General Certificate of Education
January 2007
Advanced Subsidiary Examination

ASSESSMENT and QUALIFICATIONS ALLIANCE

GENERAL STUDIES (SPECIFICATION A) **GSA2**
Unit 2 Science, Mathematics and Technology

Monday 15 January 2007 9.00 am to 10.15 am

For this paper you must have:
- an objective test answer sheet
- a Data Booklet for Questions 1 to 25 (enclosed)
- a black ball-point pen.

You may use a calculator.

Time allowed: 1 hour 15 minutes

Instructions
- Use a black ball-point pen.
- Answer **all** questions.
- Answer **both** Section 1 (Questions 1 to 25) **and** Section 2 (Questions 26 to 50) using the answer sheet provided.
- For each question there are several alternative responses. When you have selected the response which you think is the best answer to a question, mark this response on your answer sheet.
- Mark all responses as instructed on your answer sheet. If you wish to change your answer to a question, follow the instructions on your answer sheet.
- Do all rough work in this book, **not** on your answer sheet.

Information
- The maximum mark for this paper is 50.
- This paper consists of two sections.
  Section 1 contains 25 objective test questions based on material provided in a separate data booklet.
  Section 2 contains 25 objective test questions testing mathematical reasoning and its application.
- Each question carries 1 mark. You will not lose marks for wrong answers.
- 2 mm graph paper is available from the Invigilator.

SECTION 1

Answer **Questions 1** to **25**.

Each of the 25 questions carries 1 mark.

Read the passage entitled **Uses of Superconductors** which is printed in the separate booklet and answer **Questions 1** to **25** by choosing the answer represented by the letter **A**, **B**, **C** or **D** that you think best.

Refer to paragraph 4 for **Questions 1** to **3**.

1 To produce the largest current you would need

A a large resistance and a large potential difference.
B a large resistance and a small potential difference.
C a small resistance and a large potential difference.
D a small resistance and a small potential difference.

2 When the current doubles, the waste heat produced per second by the same resistance changes by a factor of

A $\frac{1}{4}$

B $\frac{1}{2}$

C 2

D 4

3 What is the resistance of a wire carrying a current of 3 A, if the heat loss per second is 36 W?

A 4 ohms
B 12 ohms
C 108 ohms
D 1296 ohms

4 Measured on the temperature scale of kelvins (K) the boiling point of water is

A 173 K
B 273 K
C 373 K
D 473 K

5 Upon reaching superconductivity the resistance of a pure material (paragraph 6 and **Figure 3**)

A reduces steadily to zero over several degrees.
B reduces suddenly to zero.
C does not quite reduce to zero.
D follows the same decrease as above critical temperature.

6 The early substances found to superconduct (paragraphs 6 and 7) were

A superconducting below 23 K.
B superconducting above 23 K.
C all elements.
D all pure substances.

7 Which of the following gases, on cooling, would liquefy first (**Figure 4**)?

A helium
B hydrogen
C oxygen
D nitrogen

8 Two gases which can be used to make 'conventional' conductors superconduct (**Figure 4** and paragraph 8) are

A air and oxygen.
B air and nitrogen.
C hydrogen and helium.
D hydrogen and carbon dioxide.

9 Which of the following is **not** a ceramic (paragraph 9)?

A brick
B plasticine
C earthenware
D china

10 Current density (paragraph 9) can be defined by the current per unit cross-sectional area of the conductor.
A thin tape conductor with a cross-sectional area of 1 mm by 1 cm carries a current of 10 A.
The current density is

A $0.1\ A\ cm^{-2}$
B $1.0\ A\ cm^{-2}$
C $10\ A\ cm^{-2}$
D $100\ A\ cm^{-2}$

11 The use of superconducting ceramics (paragraph 9) enable a current density much greater than can be obtained in any wire under normal temperatures. It increases the carrying capacity by a factor of

A 100
B 1000
C 10 000
D 1 000 000

12 The propulsion and guidance of the Maglev train comes from the attraction and repulsion of magnetic forces on the train and rails. Which of the following is/are correct?

1 The forces are produced by large currents through superconductors.
2 The forces have the polarity reversed very rapidly by changing the current direction.
3 The forces are produced by permanent magnets sited on the track and the train.
4 The forces are powerful enough to raise the train.

Answer

A if **4** alone is correct.
B if **1** and **2** only are correct.
C if **1**, **2** and **3** only are correct.
D if **1**, **2** and **4** only are correct.

13 The Maglev train has which of the following advantages over conventional trains?

1 There is virtually no energy loss because of friction.
2 The train does not need a special track.
3 The train produces very little noise as it travels.
4 There are no exhaust emissions to cause pollution.

Answer

A if **1** and **2** only are correct.
B if **1**, **2** and **3** only are correct.
C if **1**, **3** and **4** only are correct.
D if all are correct.

14 The temperature of the superconducting coil in an MRI scanner (paragraph 13 and **Figure 4**) is about

A 4 K
B 5 K
C 4 °C
D 5 °C

15 In Magnetic Resonance Imaging (MRI) the radiation which makes the hydrogen atoms resonate (paragraph 14) is

A gamma rays.
B microwaves.
C radio waves.
D ultrasound.

16 Which of the following statements are true about Magnetic Resonance Imaging (paragraphs 13 and 14)?

1 Different sizes of magnetic fields in different directions are used to identify points in space.
2 Helium atoms resonate, produce a pulse of electromagnetic radiation and return signals.
3 Signals are analysed and a picture built up of the concentration of hydrogen atoms and their environment.
4 The procedure is safe but care needs to be taken with any metallic objects such as a pacemaker.

Answer

A if **1** and **2** only are correct.
B if **2** and **3** only are correct.
C if **1**, **3** and **4** only are correct.
D if all are correct.

17 To examine areas of activity in the brain when it is performing a calculation (paragraph 15), you would use

A MRI.
B SQUIDs.
C ultrasound.
D X-rays.

18 In which of the following ways is a femtotesla related to a picotesla (paragraph 15)?
It is

A 1000 times stronger.
B 1000 times weaker.
C 100 times weaker.
D 1 000 000 times weaker.

19 Uses are continually being developed for superconductors. A possible future use may be in the transmission of electricity. The main reason that this is being considered a possibility is because

A high temperatures can be used.
B low winter temperatures will cause less effect on the network.
C more heat will be generated making the transmission more efficient.
D there will be less heat generated and a smaller heat loss.

20 Which of the following are facts rather than opinions?

1 More patients should have access to MRI technology if it is the best available.
2 Existing UK railway track should be replaced to allow the use of Maglev trains for environmental reasons.

Answer

A if neither is a fact.
B if **1** alone is a fact.
C if **2** alone is a fact.
D if both are facts.

21 To examine the brain for a tumour it would be best to use

A ultrasound.
B X-rays.
C beta rays.
D magnetic resonance.

Assertion / Reason questions

For **Questions 22** to **25** you are given an assertion followed by a reason. Consider the assertion and decide whether, on its own, it is a true statement. If it is, consider the reason and decide if it is a true statement. If, and only if, you decide that *both* the assertion and the reason are true, consider whether the reason is a valid or true explanation of the assertion. Choose your answer (**A** to **D**) as follows and indicate your choice on the answer sheet.

	Assertion	**Reason**	**Argument**
A	True	True	Reason is **a correct** explanation of assertion
B	True	True	Reason is **not a correct** explanation of assertion
C	True	False	Not applicable
D	False	–	Not applicable

	ASSERTION		**REASON**
22	Only nitrogen can be used to make conventional conductors into superconductors	because	it boils at a higher temperature than 23 kelvins.
23	Superconductivity has been used in transport since the beginning of the 20^{th} century	because	that is when helium was first liquefied.
24	MRI scans have been mainly used for images of the brain and nervous system	because	heart pacemakers can be upset by the strong magnetic field.
25	The cost of helium for MRI has been justified	because	the image of soft tissue is superior to other methods.

Turn over for SECTION 2

SECTION 2

Answer **Questions 26** to **50**.

Each of the 25 questions carries 1 mark.

For each of **Questions 26** to **50** choose the answer you consider the best of the alternatives offered in **A**, **B**, **C** and **D**. Graph paper is available from the Invigilator.

26 The speed limit on some European roads is 120 kilometres per hour. What is this speed, approximately, in metres per second?

A 33
B 43
C 45
D 60

27 Chairs are to be set out in a hall. The time taken is inversely proportional to the number of people used to set out the chairs. If it takes 4 people 15 minutes, how many people would be needed to complete the task in 10 minutes?

A 3
B 5
C 6
D 8

Questions 28 and 29

The population of New Zealand is 3.57×10^6 and the population of Australia is 1.81×10^7.
The area of New Zealand is 2.71×10^5 km^2 and the area of Australia is 7.30×10^6 km^2.

28 The total population of both countries is

A 2.17×10^7
B 2.17×10^8
C 5.38×10^{13}
D 6.46×10^{13}

29 The average number of people per square kilometre in Australia is approximately

A 0.25
B 0.4
C 2.5
D 4

Questions 30 to 32

Azeem and Brenda both work in a call centre.

During one week a random sample of the calls they have each made is taken. The length of each call is recorded. The results are summarised in the tables below.

Azeem

Length of call, t minutes	Frequency
$0 \le t < 2$	21
$2 \le t < 4$	43
$4 \le t < 6$	27
$6 \le t < 8$	9

Brenda

Length of call, t minutes	Frequency
$0 \le t < 2$	5
$2 \le t < 4$	17
$4 \le t < 6$	30
$6 \le t < 8$	39
$8 \le t < 10$	9

30 From the table, which of the following is the best estimate for the mean length of Azeem's calls that week?

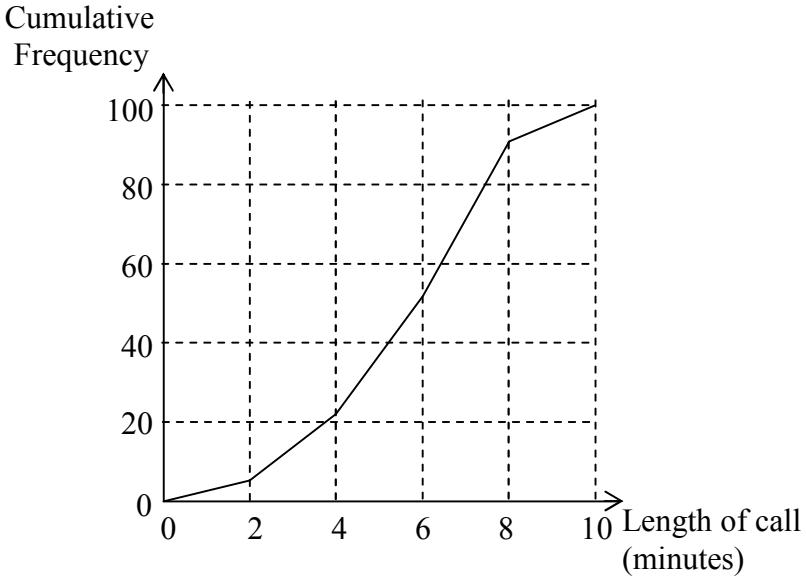
A 2 minutes
B 3 minutes
C 3.5 minutes
D 25 minutes

31 One of Brenda's telephone calls is chosen at random. What is the probability it is 6 or more minutes long?

A 0.39
B 0.40
C 0.48
D 0.78

Turn over for the next question

32 A cumulative frequency graph for Brenda's calls is given below.



From the graph, the interquartile range for Brenda's calls is approximately

A 3 minutes.
B 4.2 minutes.
C 5 minutes.
D 70 minutes.

33 The table below shows the number of road deaths per 100 000 population in the year 2000 for some countries in Europe.

ROAD DEATHS Per 100 000 population, in the year 2000	
Portugal	21.0
Greece	20.1
Luxembourg	17.5
Spain	14.6
Belgium	14.4
France	13.6
Austria	12.0
Italy	11.0
Ireland	11.0
Denmark	9.3
Germany	9.1
Finland	7.7
Netherlands	6.8
Sweden	6.7
United Kingdom	6.0

Which of the following statements can be deduced from the table?

1 Of the countries listed Portugal had the most road deaths in 2000.
2 Austria had twice as many road deaths as the United Kingdom in 2000.

Answer

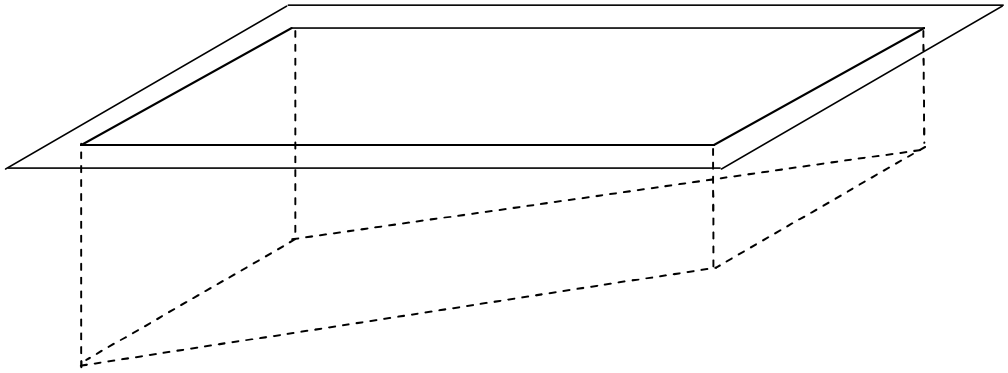
A if both **1** and **2**.
B if **1** but not **2**.
C if **2** but not **1**.
D if neither **1** nor **2**.

34 In checking the results of a school's annual sports day, it was found that the long jump record had increased by 6% every year from 2003 to 2006. If the long jump record was 5.31 m in 2006, the record in 2003 was

A 4.04 m
B 4.35 m
C 4.46 m
D 5.01 m

Questions 35 and 36

The length of the swimming pool shown below is 25 m and the width is 15 m.
The water is 1 m deep at the shallow end and 2 m deep at the deep end.



35 The volume of the pool in m^3 is

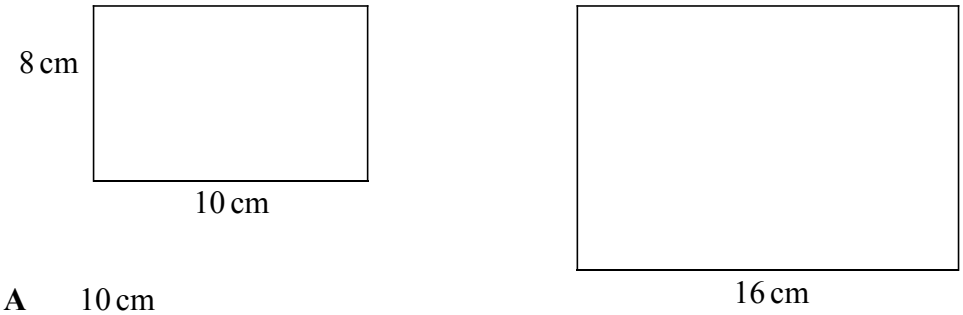
A 562.5
B 5 625
C 56 250
D 562 500

36 The edge of the pool is surrounded by a single row of square tiles. The side of each tile measures half a metre.

The number of tiles used is

A 41
B 80
C 84
D 164

37 Manjit has a photograph of length 10 cm and height 8 cm. It is enlarged, so that the new length is 16 cm. What is the height of the enlarged photograph?



A 10 cm
B 12.8 cm
C 13.2 cm
D 14 cm

Questions 38 and 39

A school sells tickets for the school play. The maximum number of tickets on sale is 200.
The number of adult tickets sold (x) must not be less than the number of child tickets sold (y).

38 Which of these pairs of values satisfy the conditions?

1 $x = 0, y = 200$
2 $x = 50, y = 60$
3 $x = 75, y = 70$
4 $x = 100, y = 100$

Answer

A if **1** and **2** only are correct.
B if **2** and **3** only are correct.
C if **3** and **4** only are correct.
D if **1**, **3** and **4** only are correct.

39 Two inequalities representing the conditions are

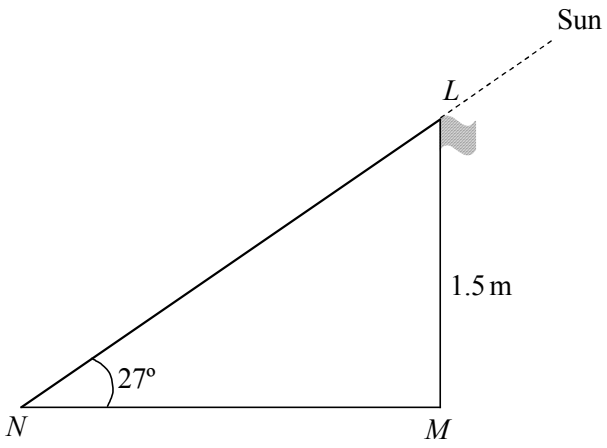
A $x \geq y, x + y \leq 200$
B $x \leq y, x + y \leq 200$
C $x \geq y, x + y \geq 200$
D $x \leq y, x + y \geq 200$

Turn over for the next question

40 If $n - 3$ is an odd integer, which of the following must also be an odd integer?

A n
B $n + 1$
C $2(n - 3)$
D $3n + 2$

41



LM is a flag pole on a playground. The sun's rays strike the ground at an angle of 27º. How long is the shadow, *MN*, of the pole?

A 0.76 m
B 1.68 m
C 2.94 m
D 3.30 m

42 Given that x is positive and less than 1, the expression which has the greatest value is

A x^2
B $x^2 + x$
C x^3
D $x^3 + x^2$

43 Which of the following is/are true for all values of x?

1 $3x + 6 = 3(x + 2)$
2 $3x + 6 = x + 2$
3 $(3x + 6)(x + 2) = 3x^2 + 12x + 12$

Answer

A if **1** alone is true.
B if **1** and **2** only are true.
C if **1** and **3** only are true.
D if **2** and **3** only are true.

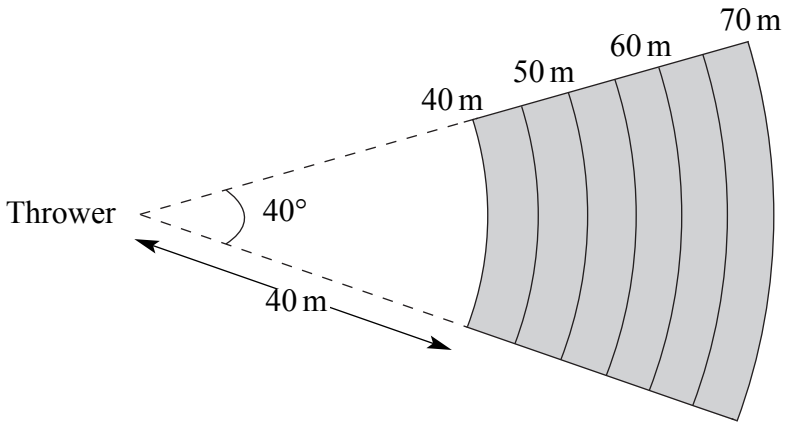
44 Which one of the following is an expression for the n^{th} term of the sequence

1, 7, 17, 31, 49,…?

A $n^3 - 1$
B $2n^2 - 1$
C $(n - 2)^2$
D $4n + 6$

Questions 45 and 46

In athletics the discus has to be thrown so that it lands within a 40° sector from the thrower. For one particular competition arcs are painted on the ground at intervals of 5 m, as shown in the diagram.



45 How much longer is the 60 m arc than the 50 m arc?

A 1.1 m
B 1.6 m
C 3.5 m
D 7.0 m

46 What is the total area shown shaded in the diagram?

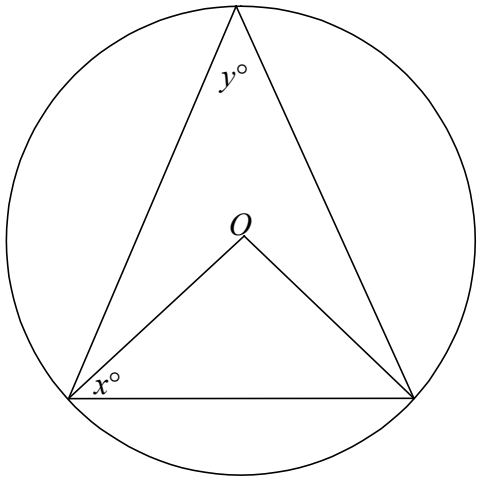
A 310 m^2
B 1 150 m^2
C 2 830 m^2
D 10 400 m^2

Turn over for the next question

47 On a distant planet there are various types of animals, including biks, gaks and hoks. Which of the following statements can be deduced from the statements *All biks are hoks* and *Some gaks are hoks?*

A All hoks are biks.
B If an animal is not a hok, it is not a bik.
C All animals are either biks or gaks.
D A bik cannot be a gak.

48



In the diagram O is the centre of the circle.

If $y = 20$ what is the value of x?

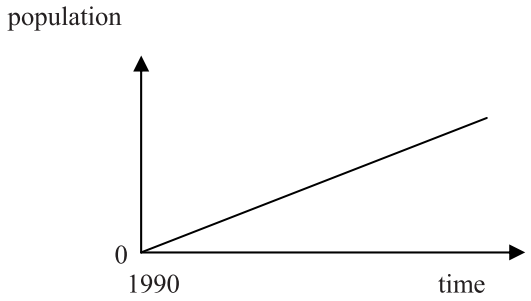
A 40
B 50
C 60
D 70

Questions 49 and 50

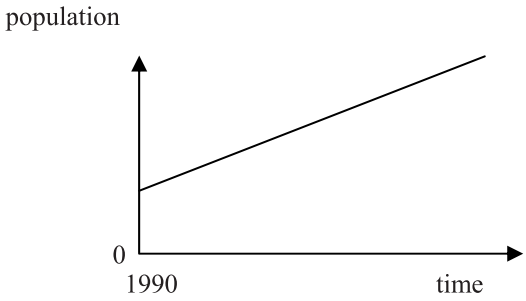
The population of a country since 1990 has increased by 5% each year.

49 The graph that best illustrates this is

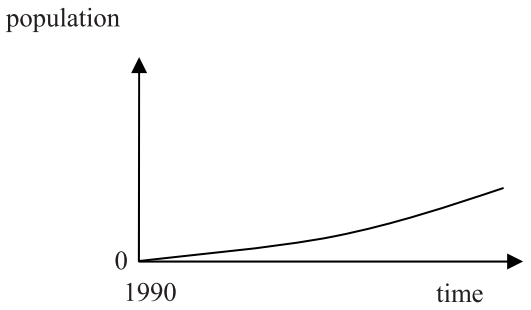
A



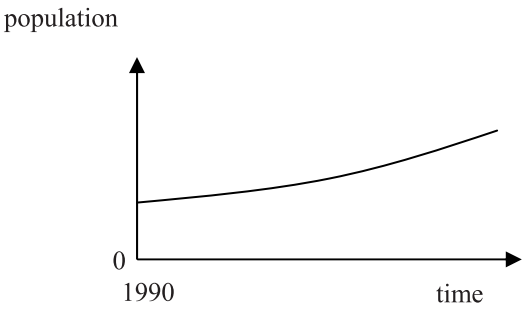
B



C



D



50 A population growth of 5% each year means that

1 the population grows by the same amount each year.
2 the population grows by the same proportion each year.
3 the population grows by an increasing amount each year.
4 the population one year is 105% of the population of the previous year.

Answer

A if **1** alone is true.
B if **1** and **2** only are true.
C if **2** and **3** only are true.
D if **2**, **3** and **4** only are true.

END OF QUESTIONS

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GENERAL STUDIES (SPECIFICATION A) **GSA2**
Unit 2 Science, Mathematics and Technology

ASSESSMENT and QUALIFICATIONS ALLIANCE

Data Booklet

Data Booklet for use with **Section 1 Questions 1** to **25**

PASSAGE AND FIGURES FOR QUESTIONS 1 TO 25

Uses of Superconductors

(1) As our knowledge of science increases, the development of new technologies becomes possible leading to designs and inventions that would previously have been little more than a dream. Who a generation ago would have expected to see a train that can travel faster than conventional land-based transport, produce no emissions and have no contact with the rails, so allowing a quieter and smoother journey? This however has been achieved with the design of the Maglev train.

(2) People have known about magnetism and its effect on metals for thousands of years, but it is only recently that it has been possible to use magnetism to create internal images of the human body, with more detail than those produced by X-rays. Such images are produced by a process known as Magnetic Resonance Imaging.

Figure 1: The transport of the future? A Maglev Train

Figure 2: A Magnetic Resonance Imaging scanner

(3) Both of these technologies depend on the production of very strong magnetic fields, made possible by the use of superconductors (materials that have no resistance to the flow of electricity). Our knowledge of superconductors and the behaviour of electric current within them is still increasing, but they are already being used where large currents are necessary, for example to create very strong electro-magnets.

(4) When an electric current flows in a wire it normally encounters ‘resistance’. This resistance (measured in ohms) determines the size of the current (measured in amps) for a particular potential difference (measured in volts) along the wire. At normal temperatures it has long been established that the resistance (R) is the ratio of the potential difference (V) to the current (I) produced; this relationship is commonly known as Ohm’s law.

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

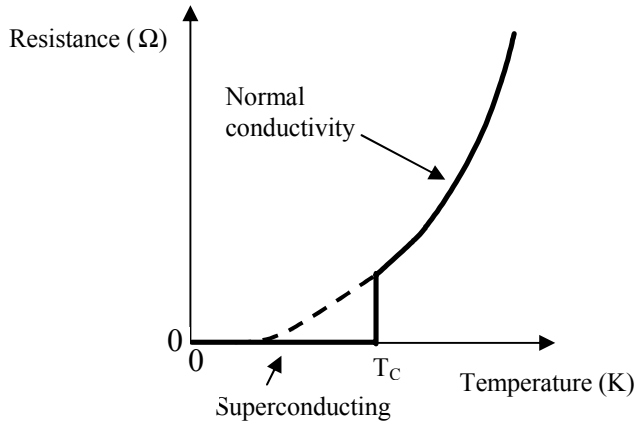
As current flows, energy is dissipated as wasted heat. The relationship between the energy dissipated per second (power, P, measured in watts), the current (I) and the resistance (R) is given by the following equation.

$$P = I^2 R$$

(5) However, in the 19th century, experiments determined that resistance generally decreases when the temperature is decreased significantly. Then, in the early 1900s, helium was liquefied for the first time when it was cooled to 4.2 K *. By using liquid helium it then became possible to conduct many electrical experiments at much lower temperatures than had previously been possible, leading to some surprising results.

(6) The first of these occurred in 1911 when the Dutch physicist Heike Kamerlingh Onnes was carrying out experiments using mercury. When he cooled mercury to the temperature of liquid helium its resistance suddenly disappeared. Subsequent research found that 21 metallic elements and many alloys suddenly lost their resistance **completely** at a particular 'critical' temperature, and so a current could circulate for days without any loss of energy. This property of some materials is what we now know as 'superconductivity'.

Figure 3: Graph illustrating how resistance in a pure metal may fall suddenly at a particular temperature



(7) The highest temperature at which this 'superconducting' state occurred for any of the substances tested in those early days was 23 K. The critical temperature was found to depend on the purity of the specimen. When pure, the resistance dropped suddenly at a particular temperature. The resistance of a less pure sample of the same specimen dropped over a range of temperatures rather than at a particular point.

Figure 4: Table of boiling points of common gases

Gas	Boiling point (K)
air	≈ 83
carbon dioxide	195
helium	4.25
hydrogen	20.35
nitrogen	77
oxygen	90

(8) Liquid nitrogen is much cheaper and easier to prepare than liquid helium (just one twentieth of the cost) and is safer to use than liquid hydrogen. Unfortunately nitrogen boils at a higher temperature than 23 K so **cannot** be used to make **conventional** conductors cold enough to superconduct. The expense of liquid helium can only be justified for specialised uses, e.g. Magnetic Resonance Imaging (see paragraph 13).

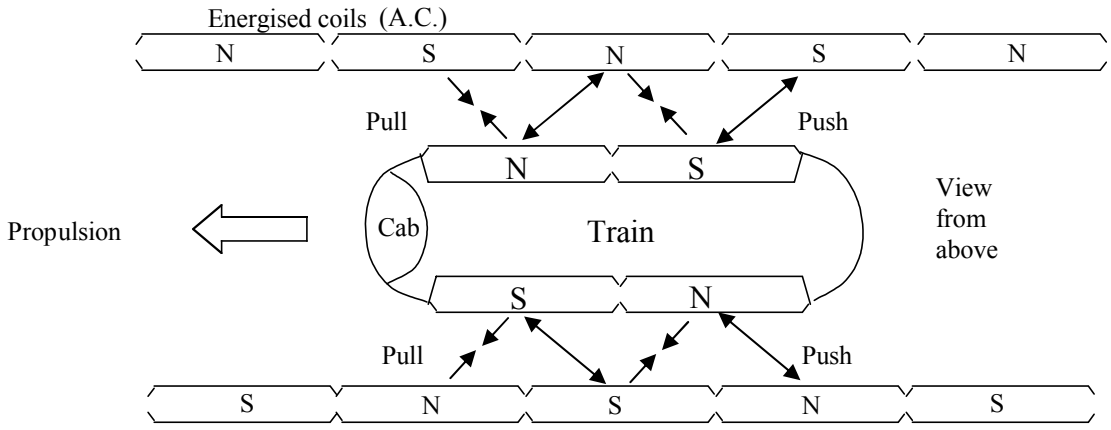
* To convert 4.2 K (kelvins) to °C (degrees Celsius), 273 must be subtracted, giving -268.8 °C.

(9) Since the mid-1980s it has been discovered that various ceramic compounds become superconducting at **much higher** temperatures than metals, even over 100 K. However, ceramics are brittle so a thin film or a fine thread needs to be mounted on to a less brittle substance to avoid breaking. A single thin tape, 1cm wide, may have a current density of 10^6 amps per square centimetre (A cm^{-2}) when superconducting. The maximum for a wire used at normal temperatures would be about 1000 A cm^{-2}. As these new conductors become commercially available more ambitious uses will arise because they are less expensive than metals as they do not require as much cooling.

(10) The possibility of such large currents flowing without producing any heat means that very strong magnetic fields can be created. Two uses of powerful superconducting electromagnets which need very little energy input are the Japanese version of the Maglev train and Magnetic Resonance Imaging (MRI).

(11) 'Maglev' stands for magnetic levitation. Maglev trains travel along a set of rails, but without anything touching the train as it speeds along. This means that most of the energy loss caused by friction with conventional trains does not occur. The train itself has no engine so produces no emissions. The train is both raised above the track and propelled forwards by the interaction of superconducting magnets on the train and coils down the sides of the track.

Figure 5: Diagram showing magnetic forces on a Maglev train, seen from above



(12) Speeds of 310 mph are possible due to a shifting magnetic field in the track. Reversing the electric currents in the coils quickly changes the polarity of the magnets to produce a push or a pull as required for propulsion. Tanks of liquid nitrogen and helium are carried on board together with a refrigeration system to recycle the helium when it becomes warm. Additional levitation and centering coils rely on induced currents which always flow to oppose the change causing them. If the train veers to one side it will be pushed back in line.

(13) Magnetic Resonance Imaging (MRI) is a very different application of the use of superconductors to produce very strong magnetic fields. The technique was originally developed in 1946 to study molecular structure, but in 1973 it was suggested that it could also be useful in medicine. The patient is placed in a very strong magnetic field and an image is produced by observing how hydrogen atoms in the body are affected. The strengths of magnetic fields are measured in units of teslas, although most magnetic fields are considerably smaller than a tesla, for example the Earth's magnetic field is about 50 microteslas (micro = 10^{-6}); the magnetic field required for MRI however is about 2 teslas. This very strong magnetic field is produced by a superconducting coil kept cool in liquid helium. A major expense in diagnoses using MRI is the replacement of helium that has boiled away.

(14) Small differences in the size of the magnetic field applied in different directions through the body means each point in space can be identified. When a pulse of radio-frequency electromagnetic radiation is added the hydrogen atoms resonate and respond by returning signals. From an analysis of these signals a picture is built up of the concentration of hydrogen atoms and their immediate environment. This gives a clear image of the different tissues of the body. The method is particularly good for distinguishing between various soft tissues. A computer sorts the data and produces pictures as slices or as 3D images. Care has to be taken with any metallic object because of the strong magnetic field and heart pacemakers can be upset, but otherwise MRI scans are thought to be risk free. As they are relatively expensive, however, they have only been used extensively for images of the brain and nervous system.

(15) A different use of superconductors in medicine is for the detection of very small magnetic fields. A mechanism called a SQUID (Superconducting Quantum Interference Device) has been developed. This can use the new high-temperature superconductors and detects fields as small as 2 picoteslas (pico = 10^{-12}). With modifications, the ability to detect just 100 femtoteslas (femto = 10^{-15}) has been demonstrated. The SQUID can be used to study the heart and blood circulation. This is called a magnetocardiogram and is an alternative to the well-known electrocardiogram. If SQUIDs are placed around the head in a helmet, the fields and currents generated in the brain can be monitored. This is leading to direct observation of brain activity in different circumstances and comparisons between people sharing the same experience.

(16) As high-temperature superconductors become better established we may see great changes in the transmission system for electricity, in addition to finding many completely new uses for the superconductors.

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