier studies.

The answer to the third part of the task can be done long hand, using a spreadsheet if it is available. Preferably, it might be better to hint to pupils to use an index to convert the interest rate of 2% to a multiplicative factor of 1.02 and then raising the monthly interest factor of 1.02 to the power 12. It is assumed that they will have used indices before embarking on this exercise.

The following slide explains the use of the compounding formula.

REFERENCE SLIDES



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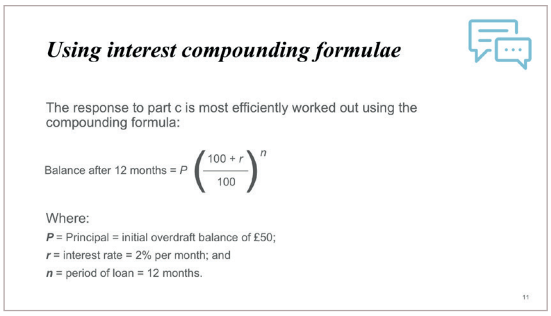

Slide 11

EXPLANATORY NOTES

Explain the elements of the compounding formula. It is assumed that the use of compounding formulae has been illustrated and discussed before this session. The following notes act as a reminder to this.

The answer to the third part of the task can be done long hand, using a spreadsheet if it is available. Preferably, it might be better to hint to pupils to use an index to convert the interest rate of 2% to a multiplicative factor of 1.02 and then raising the monthly interest factor of 1.02 to the power 12. It is assumed that they will have used indices before embarking on this exercise.

The compounding formula is a short cut for calculating loan or savings balances. Remember that, previously, we calculated account balances year on year by adding interest to them and compounding makes sure that we add interest to the interest. This is important as it is the way that banks operate. Compounding is applied to both savings and loan accounts. With savings accounts, you will receive the interest. With loan accounts, you will pay the interest.

There are three elements to compounding. The Principal (P) is either the initial loan amount that you receive or the initial amount of savings you place on deposit with the bank. The interest, i, is the interest rate received or paid. It is expressed in its usual form, so a 5% rate is inserted in the formula as '5'. The period over which the savings are held on deposit or the loan is held is referred to as 'n'. They way to know how this works is to look at the interest rate since it will say something like '5% per year or 1% per month. If it is a 'per year' interest rate, then 'n' will refer to the number of years the loan is owed or the savings are held on deposit. If it is a 'per month' interest rate then 'n' will refer to the number of months. If it is a 'per day' interest rate (and these do exist!) then 'n' refers to the number of days.

Be sure to emphasise that the compounding formula only applies to loans as long as no repayments are made which isn't usually the case. Similarly, it only applies to savings as long as the initial balance does not change.

PUPILS ARE ANSWERING TASK 2

EXPLANATORY NOTES

If pupils have access to spreadsheets then this is a good but routine exercise for them to do long hand. If they don't have access to a spreadsheet then it will be worthwhile showing the worksheet on a projector to show them just how many calculations are involved and why the mathematical treatment using the formula is so much neater and far shorter!

Emphasise the importance of compounding to ensure that pupils add interest costs on previously incurred interest charges.

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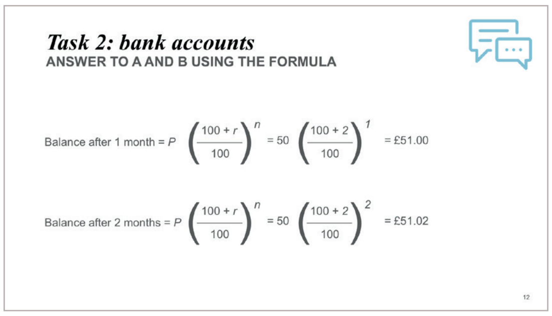

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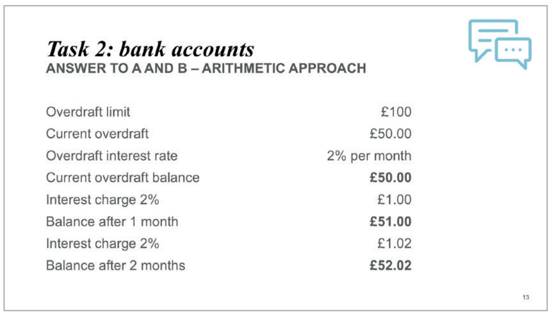

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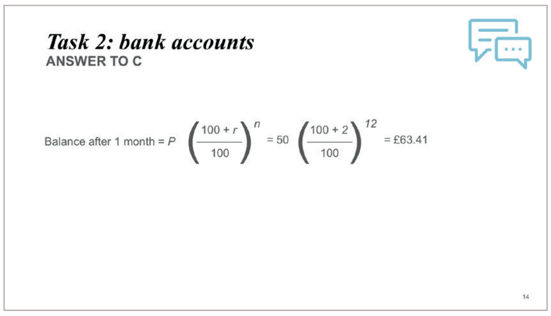


Slide 14

TEACHING: THE EFFECT OF COMPOUNDING

The following is an introduction to how the frequency of compounding can affect interest paid or received. The example is with a car loan and so the interest relates to the amount paid.

Please be careful to note that the example is somewhat artificial in that no part repayments are made and the loan is settled in entirety at the end. The reason for the artificiality is that there are no easy formulae to use (and certainly not at this level) that show how interest compounding works with periodic repayments. We will look at an example with a repayment in it later on.

Note: depending on available time, these slides may be used as an additional in-class task.

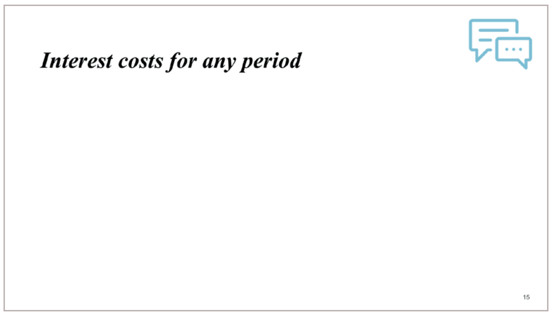
Let's have a look at how the number of times interest is compounded can affect interest cost on a loan to buy a car. The loan is very straightforward in that we borrow an amount and pay it back in a single instalment one year later. In reality, you would need to make monthly payments on a loan. Our example, though, using just one repayment still illustrates a valid point to make about compounding. Let's see ...

Draw-out the 'apparent', but incorrect, equivalence between the two loans. That is Loan 1 'appears' to be the same as Loan 2 if we multiply Loan 2 by the number of months that the loan would be outstanding (12 months x 1% = 12%). But such arithmetic is incorrect because it ignores the effect of compounding ... Which we see the result of in the next few slides.

Work through the slides.

This point demonstrates that, in effect, what is happening is that interest is charged on interest incurred. With the single repayment loan, there is no interest incurred until the end of the loan and hence no possibility of interest being charged on interest incurred. With the monthly interest loan then interest is incurred from the first month. In the second month the interest charge will be on the outstanding balance at the end of month one which is the loan of £1,000 plus one month's interest of £10 = £1,010. Hence, the balance at the end of the second month is £1,010 x 0.001 = £1,020.10.

REFERENCE SLIDES



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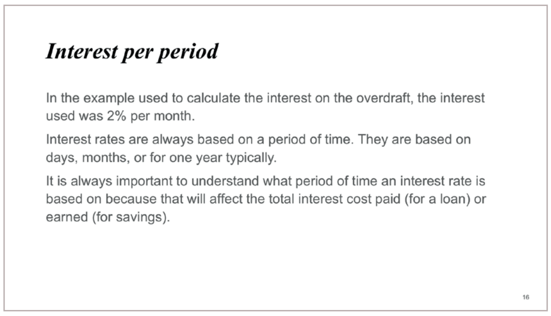

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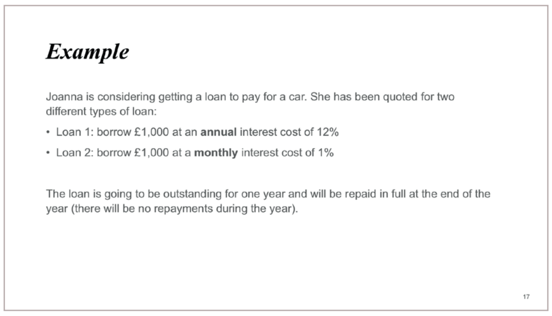

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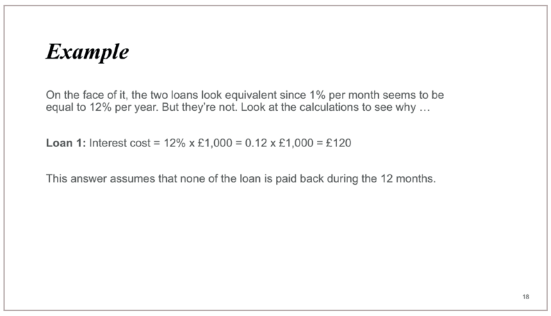

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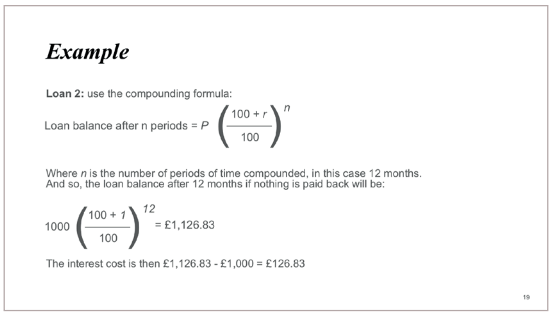

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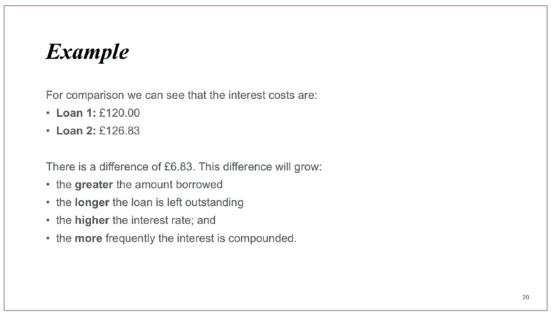


Slide 20

TEACHING OR TASK

This is the final part of the lesson to be taught by the teacher. It prepares pupils for the homework and brings in a more realistic example using a loan with repayments.

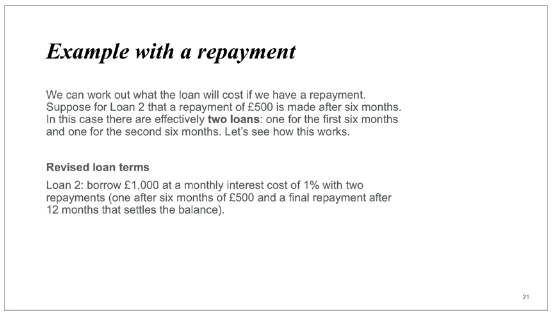
The slides use the compounding formula. There is also a spreadsheet version to cross-check the calculations. This is available to you.

Work through the slides.

The major intuitive point to emphasise is that the answer illustrates the point that a repayment, in effect, begins a new loan where we can again apply the compounding formula using the new balance.

The example shows one repayment but this approach can be used for any number of repayments.

REFERENCE SLIDES



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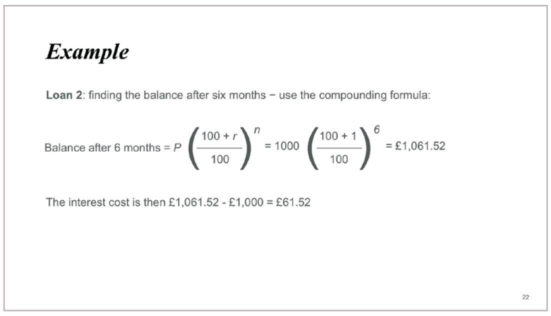

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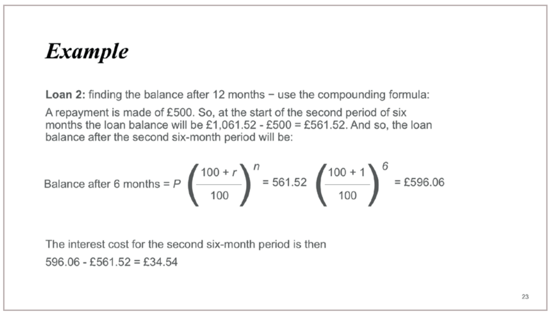

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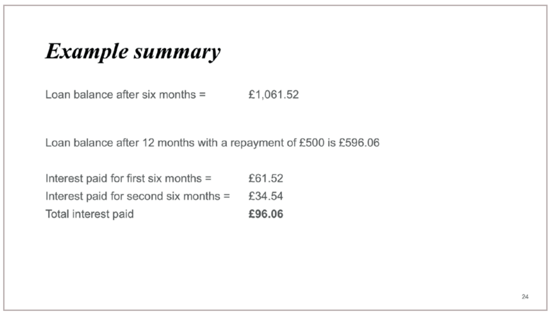


Slide 24

Homework for lesson 2

We've now got a fairly good understanding of how to use compounding to understand interest and loan repayments. Have a go at the homework which we'll deal with in the next lesson.

Homework B: Ask the pupils to complete the homework. This is included in the Tasks folder to print off if necessary.

PART 1

Joanna has heard about payday loans where interest rates can become very high, as much as 40% per month. Joanna is not considering taking out a payday loan but was wondering how mathematics could help her understand the implications of taking out one of the following loans.

Loan 1: borrow £200 at a monthly interest cost of 40%. Loan 1 is taken out on 1 July and will be repaid over a two-month period. The first repayment instalment due on 31 July will repay half of the original loan: £100, plus outstanding interest at that time. The second instalment will settle the outstanding loan and interest balance on 31 August.

1. What is the amount of the second instalment payment?
2. What is the total interest cost in £ of the loan?

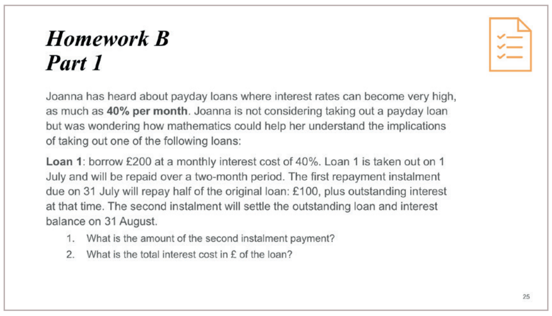
PART 2

Joanna is considering a different loan.

Loan 2: borrow £200 at a daily interest cost of 1.5%. Loan 2 is taken out on 1 July and will be repaid over a two-week period. The first repayment instalment due on 8 July will repay half of the original loan: £100, plus outstanding interest at that time. The second instalment will settle the outstanding loan and interest balance on 15 July.

1. What is the amount of the final instalment payment?
2. What is the total interest cost in £ of the loan?

REFERENCE SLIDES



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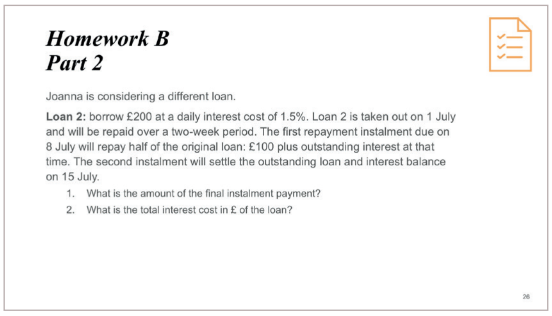

Slide 26

Before lesson 2

HOMEWORK B FOR THE PUPILS: THE FOLLOWING WORK TO BE SET BEFORE THE LESSON:

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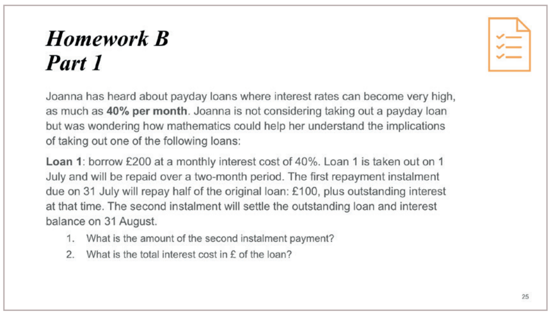
1. What is the amount of the final instalment payment?
2. What is the total interest cost in £ of the loan?

Encourage pupils to use both the compound formula approach and to confirm their answers on a spreadsheet if available.

REFERENCE SLIDES



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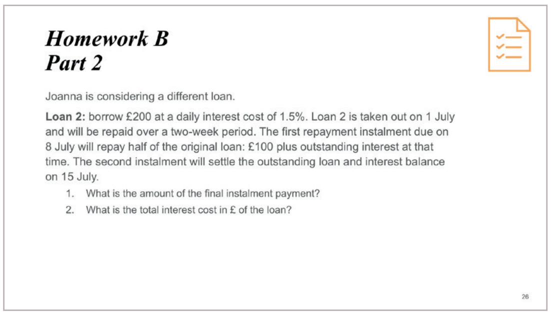


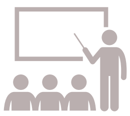
Slide 29

Lesson time

General notes: The associated powerpoint presentation has supporting script notes to help you. These can best be viewed by clicking 'View/Notes Page' in powerpoint. Items in italics are a proposed script for you to say. The content of the lesson plan follows closely the notes contained in the powerpoint.

Teaching and activities

CLASS DISCUSSION: INTRODUCE DISCUSSION ON THE HOMEWORK



Ask for volunteers to say or present their homework results to the class. (How this is tackled by the teacher will vary depending on how willing the class is to present their ideas). It may be preferable to have group ideas presented or to choose one or two pieces of homework for the teacher to present.

HOMEWORK

PART 1

Joanna has heard about payday loans where interest rates can become very high, as much as 40% per month. Joanna is not considering taking out a payday loan but was wondering how mathematics could help her understand the implications of taking out one of the following loans.

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1. What is the amount of the second instalment payment?
2. What is the total interest cost in £ of the loan?

PART 2

Joanna is considering a different loan.

Loan 2: borrow £200 at a daily interest cost of 1.5%. Loan 2 is taken out on 1 July and will be repaid over a two-week period. The first repayment instalment due on 8 July will repay half of the original loan: £100, plus outstanding interest at that time. The second instalment will settle the outstanding loan and interest balance on 15 July.

1. What is the amount of the final instalment payment?
2. What is the total interest cost in £ of the loan?

Encourage pupils to use both the compound formula approach and to confirm their answers on a spreadsheet if available.

EXPLANATORY NOTE

Work through the slides.

Although we should not advocate payday loans it is important to understand them. One reason a person may take out a payday loan is that, in the face of not having enough money to pay bills for example, the total interest cost of £35.37 for a loan of £200 might be preferable than not being able to afford food. The reality and key problem of the choice for individuals choosing payday loans is one of liquidity (not having available cash) which for them takes priority over interest costs. The interest rate may be high but if the loan is repaid quickly then the interest cost in terms of £ is arguably not large when seen as a charge for the benefit to gain liquidity. This is not advocacy for payday loans but an explanation of why they might be used.

Payday loans are part of the wide spectrum of loans that are available. The general rule is that the higher the risk of the individual not meeting the commitments under the loan, the higher the interest rate they will pay. Risk is judged on a number of factors: previous credit history, security for the loan (eg, a car or house), financial capacity, and so on. Money lenders must be licensed by the Financial Conduct Authority to offer credit: **https://www.gov.uk/offering-credit-consumers-law**

REFERENCE SLIDES

Homework B
Part 1

Joanna has heard about payday loans where interest rates can become very high, as much as **40% per month**. Joanna is not considering taking out a payday loan but was wondering how mathematics could help her understand the implications of taking out one of the following loans:

Loan 1: borrow £200 at a monthly interest cost of 40%. Loan 1 is taken out on 1 July and will be repaid over a two-month period. The first repayment instalment due on 31 July will repay half of the original loan: £100, plus outstanding interest at that time. The second instalment will settle the outstanding loan and interest balance on 31 August.

1. What is the amount of the second instalment payment?
2. What is the total interest cost in £ of the loan?

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Homework B
Part 2

Joanna is considering a different loan.

Loan 2: borrow £200 at a daily interest cost of 1.5%. Loan 2 is taken out on 1 July and will be repaid over a two-week period. The first repayment instalment due on 8 July will repay half of the original loan: £100 plus outstanding interest at that time. The second instalment will settle the outstanding loan and interest balance on 15 July.

1. What is the amount of the final instalment payment?
2. What is the total interest cost in £ of the loan?

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Homework B
Class discussion

30

Slide 30

Homework B
Answer, part 1

Using the formula approach, here is the loan balance after one month

$$\text{Balance after 1 month} = P\left(\frac{100+r}{100}\right)^{n} = 200\left(\frac{100+40}{100}\right)^{1} = £280$$

A repayment of £100 is made to bring the loan balance down to:

£280 - £100 = £180.

This becomes the new balance to begin the second period of the loan

Interest costs for the first 1 month period are therefore £280 - £200 = £80

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Slide 31

Homework B
Answer, part 1

Using the compounding formula, we see that the loan balance after the second one month period is:

$$\text{Balance after 2 months} = P\left(\frac{100+r}{100}\right)^{n} = 180\left(\frac{100+40}{100}\right)^{1} = £252$$

Interest costs for the second one month period is therefore £252 - £180 = £72

The answers to the questions in the homework are therefore:

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Homework B
Answer

First instalment	£100.00
Final instalment	£252.00: **answer to question 1**
Total interest paid	£152.00: **answer to question 2**

Total interest costs are 80 + 72 = £152

Total amount repaid for a loan of £200 is £352

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Homework B
Answer, part 2

Using the formula approach, here is the loan balance after one week

$$\text{Balance after 1 week} = P\left(\frac{100+r}{100}\right)^{n} = 200\left(\frac{100+1.5}{100}\right)^{7} = £221.97$$

A repayment of £100 is made to bring the loan balance down to:

£221.97 - £100 = £121.97

This becomes the new balance to begin the second period of the loan.

Interest costs for the first week are therefore £221.97 - £200 = £21.97

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Homework B
Answer, part 2

Using the compounding formula, we see that the loan balance after the final 7 day period is:

$$\text{Balance after 2 weeks} = P\left(\frac{100+r}{100}\right)^{n} = 121.97\left(\frac{100+1.5}{100}\right)^{7} = £135.37$$

Interest costs for the second week are therefore £135.37 - £121.97 = £13.40

The answers to the questions in the homework are therefore:

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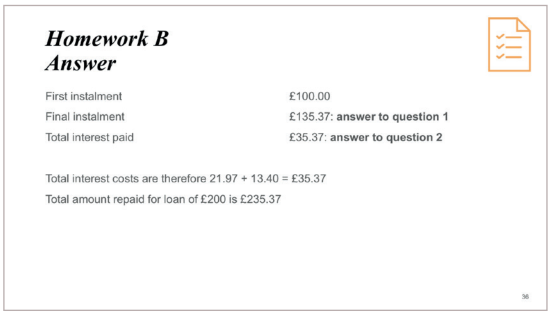
REFERENCE SLIDES (CONT)



Slide 36

RECAP ON WHAT HAS ALREADY BEEN DONE

IF NEEDED, RECAP THIS FROM THE PREVIOUS SESSION: *Meet Maya and her family. Maya lives with her parents and her brother, Rohan. Maya is wondering whether it is the right time to open a bank account. She is keen to understand how savings and loans work and has read that interest received and paid is key to understanding both. She wants to know how interest is calculated and how it can affect her. Her great aunt has told her to be aware of credit cards because of the high interest charges. Maya feels that she should understand these too.*

REFERENCE SLIDE

Slide 6

INTRODUCE AND MOTIVATE THE NEXT TASK

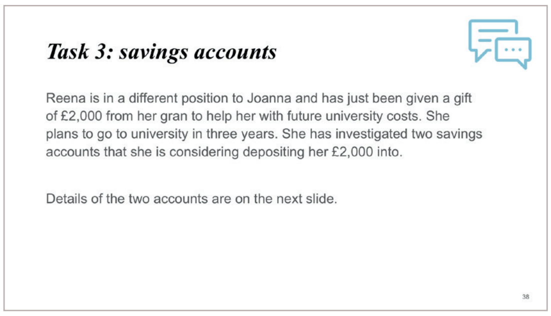
We now turn our attention to savings accounts to illustrate that compounding also works here. It will be important in what follows to pay attention to the detail of what is on offer. Only by looking at the detail can we fully understand how to make the right decisions to choose between alternatives. Our mathematical analysis will help us in this respect.

EXPLANATORY NOTES

The idea behind the problems is to get the pupils to be very comfortable about thinking about the three elements of compounding (principal, interest and period), how these can vary, and what effect variations in one element has on the remaining two. These examples reflect the level of some of the questions used in examinations.

If running short of time then omit part b.

REFERENCE SLIDES



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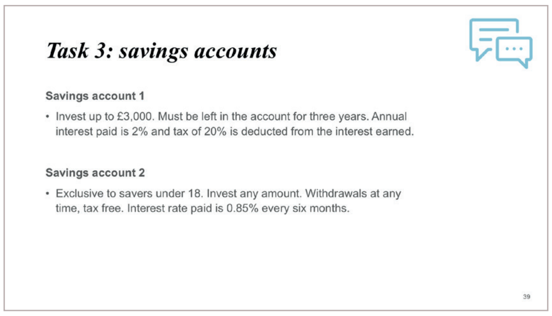

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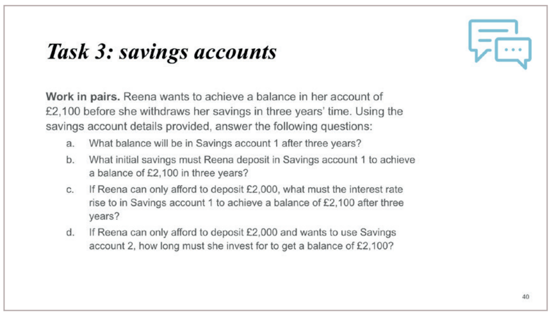

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Task 3

PUPILS ARE ANSWERING TASK 3

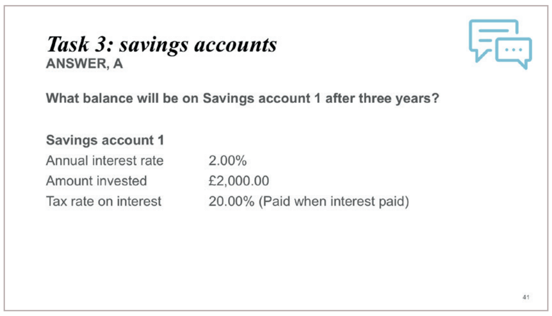
The answer to the problem is … (go through the slides)

First, here are the answers to the calculations.

EXPLANATORY NOTE PART A

It is best to do the long-hand calculation to demonstrate to pupils how to adjust the interest rate for tax deductions which will then enable them to use the compounding formula directly.

REFERENCE SLIDES



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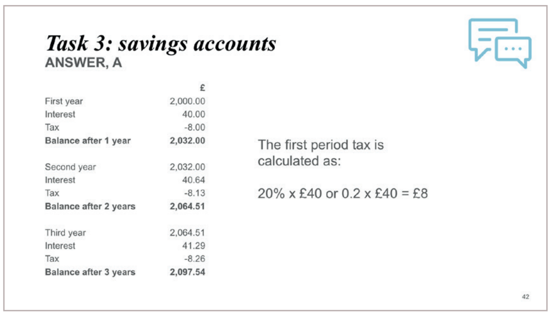

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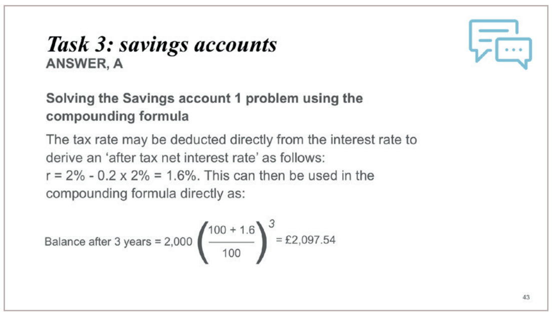

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The answer to the problem is … (go through the slides)

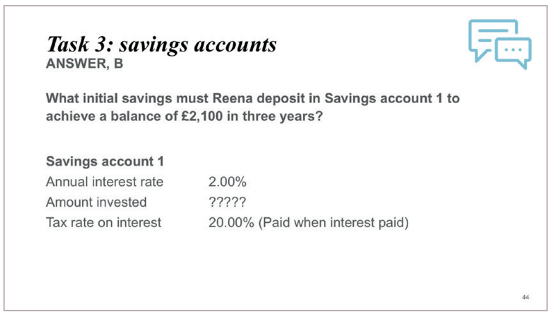
First, here are the answers to the calculations.

EXPLANATORY NOTE PART B

This can be calculated from the compounding formula but requires the use of indices manipulation which will be beyond the group being taught. It is answered by trial and error or trial and improvement and the purpose is to get pupils to practise how the basic relationships work in the compounding formula. Pupils will need access to a calculator that is capable of answering $y=x^n$ problems.

The teacher might illustrate how the answer can be arrived at by using the accompanying spreadsheet.

REFERENCE SLIDES



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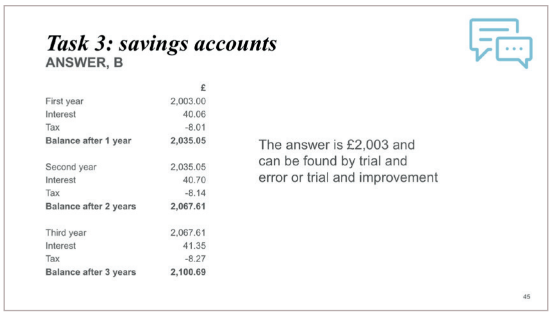


Slide 45

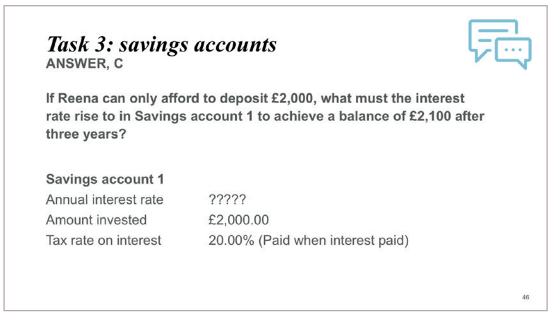
The answer to the problem is … (go through the slides)

First, here are the answers to the calculations.

EXPLANATORY NOTE PART C

Again, this is another trial and error approach to solve the problem and get pupils used to understanding the relationships between interest rates, amounts owed/invested, and time.

REFERENCE SLIDES



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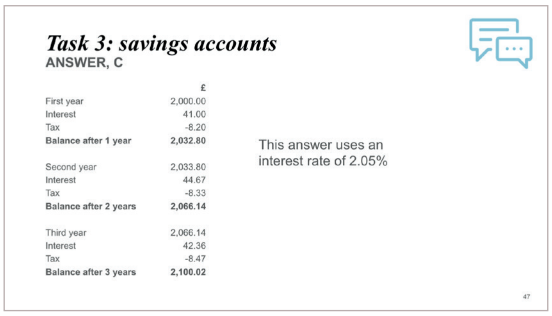


Slide 47

The answer to the problem is … (go through the slides)

First, here are the answers to the calculations.

EXPLANATORY NOTE PART D

The answer to this is in two parts. Pupils need to establish what the year three balance will be investing £2,100 to discover whether they should then lengthen or shorten the time period over which the investment is made. Using the initial data in the question, the balance after three years is £2,104.19 and hence the period to achieve £2,100 is less than three years and so the value of n must be reduced.

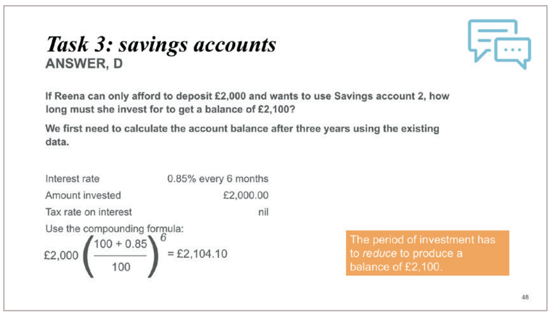
Note the use of the compounding formula: the period over which the interest is calculated must relate to the period value for 'n'. That is, 'n' is represented as '6' or 6 x ½ years. It would be a mistake to write this as '3' to represent three years.

This is a potentially tricky calculation because pupils will need to realise that the value of n in the compounding formula will now involve a decimal point. In the initial data n=6. It must be lowered to reflect a shorter period, the correct answer is to use n = 5.75 (equal to five years and nine months). The instructor may need to give some hints to focus attention on how the value of n may be changed to provide the answer required.

Pupils, using trial and error in the compounding formula, would have worked out – had they tried a value of n greater than 6 – that a value lower than 6 needed to be tried. This is a useful exercise for pupils to practise the relationships in the compounding formula to understand how bank accounts paying interest work.

Of course, the calculations work for loans. However, stress to pupils that there are further complications in loan accounts that need to be taken account of, such as periodic repayments, which mean that straightforward calculations of the type used here need adjusting to account for such complicating factors.

REFERENCE SLIDES



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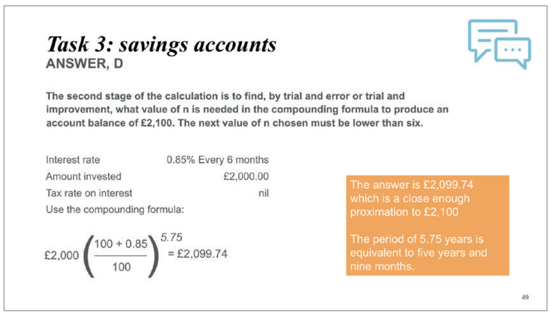

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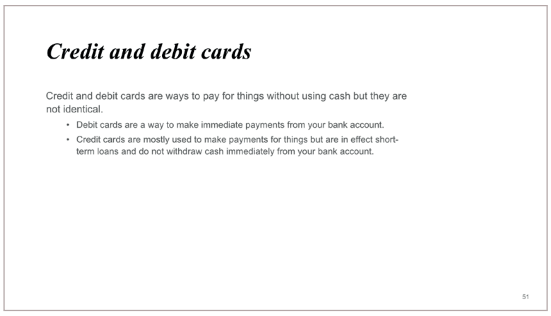
SOME FINAL THOUGHTS

Debit cards withdraw money immediately from your bank account (if you have enough money in the bank account). They reduce your bank balance almost immediately and are similar in that respect to writing a cheque, withdrawing cash from a machine (automated teller) or paying contactless by phone.

Credit cards are short-term loans that require minimum payments to be made each month. Outstanding balances are charged interest, which is normally quite high (at about 1.5%-2% per month, or even higher). Credit cards are best used when the full balance is paid off each month. When that is done interest is not charged. It is unwise to use credit cards and maintain a loan balance over a long period of time.

The following website contains good details on how interest is calculated
https://www.hsbc.co.uk/1/2/credit-cards/credit-card/interest-rates

REFERENCE SLIDES



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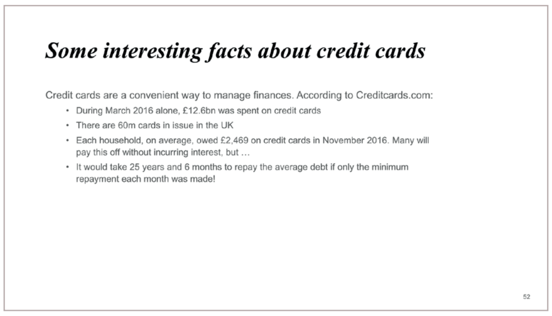

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Resources

1. LESSON PLAN (THIS DOCUMENT)
2. POWERPOINT
3. TASK HANDOUTS
4. SPREADSHEET

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