What's the time?

UNIT 17

This unit helps students to learn about the background to our present day calendar and about calendars used by people in other places and at other times. It goes on to encourage them to think about their own approaches to time and the uses they make of it.

Using this unit

This unit could be used with students of any tier at GCSE. Some mathematical content may need revision with lower tier students.

It should take about 2 hours, but the length of time will depend on the amount of discussion.

The unit contains several sections all related to the theme of time. There is quite a lot of information so you will need to consider whether you allow students to work independently on the text or whether to present some of the ideas yourself. Each section can lead to class discussion of the issues raised.

Additional sources

A good source on the theory of relativity is *Introducing Einstein's Relativity*, by D'Inverno (OUP, 1992).
A very informative Web site is
http://astro.nmsu.edu/~lhuber/leaphist.html

Students will require a calculator.

Mathematical content

Number (AT2)
- **Using calculation skills**
- **Using negative numbers**
- **Using large numbers (million/billion)**

Algebra (AT2)
(extension activity only)
- **Using formulae**
- **Constructing graphs**

Handling data (AT4)
- **Calculating mean average**

Spiritual and moral development

The aim of this unit is to give students an opportunity to reflect on the nature of time and their use of it and thereby leads into issues of purpose and meaning.

Looking at the way in which non-European societies have developed alternative calendars, it aims to help them to appreciate other views of reality.

TEACHER'S NOTES

Notes on the activities

BC/AD

This section requires students to have some basic understanding of negative numbers. It illustrates the importance of religious belief in the history and culture of a society. All three calendars mentioned are based on an important religious event, as seen by that society. The predominance of Western European culture has made the Christian calendar the standard one, but the others are still used, particularly by religious communities in some other cultures.

A possible discussion point here is the difference between a cyclic calendar – perhaps containing the message that progress is illusory – and a linear one, which suggests that history is going forward.

The details of different calendars can become extremely complicated, and would probably not be worth pursuing in detail.

Leap Years

This section requires students to have some understanding of mean average and decimal fractions. The year 2000 is a Leap Year, although many people think otherwise. The divisible-by-400-and-not-simply-by-100 rule explains this.

It may be worth discussing the extent to which our awareness of the natural environment affects our consciousness of the changing seasons. For some students, the start of the football season in August may be much more significant than harvesting the crops.

Big numbers

This section requires students to have some understanding of large numbers, such as a million and a billion. A second is sufficiently small - but still perceptible- that we can use it to gauge the meaning of some very large numbers.

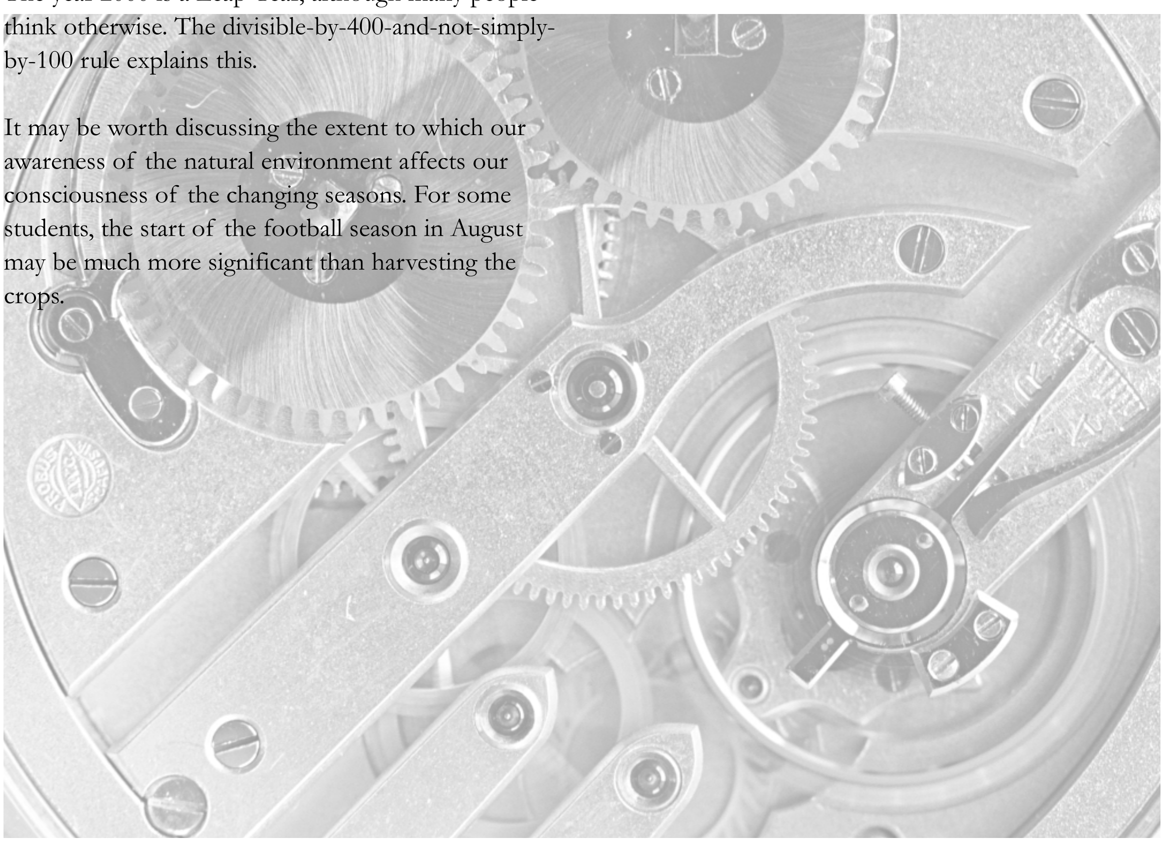
The time of your life?

This section requires students to calculate fractions of quantities and to know how to construct a pie chart. The paradox could lead to a discussion of Venn diagrams and the importance of not counting the intersection of two sets twice.

Science and time (extension activity)

This section is for extension work at higher level.

It requires students to use a complex formula and to interpret graphical information.



Answers

(Some questions are for discussion with no prescribed answers)

1. BC/AD

1. Because it is regarded as a very important event.
2. In the year that we call 44 BC, the coin minters could hardly have known that Jesus would be born 44 years later!
3.

Event	Date in Christian calendar	Date in Jewish calendar	Date in Muslim calendar
Creation	3761 BC	0	- 4341
Birth of Christ	0	3761	- 580
Mohammed flees from Mecca	580	4341	0
Battle of Hastings	1066	4837	486
Yom Kippur War	1973	5734	1393

4. Religious events were regarded as the most important events in history, particularly when calendars were being instituted. It may be worth while asking what event would society use today?
5. Clearly the Christian calendar predominates throughout the world, and is the *de facto* standard. The others are still used in their own communities.
6. The original Roman year had ten months. This was changed to 12 months (based on the lunar cycle) with the insertion of July and August (named after Julius Caesar and Augustus Caesar). This meant that September, October, November and December, formerly the 7th, 8th, 9th and 10th months became the 9th, 10th, 11th and 12th months.

2. Leap Years

1. It would be 0.24219 days or 5 hours 49 minutes.
2. After 100 years, 24.219 days; after 700 years, about 6 months.
4. Caesar: error is 0.00781 days, or 11.2 minutes.
5. After 1500 years, error is 12 days.
7. Gregorian: in 400 years, get 97 leap years and 303 normal years, so the total number of days in 400 years is 303 x 365 + 9 7x 366 = 146097, and the average length of the year is then 146097/400 = 365.2425.
8. Alternative system would give (304 x 365 + 96 x 366)/400 = 146096/400 = 365.24
9. The current error is 0.00031 days per year, or 27 seconds per year. After 10,000 years, there will still be an error of only 3.1 days.

3. Big numbers

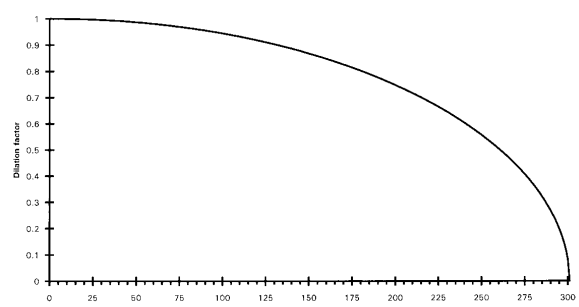
1. a) 11 days 14 hours.
   b) 31.7 years.
2. 2.2 billion seconds.
3. 60 billion seconds.

4. The time of your life?

1. 48 years, 24 years, 3.4 years, 0.4 years left for work!

5. Science and time

1. 0.9999999992.
2. Graph:



3. (The following answers are obtained by calculation rather than from the graph.)
   a) (i) 259,808 km/s.
   (ii) 298,496 km/s.
   (iii) 299,985 km/s.
   b) (i) 10.01 years.
   (ii) 20.02 years.
   (iii) Dilation factor is 0.0447.
   (iv) 0.895 years i.e. 11 months.

What's the time?

UNIT 17

The Millennium year, 2000 AD, has generated lots of excitement and interest. It reminds us of the importance of time and dates. It is interesting to see how time is measured, and to reflect on how much we appreciate and value the time we have.

BC/AD

1

1. Most countries in the Western world measure the year from the supposed birth date of Jesus Christ. Why do you think they do this?
2. An archaeologist dug up a coin inscribed 'Julius Caesar 44 BC'. How did she know it was a fake?

info

In fact, several hundred years after this system started, it was realised that there had been a mistake in calculating the year in which Christ was born. It is now thought that he was probably born in 6 BC but it would be too complicated to change the worlds' calendars!

Other cultures use different starting points for their calendars. It is well known that the Chinese name their years after animals – the Year of the Dog etc. When they have gone through the list of animals, they then repeat the sequence, so theirs is a *cyclic calendar*.

Jewish people count from 3761 years before Christ, so they are now in the year 5757. Their starting point is the time at which they suppose the world was created.

Muslims measure from 580 years after the birth of Christ, when Mohammed fled from Mecca. So for them, the year 2000 AD is 1420.

3. Complete the following table

Event	Date in Christian calendar	Date in Jewish calendar	Date in Muslim calendar
Creation		0	
Birth of Christ	0		
Mohammed flees from Mecca			0
Battle of Hastings	1066		
Yom Kippur War		5734	

1

Task 1 continued

4. What sort of event is the basis for all of these calendars? Why is this?

5. Do you think it would be better if all countries agreed on the same year numbering method? If so, which one should they use? Why?

info

Different cultures also have different ways of dividing the year up. The Western world uses 12 months of slightly different lengths. The names of these months are interesting, reflecting their origin in the Roman civilization; so, for example, October is literally the eighth month, and December is the tenth.

6. Investigate why October is not our eighth month now.

info

In the Muslim calendar, months have 29 and 30 days alternately. This means that after 12 months have passed and the first one starts again, less than a year has passed. This is why religious feasts like Ramadhan move forward 11 days each year – in 1992 it was in April and in 1996 it was in February.

Leap Years

A year is the time the earth takes to go exactly once around the sun. Unfortunately, this is not a whole number of days. In fact, it takes 365.24219 days, as accurately as we can measure it.

2

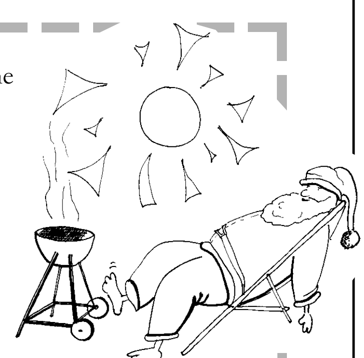
1. If we took each year to be exactly 365 days, what would the error be? What is this in hours?

2. The error may seem small, but it would accumulate. What would it be after 100 years? After 700 years?

!

This would mean that, after 100 years, when it should be, say, June, the weather would be a month 'behind', and it would feel like May. After about 700 years, there would be a slippage of 6 months, so on December 25th, Christmas Day, we would be enjoying hot sunshine, and barbecuing the turkey – just as they now do in Australia!

To avoid this problem, and to keep the different calendar dates at the same time of the 'weather year', people have introduced simple modifications to the basic idea of 365-day years.



2 Task 2 continued

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The first change was made by Julius Caesar in 46 BC (he didn't know it was BC, as we've seen already!). The standard 365-day calendar had been started several hundred years earlier, and there was already a slippage of about 3 months. To remedy this, Caesar invented Leap Years.

He ordered that every fourth year should have an extra day. This means that in every cycle of four years, the total number of days is

$$3 \times 365 + 1 \times 366$$

This comes to 1461 days. If we average this over the four years, we get a mean length of 365.25 days.

This is clearly very close to the correct value, and so this system was used for almost 1600 years. It is called the Julian calendar.

There are other ways of getting an average near 365.24219 days. For example, suppose there were 8 leap years in every cycle of 33 years. The total number of days in the cycle would be

$$25 \times 365 + 8 \times 366 = 12{,}053$$

If we average this over 33 years, we get 12053/33 = 365.242424... This is an even better result, but it would be difficult to remember which years were leap years!

3. Can you invent other leap year systems which would give an average year length near to 365.24219?

4. Calculate the difference between the average under Caesar's system, 365.25 days, and the best measured value at present, 365.24219 days
   a) in days, b) in minutes.

5. Over many years, the error in the Julian calendar will again build up. What is the accumulated error after 1500 years?

info

A slippage of almost 12 days was beginning to become noticeable. To solve this difficulty, a further modification was made: century years (although divisible by 4) would only be leap years if they were divisible by 400. So, for example, 1600 and 2000 are leap years, but 1700, 1800 and 1900 aren't. This system was introduced by Pope Gregory in 1582 on the continent, but not until 1752 in Britain. By that time, the calendar was 12 days out, and so it was decided by the government that September 2nd should be followed by September 14th. This apparent loss of 12 days caused serious rioting in many parts of the country – people thought that they were losing twelve days of their lives.

We can see that people were not losing part of their lives – it was just a re-labelling of the days of their lives. However, their reaction can make us think about the importance of time in our own lives.

2

Task 2 continued

6. Suppose you really did lose 12 days from your life – perhaps in a coma after a road accident. Would you feel very upset about the lost time? Some people might feel most upset because they had missed episodes from their favourite soap on TV; others because of the things that they have not been able to do in the lost time. What would you miss most?

info

The calendar devised by Pope Gregory means that on a cycle now of 400 years, instead of 100 leap years and 300 normal years, there are now 97 leap years and 303 normal years.

7. How many days does this give in each complete cycle of 400 years? What is the average length of a year?

8. What would the average be if the '400 years' were like the other century years, and not leap years?

9. Calculate the error in the current Gregorian system. How much would it amount to after 10,000 years?

10. In previous times, it was important to know about the seasons of the year. Nowadays, most of us are much more cut off from agriculture and the natural world. We don't know much about the lambing season, or about harvest time. Do you think that this lack of awareness of our natural environment matters?

In other societies e.g. Iran,the slippage of the seasons relative to the calendar is tolerated. Do you think we should be so bothered about it? Would it matter if we had Christmas in the hottest time of the year?

Big numbers

Most of us are not very good at imagining what a million or a billion is really like – how big is it? One easy way to get some idea of what these huge numbers mean is to find out how many seconds there are in various periods of time.

For example, how many seconds are there in a year? There are 60 seconds in a minute, 60 minutes in an hour, 24 hours in a day, 365 days in a (normal) year. This gives 60 x 60 x 24 x 365 = 31,536,000 seconds in a year.

3

1. From this result, estimate roughly how long
   a) one million seconds lasts (give your answer in days);
   b) one billion seconds lasts (i.e. one thousand million seconds), (give your answer in years).

2. How long, in seconds, can you expect to live?

3. How long, in seconds, is it since 0 BC?

The time of your life?

It can be surprising to consider how you are going to spend all the time of your life.

4

Firstly, a paradox:

1. Suppose you live for 72 years (about average, and a nice number for division!). About one third of your life is spent sleeping. After taking that away, how long does it leave you with?

   Another third is spent in leisure activities, between sleeping and working. How much does that leave?

   2/7 of your 72 years is spent in weekends. What is left now?

   Take an hour each day for eating – 1/24th of your life. How much time is finally left for work? Where is the catch?

2. Do a class survey on how much time, on average, each week is spent
   at school; eating; sleeping; travelling; being with friends.

   Illustrate the results with a pie-chart.

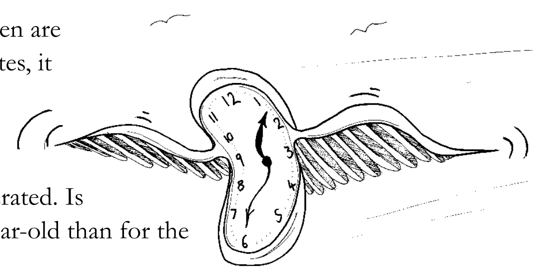
Do you think that you spend your time well?

Do you waste a lot of it?

Are there things that you wish you had done instead?

How good are you at telling the time? As an exercise for the whole class, close your eyes and put your hand up when you think one minute has passed. Your teacher will tell you who got closest.

'Time flies when you're enjoying yourself' – which lessons seem to last the longest?



When 3-year-old children are told to wait for 5 minutes, it can make them very impatient. For a 15-year-old, a similar request is more easily tolerated. Is this because 5 minutes is a bigger fraction of life for the 3-year-old than for the 15-year-old? How much bigger?

Similarly, for a 40-year-old, the previous year in his or her life represents a fairly small fraction (one fortieth) of the total, but for a 5-year-old, the previous year is one fifth of his whole life so far. This can give a different perspective on time and the way we use it. It can make the experiences we have in the first years of our lives more significant than those in later life.

Not many of us know when we are going to die, and so we cannot count off the days until that event. However, convicts sentenced to death do know the precise hour, and this can give us some insight into our approach to time, and into what things in life are most important to us.

Suppose you knew that you were going to be executed in exactly one week from now.

What would you do in the last week of your life?

What would you do in the last hour?

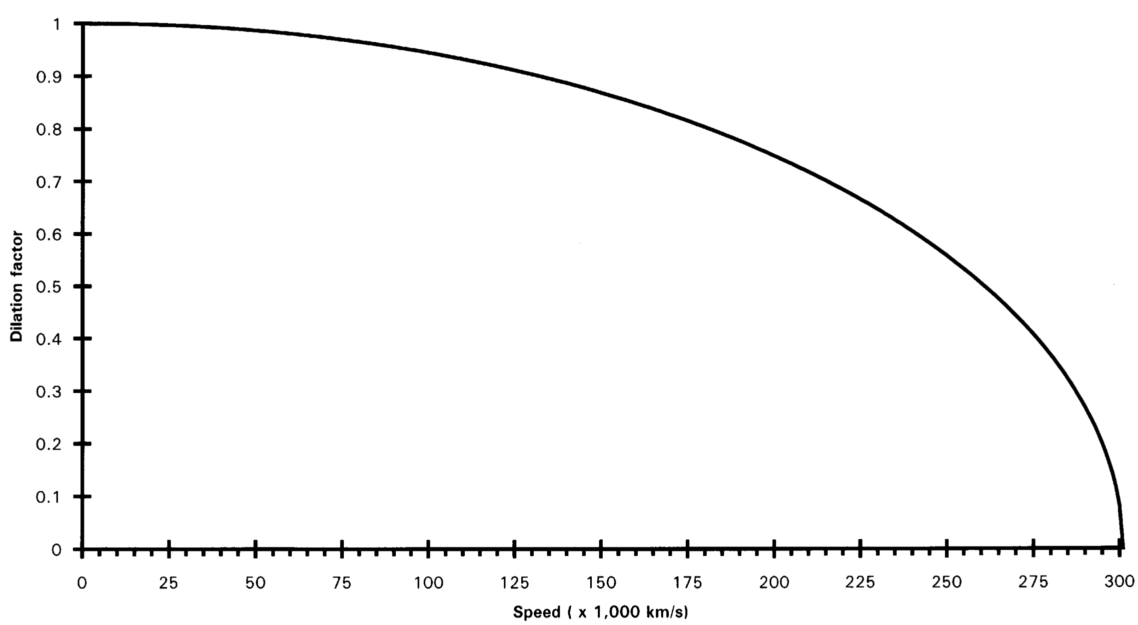
This theme has been explored in *The Chamber* by John Grisham, and the film *Dead man walking*.

Science and time

One of the great surprises of modern science is Einstein's discovery that for someone moving at a certain speed v, relative to us, the rate at which their clocks measure time is related to our clocks by a multiple

$$\sqrt{1-(v/c)^2}$$

where c is the speed of light, about 300,000 km/second. This is called the *time dilation factor*.



5

1. The fastest any human has ever travelled is about 12 km/sec (astronauts returning from the moon). Work out their time dilation factor.

info

It is clear that this factor is very close to 1 for any reasonable human speed. However, scientists have accelerated very small particles, such as electrons and protons, to very high speeds, and for the particles it does indeed seem that time goes slower.

2. Plot a graph of the time dilation factor for speeds from 0 to 300,000 km/sec.

3. Use the graph to answer these questions:
   a) How fast should you go for time to pass at
      (i) half the normal rate;
      (ii) one tenth of the normal rate; and
      (iii) one hundredth of the normal rate.
   b) Suppose the crew of the Starship Enterprise travel at 0.999c.
      (i) How long would they take to get to a nearby star 10 light years away? (A light year is the distance travelled by light in one year).
      (ii) If they turned round and came straight home again, how much time would have passed on earth during their voyage?
      (iii) Calculate their time dilation factor.
      (iv) How much older would the crew be when they returned?

This effect has caused much bewilderment but it seems to be fully confirmed by atomic experiments. We will have to wait a long time before testing it on humans!

The way that time passes is a great mystery. We can't manipulate it or use it, but simply have to go with it.

Why, for example, can we remember the past but not the future?

Why does time only seem to go in one direction?

Why can't we travel back in time?

!

Time travel is very popular in science fiction stories, but it raises deep logical problems. Suppose that you could travel back into the past, and that you then chose to kill your great-grand parents whilst they were still children.

What would be the consequences of this?!

Many scientists, philosophers and theologians think that time is something that was created as part of the universe, and that God the creator is not in time. Somehow, he is like the author of a novel, who is not in the same time-sequence as the characters he is writing about. This is extremely difficult to imagine! As beings in time, we cannot easily envisage a situation in which time does not exist.