Telephones Telephones Telephones

Science content

Telephone, telephone exchanges, pulse and tone dialling, sound waves, transmitter, receiver, electrical resistance.

Science curriculum links
AT11 Electricity and magnetism
AT12 IT including microelectronics
AT17 The nature of science

Syllabus links
○ GCSE Science, Physics,

Lesson time
1–1½ hours

Links with other SATIS materials
306 Fibre Optics and Telecommunications

NERIS
Search on
TELEPHONES
and UPPER SECONDARY

SUMMARY

The unit covers the invention and development of the telephone up to the electronic tone dialling instruments of today.

STUDENT ACTIVITIES

☐ **Part A** Reading and answering questions about the development of the telephone and its human benefits, group discussion and investigation activities, role-play situations.

☐ **Part B** The physics of the telephone.

☐ **Part C** Information and calculations: how many telephones you can have on a line.

AIMS

☐ To complement work on information transmission systems and on electrical resistance

☐ To illustrate the development of the telephone and the human benefits of new technologies

☐ To provide students with an understanding of the science involved in the telephone system

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Teaching notes

Telephones like the 'Venue 24E' incorporate a microprocessor chip to allow a versatile display and memory access. It was hoped that all such telephone instruments could be operated by line current provided by the exchange but BT's policy of restricting the drain to μA's prevented all but the simplest of modern 'phones working without a battery.

Electronic sounders are transducers and it may be appropriate to point this out to the students.

Answers to the questions

Q1 *Diagram.*

Q2 *The government gave him the sole right to make, use or sell his invention for a limited period. Bell's patent application prevented Elisha Gray developing his telephone.*

Q3 *A 10 digit number would take 10 s to dial, ignoring the dial return time.*

Q4 *With MFD the dual tones are to prevent anybody whistling tones down a telephone.*

Q5 *Exchange connection – in the case of electromechanical exchanges, the slow movement of the mechanism.*

Q6 *1876 patent granted; 1877 first commercial telephone; 1878 first telephone exchange; 1906 Strowger dialling system and automatic exchange (gradually introduced into Britain) necessitating the use of dial telephones; 1974 push-button telephone introduced to Britain; late 1980s tone-dialling telephones.*

A1 *The order of importance might be – push-button dialling; 10 memories (some 'phones have 24); last call redial; tone dialling; etc.*

(b) the elderly may prefer – push-button dialling (keys are easier to work); 10 memories (to program numbers for relatives, doctor etc.); call timer; etc.

A2 *(a) A modem is a device for connecting two computers over the telephone line. It has a MOdulator for converting binary voltage signals into analogue audio signals and a DEModulator for decoding them again. Schools use a modem to communicate with data bases such as NERIS and PRESTEL. Shop tills, bank computers etc. also communicate with each other over telephone lines.*

(b) Fax (facsimile) machines are widely used for transmission of the images of documents by telephone line. A fax machine combines the functions of electronic scanner, modem and printer.

A3 *Answers may include suggestions such as:*

(a) memory telephone, tactile telephone adaptor;

(b) extra loud telephone bell, flashing bright light;

(c) public payphones are equipped with an inductive coupler which produces a magnetic field that can be picked up by the hearing aid,

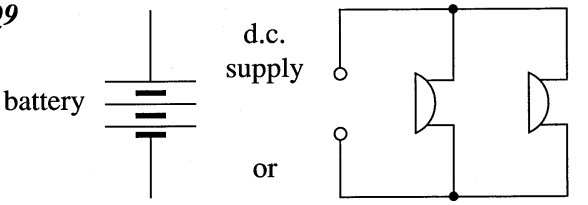
(d) cordless phones.

For more details see the BT guide to equipment and services for the disabled.

Q7 *(a) Similarities – work by varying the current from a d.c. supply; sound waves act on a diaphragm; receiver is based on an electromagnet. Differences – the transmitters; the receiver causes the vibration of a metal reed instead of a diaphragm in modern telephones.*

Q8 $V = I R = (0.01\ A) \times (4000\ \Omega) = 40\ V$

Q9



Q10 *(a) 4, (b) 1.*

Q11 *(a) Telephone (4000 Ω) + line (1000 Ω) = 5000 Ω.*

(b) $V = I R = (0.01\ A) \times (5000\ \Omega) = 50\ V$.

It is different because energy is dissipated in the line from the exchange.

Further information

- British Telecom: 'Electricity and Telecommunications'
- British Telecom: 'Guide to equipment and services for disabled customers' is available from BT shops.
- The Science Museum, London.
- *National Geographic Magazine*, 'Alexander Graham Bell', September 1988.

Acknowledgements

Figure 1 is reproduced from material held by the United States Library of Congress.

Telephones Telephones Telephones

Part A Talking about the telephone

'Mr Watson, come here, I want to see you', were the first words ever transmitted by telephone.

The speaker, Alexander Graham Bell was a Scottish-born doctor who had emigrated to the USA. The device he invented gave rise to the first commercial telephones.

It was on the 14th February 1876 that the US Patent Office received two similar descriptions of a 'talking telegraph'. The first was from Bell and the second, only hours later, was from Elisha Gray, a professional inventor. Gray did not contest Bell's invention, believing that the telephone was not worth serious attention. Bell, however, wrote to his father, 'I am sure of fame, fortune and success'.

Part A Talking about the telephone – its development, features available on electronic telephones.

Part B The physics of the telephone.

Part C How the telephone transmits speech, how many telephones you can have on a line, simple calculations.

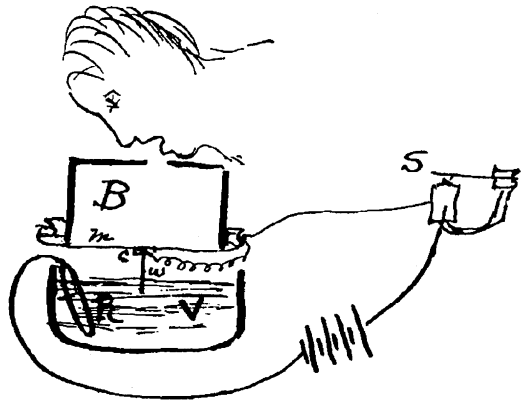


Figure 1

This sketch was produced by Bell, on 9th March 1876. The telephone worked by varying the resistance to a current from a battery.

A voice spoke into the box (B) and would make the diaphragm (m) vibrate. This caused a wedge-shaped needle (w) to move in and out of a bath of liquid (V), changing the resistance of the circuit.

The receiver consisted of an electromagnet (s) which caused a metal reed to vibrate.

Q1 *Redraw and label Bell's sketch and see if you are a better artist than one of the world's great inventors.*

Q2 *Suggest what benefits Bell may have had from patenting his telephone.*

In fact, Bell's telephone gave very poor sound. The quality was improved using Edison's carbon-granule microphone for the transmitter and keeping Bell's design of receiver.

Commercial telephones appeared in 1877 and soon became popular in the USA. At first they were connected in pairs, rather like the tin-can telephones you may once have made. You could talk to one person at the other end of the line and that was all.

1900 The world's first automatic telephone exchange in New Bedford, MA, USA.

1909 Europe's first automatic exchange, operating on Strowger's dialling system.

1912 London's first automatic telephone exchange with 480 lines.

1960 An experimental electronic telephone exchange is built by the Bell Telephone Co in the USA.

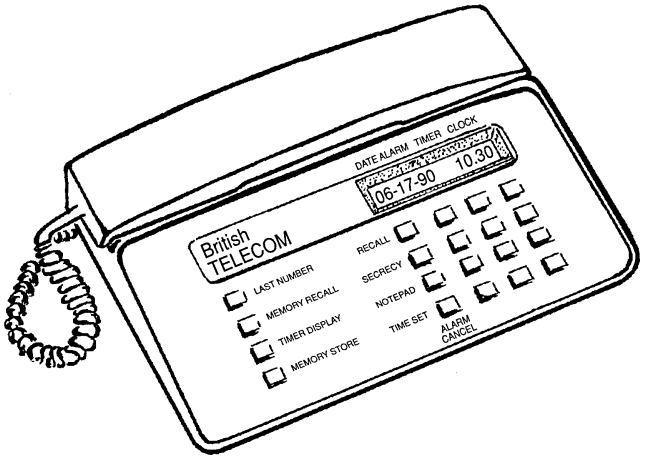
1990s Old exchanges in Britain are being replaced by digital ones.

The first telephone exchange was opened one year later with 21 subscribers. Early telephones did not have dials or push buttons, the caller simply asked the operator to connect the call.

Then in 1906 an American undertaker called Almon Brown Strowger discovered that telephone calls were being switched to his rival's business. He was so furious he invented an automatic switching system. A dial on the telephone sent pulses down the line to work electromechanical switchgear in the exchanges.

From the 1930s to 1970s the telephone remained relatively unchanged. Strowger electromechanical exchanges were installed in Britain and used until electronic exchanges began to replace them in the late 1970s.

When electronics and chips became part of telecommunications changes started to happen. In business speed of communication is important: time costs money. Electronic telephones are able to offer extra features and electronic exchanges have no moving parts. They connect calls faster than the older electromechanical switch gear, which was slow and not always reliable.



- Attractive design
- Push-button dialling
- Call timer
- 10 memories
- High quality microphone
- 16 digit display
- alarm clock
- Last call redial
- Secrecy button (switches off the microphone)
- Ringer volume control
- Dual signalling (may be set to pulse or tone dialling)

Figure 2 An electronic telephone with a microprocessor

Push-button telephones were introduced to Britain in 1974, designed to be used with the electronic exchanges of the future.

Today, newer telephones use tone dialling. When used with digital exchanges they offer the customer greater speed, reliability and access to more services. However, electronic telephones have two disadvantages – electrical storms may damage their chips and those with large memories or timers need batteries. The problem is that when the batteries run down the memory is lost.

From the outside, the telephone seems little changed, although most have a key pad instead of a dial. Although today's telephones are available in many styles and colours, the real advantages lie hidden inside.

Dialling

How does the telephone signal to the exchange what number you are dialling? There are two different methods in use at the moment.

Pulse dialling

A dial telephone uses pulse dialling. As you dial a number, the line is quickly disconnected and reconnected over and over again. This produces a series of pulses. The number of disconnection pulses represents the number being dialled. A number 9 would be 9 pulses and this would take a second to dial.

Q3 *Dialling a long distance call in Britain needs 10 digits. (For example, the STD code for Worksop is 0909 followed by a six digit local number.) How long would it take to dial 0909 - 900909 with a dial telephone? You may assume that a '9' or a '0' take about a second each to dial.*

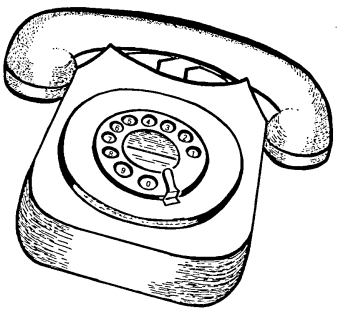


Figure 3 A telephone with dial

Tone dialling

Tone dialling works with digital exchanges. When you press a number on the key pad, the telephone sounds a musical note or tone. The notes are different for each number and are made up of two tones sounded together. The exchange equipment recognises the tones as soon as they sound – faster than you can press the push-buttons. (Some telephone instruction books refer to tone dialling as *Multi-Frequency Dialling*, or *MFD* for short.)

Q4 *Would it be possible for someone whistling down the telephone to tone dial a number on a digital exchange?*

Figure 4 A telephone with keypad

New push-button telephones can be set to pulse or tone dial. Although digital exchanges can recognise pulse or tone signals, tone dialling produces much quicker call connections.

Q5 *What causes the delay between the time you dial a call and the time the number rings at the other end?*

Q6 *Produce a time chart showing the development of the telephone.*

Organising the discussion

- Work in a small group.
- Appoint someone to chair the group who will report back to the class if needed.

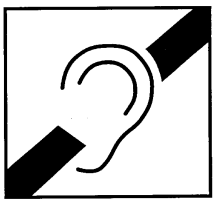


Figure 5 Inductive coupler symbol

Activities for group discussion and investigation

A1 *Arrange the list of features of a typical electronic telephone in order of importance*
(a) to a teenager, (b) to an elderly person living alone.

A2 *Find out what the following are used for*
(a) a modem, (b) a fax machine.

A3 *Disabled people may have difficulty in using a normal telephone. Find out what is available to help*
(a) blind people to dial telephone numbers
(b) partially deaf people to know when the telephone is ringing
(c) hearing aid users to use public payphones
(d) people who have difficulty moving around the house or use a wheelchair.

Role-play situations

Consider these situations. Jot down some ideas about how you could act out the scene.

Scene one

The year is 1876 in the USA.
A: You are Alexander Graham Bell, age 29. You are about to test your invention. You send your assistant into the next room to listen at the other end.
B: You are Mr Watson, age 22 and assistant to Mr Bell.

Scene two

The year is 1875 in the home of Mr and Mrs Hubbard in the USA.
A: You are Alexander Graham Bell. You believe you are going to make a fortune from your invention of the telephone.
You are interested in deafness and you tutor deaf students. You have fallen in love with one of them, Mabel Hubbard.
B: You are Mabel Hubbard, age 17. You are deaf and in love with Bell. Your parents say you are too young to marry.
C: You are Mr Gardiner Hubbard, Mabel's father. You cannot see how Mr Bell can support your daughter on money from inventions. Your daughter is deaf and also too young to marry.

Scene three

A: You are a grandparent. You have an old dial telephone.
B: You are a grandchild. You are giving your grandparent the eletronic telephone in figure 2 for a birthday present. Explain how useful it will be.

Part B – The physics of the telephone

How does the telephone transmit speech?

Nowadays, the mouthpiece (transmitter) and earpiece (receiver) are usually made the same. In design they are similar to a loudspeaker. They contain a strong circular magnet, a plastic diaphragm and tiny coil through which the current flows.

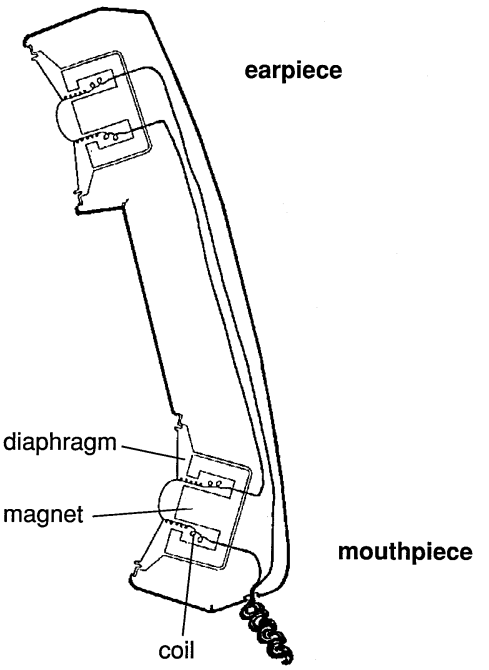


Figure 6 The parts of a modern telephone

The transmitter is a moving-coil microphone. When someone speaks into the mouthpiece, their sound waves hit the plastic diaphragm and make it vibrate. The coil is fixed to the diaphragm and moves to and fro in a magnetic field. The vibrations cause the current through the coil to increase and decrease with the sound.

At the other end, the changing current in the earpiece causes the force on the coil in the magnetic field to vary. The coil moves the diaphragm to and fro sending compressions and rarefactions which make sound to the listener's ear.

> ***Q7*** *Describe the similarities and differences between the modern telephone and Bell's original design (on page 1).*

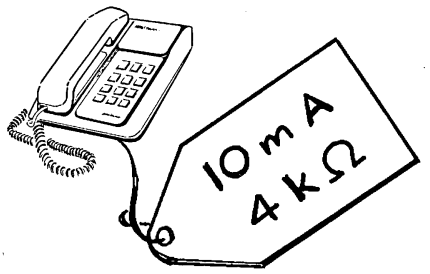


Figure 7 A telephone with an electronic sounder

Figure 8 Circuit symbol for a sounder

Useful formulas

in series

$$R = r_1 + r_2$$

in parallel

$$\frac{1}{R} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} + \frac{1}{r_4}$$

$$\text{resistance} = \frac{\text{p.d.}}{\text{current}}$$

$$R = \frac{V}{I}$$

Answers to the questions are in the *Teachers' Notes*.

Part C – How many telephones can you have?

Modern telephones have **electronic sounders** instead of bells. You can use more telephones with sounders on the line than telephones with bells. Sounders have a high resistance and draw less current from the exchange. For example, a typical electronic telephone has a resistance of 4 kΩ (4000 ohms) and the current required to work it is only 10 milliamps (0.01 A)

The rule for connecting telephone equipment is that its total resistance must always be greater than the resistance of the telephone line. But how do you work this out?

Modern extension telephones have their sounders wired in parallel. The more telephones you connect to the system, the lower the total resistance. If you want to find the total resistance (R) of all the telephones (r_1, r_2, r_3, etc.) on a single line, you will need to use the formula

$$\frac{1}{R} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} + \text{etc.}$$

Some customers could find this a little daunting!

Instead, telephones are given a **REN** number (the **R**inger **E**quivalence **N**umber) and you just add them up. The total you can connect to a single line is 4 REN. Most modern telephones have a REN of 1. Some modems have a REN of 3.

Telephone lines have a resistance of about 1 kΩ (1000 ohms). About one-fifth of the power sent by the exchange to operate the sounder is wasted in the line.

The local telephone exchange has a large battery room of lead-acid cells which can supply about 2000 A at 50 V. They allow the exchange to carry on operating in the event of a power cut for about six hours.

Use the figures given for the telephone in figure 7.

Q8 *Calculate the voltage needed to make it work.*

Q9 *Draw a circuit diagram showing 2 sounders wired in parallel with a d.c. supply.*

Q10 *The total load on a line is 4 REN. If your telephones have a REN of 1 and you have a modem with a REN of 3,*
(a) how many telephones can you connect to a line?
(b) how many telephones can you connect with a modem to a single line?

Q11 *(a) What is the total resistance of telephone and line?*
(b) Work out the exchange voltage needed to ring your telephone. Why is the answer different from that in Q8?