Fill in these boxes and read what is printed below.

Full name of centre

Town

Forename(s)

Surname

Date of birth

Scottish candidate number

Year

Number of seat

Reference may be made to the Physics Data Booklet.

1 All questions should be answered.

2 The questions may be answered in any order but all answers must be written clearly and legibly in this book.

3 Write your answer where indicated by the question or in the space provided after the question.

4 If you change your mind about your answer you may cross it out and rewrite it in the space provided at the end of the answer book.

5 Before leaving the examination room you must give this book to the invigilator. If you do not, you may lose all the marks for this paper.

6 Any necessary data will be found in the data sheet on page two.

7 Care should be taken to give an appropriate number of significant figures in the final answers to questions.
### DATA SHEET

#### Speed of light in materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Speed in m/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air</td>
<td>$3 \times 10^8$</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>$3 \times 10^8$</td>
</tr>
<tr>
<td>Diamond</td>
<td>$1.2 \times 10^8$</td>
</tr>
<tr>
<td>Glass</td>
<td>$2 \times 10^8$</td>
</tr>
<tr>
<td>Glycerol</td>
<td>$2.1 \times 10^8$</td>
</tr>
<tr>
<td>Water</td>
<td>$2.3 \times 10^8$</td>
</tr>
</tbody>
</table>

#### Speed of sound in materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Speed in m/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium</td>
<td>5200</td>
</tr>
<tr>
<td>Air</td>
<td>340</td>
</tr>
<tr>
<td>Bone</td>
<td>4100</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>270</td>
</tr>
<tr>
<td>Glycerol</td>
<td>1900</td>
</tr>
<tr>
<td>Muscle</td>
<td>1600</td>
</tr>
<tr>
<td>Steel</td>
<td>5200</td>
</tr>
<tr>
<td>Tissue</td>
<td>1500</td>
</tr>
<tr>
<td>Water</td>
<td>1500</td>
</tr>
</tbody>
</table>

#### Gravitational field strengths

<table>
<thead>
<tr>
<th></th>
<th>Gravitational field strength on the surface in N/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earth</td>
<td>10</td>
</tr>
<tr>
<td>Jupiter</td>
<td>26</td>
</tr>
<tr>
<td>Mars</td>
<td>4</td>
</tr>
<tr>
<td>Mercury</td>
<td>4</td>
</tr>
<tr>
<td>Moon</td>
<td>1.6</td>
</tr>
<tr>
<td>Neptune</td>
<td>12</td>
</tr>
<tr>
<td>Saturn</td>
<td>11</td>
</tr>
<tr>
<td>Sun</td>
<td>270</td>
</tr>
<tr>
<td>Venus</td>
<td>9</td>
</tr>
</tbody>
</table>

#### Specific heat capacity of materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Specific heat capacity in J/kg °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohol</td>
<td>2350</td>
</tr>
<tr>
<td>Aluminium</td>
<td>902</td>
</tr>
<tr>
<td>Copper</td>
<td>386</td>
</tr>
<tr>
<td>Diamond</td>
<td>530</td>
</tr>
<tr>
<td>Glass</td>
<td>500</td>
</tr>
<tr>
<td>Glycerol</td>
<td>2400</td>
</tr>
<tr>
<td>Ice</td>
<td>2100</td>
</tr>
<tr>
<td>Lead</td>
<td>128</td>
</tr>
<tr>
<td>Water</td>
<td>4180</td>
</tr>
</tbody>
</table>

#### Specific latent heat of fusion of materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Specific latent heat of fusion in J/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohol</td>
<td>$0.99 \times 10^5$</td>
</tr>
<tr>
<td>Aluminium</td>
<td>$3.95 \times 10^5$</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>$1.80 \times 10^5$</td>
</tr>
<tr>
<td>Copper</td>
<td>$2.05 \times 10^5$</td>
</tr>
<tr>
<td>Glycerol</td>
<td>$1.81 \times 10^5$</td>
</tr>
<tr>
<td>Lead</td>
<td>$0.25 \times 10^5$</td>
</tr>
<tr>
<td>Water</td>
<td>$3.34 \times 10^5$</td>
</tr>
</tbody>
</table>

#### Melting and boiling points of materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Melting point in °C</th>
<th>Boiling point in °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohol</td>
<td>−98</td>
<td>65</td>
</tr>
<tr>
<td>Aluminium</td>
<td>660</td>
<td>2470</td>
</tr>
<tr>
<td>Copper</td>
<td>1077</td>
<td>2567</td>
</tr>
<tr>
<td>Glycerol</td>
<td>18</td>
<td>290</td>
</tr>
<tr>
<td>Lead</td>
<td>328</td>
<td>1737</td>
</tr>
<tr>
<td>Turpentine</td>
<td>−10</td>
<td>156</td>
</tr>
</tbody>
</table>

#### Specific latent heat of vaporisation of materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Specific latent heat of vaporisation in J/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohol</td>
<td>$11.2 \times 10^5$</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>$3.77 \times 10^5$</td>
</tr>
<tr>
<td>Glycerol</td>
<td>$8.30 \times 10^5$</td>
</tr>
<tr>
<td>Turpentine</td>
<td>$2.90 \times 10^5$</td>
</tr>
<tr>
<td>Water</td>
<td>$22.6 \times 10^5$</td>
</tr>
</tbody>
</table>

#### SI Prefixes and Multiplication Factors

<table>
<thead>
<tr>
<th>Prefix</th>
<th>Symbol</th>
<th>Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>giga</td>
<td>G</td>
<td>$1000000000 = 10^9$</td>
</tr>
<tr>
<td>mega</td>
<td>M</td>
<td>$1000000 = 10^6$</td>
</tr>
<tr>
<td>kilo</td>
<td>k</td>
<td>$1000 = 10^3$</td>
</tr>
<tr>
<td>milli</td>
<td>m</td>
<td>$0.001 = 10^{-3}$</td>
</tr>
<tr>
<td>micro</td>
<td>μ</td>
<td>$0.000001 = 10^{-6}$</td>
</tr>
<tr>
<td>nano</td>
<td>n</td>
<td>$0.000000001 = 10^{-9}$</td>
</tr>
</tbody>
</table>
1. A computer is connected to the Internet by means of a copper wire and a glass optical fibre as shown.

(a) In the table below, enter:

(i) the speed of the signal in each material;
(ii) the type of signal in each material.

<table>
<thead>
<tr>
<th>Copper wire</th>
<th>Glass optical fibre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed of signal</td>
<td></td>
</tr>
<tr>
<td>Type of signal</td>
<td></td>
</tr>
</tbody>
</table>

(b) Complete the diagram to show how the signal travels along the optical fibre.

(c) Copper wire or glass optical fibre can be used in telecommunication systems.

(i) Explain which material, copper or glass, would need less repeater amplifiers over a long distance.

(ii) A broadband communication system carries 100 television channels and 200 phone channels.

Explain which material, copper or glass, should be used in this system.
2. A ship has a satellite navigation system. A receiver on the ship picks up signals from three global positioning satellites.

These satellites can transmit radio signals at three different frequencies, 1176 MHz, 1228 MHz and 1575 MHz. The satellites orbit at a height of 20 200 km above the Earth's surface.

(a) (i) State the speed of the radio signals.

........................................................................................................................................ 1

(ii) One of the satellites is directly above the ship.

Calculate the time taken for the signal from this satellite to reach the ship.

\[ Space \ for \ working \ and \ answer \]

(ii) Calculate the wavelength of the 1228 MHz signal.

\[ Space \ for \ working \ and \ answer \]
2. (continued)

(b) State which of the three signals has the shortest wavelength.

(c) One of the global positioning satellites is shown below.

![Curved reflector and transmitter diagram]

(i) Complete the diagram below to show the effect of the curved reflector on the transmitted signals.

(ii) A satellite in orbit a few hundred kilometres above Earth has a period of one hour. A geostationary satellite orbits 36,000 km above Earth.

Suggest the period of the global positioning satellite.

..................................................................................................................................................

[Turn over
3. Two students are investigating voltage, current and resistance.

(a) The first student builds the circuit shown.

![Circuit Diagram]

The ammeter displays a current of 0.10 A and the voltmeter displays a voltage of 3.0 V.

(i) Calculate the resistance of R when the current is 0.10 A.

**Space for working and answer**

(ii) The student inserts another ammeter at position X.

What is the reading on this ammeter?

.............................................................................................................................

(b) The second student uses the same resistor in the circuit below.

![Circuit Diagram]
3. (b) (continued)

This student obtains the following set of results.

<table>
<thead>
<tr>
<th>Result number</th>
<th>Voltage across $R$ (V)</th>
<th>Current through $R$ (A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.0</td>
<td>0.20</td>
</tr>
<tr>
<td>2</td>
<td>7.5</td>
<td>0.25</td>
</tr>
<tr>
<td>3</td>
<td>9.0</td>
<td>0.30</td>
</tr>
<tr>
<td>4</td>
<td>10.0</td>
<td>0.35</td>
</tr>
<tr>
<td>5</td>
<td>12.0</td>
<td>0.40</td>
</tr>
</tbody>
</table>

(i) Describe how these different values of voltage and current are obtained.

........................................................................................................................................

........................................................................................................................................ 2

........................................................................................................................................

(ii) Explain which result should be retaken.

........................................................................................................................................ 2

........................................................................................................................................

(c) What additional information about resistance does the second student’s experiment give compared to the first student’s experiment?

........................................................................................................................................

........................................................................................................................................

........................................................................................................................................ 1

[Turn over]
4. A circuit breaker as shown below is used in a circuit.

fixed contact moveable contact

terminal

(a) (i) State one advantage of a circuit breaker compared to a fuse.

........................................................................................................................................................................ 1

........................................................................................................................................................................

(ii) The circuit breaker breaks the circuit when the current becomes too high.

fixed contact moveable contact

terminal

Explain how the circuit breaker operates when the current becomes too high.

........................................................................................................................................................................

........................................................................................................................................................................

........................................................................................................................................................................ 2
4. (continued)

(b) A 5 ampere circuit breaker is used in a household lighting circuit which has three 60 W lamps as shown below.

(i) Show that the resistance of one lamp is $882 \, \Omega$.

(ii) Calculate the combined resistance of the three lamps in this circuit.

(iii) Show by calculation whether the circuit breaker will switch off the lamps when all three are lit.
5. A radioactive source is used for medical treatment. The graph shows the activity of this source over a period of time.

\[ \text{activity in kBq} \]

\[ \text{time in days} \]

(a) Use information from the graph to calculate the half-life of this source.

Space for working and answer
5. (continued)

(b) Describe a method that could be used to measure the half-life of this radioactive source, using the apparatus shown. You can ignore background radiation.

\[ \text{clock} \]

\[ \text{detector} \]

\[ \text{stopclock} \]

\[ \text{source} \]

\[ \text{counter} \]

(c) A sample of this source is to be given to a patient at 9.30 am on May 17. When the sample is prepared, its initial activity is 200 kBq. The activity of the sample when given to the patient must be 12.5 kBq.

Calculate at what time and on what date the sample should be prepared.

\[ \text{Space for working and answer} \]
6. The table below gives information about some types of laser.

<table>
<thead>
<tr>
<th>Type of laser</th>
<th>Wavelength (nm)</th>
<th>Output power (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Krypton fluoride</td>
<td>248</td>
<td>1·0</td>
</tr>
<tr>
<td>Argon</td>
<td>488</td>
<td>2·0</td>
</tr>
<tr>
<td>Helium neon</td>
<td>633</td>
<td>0·005</td>
</tr>
<tr>
<td>Rhodamine</td>
<td>570 to 650</td>
<td>50·0</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>10 600</td>
<td>200·0</td>
</tr>
</tbody>
</table>

(a) The visible spectrum has wavelengths ranging from 400 nm to 700 nm.

(i) Name one type of laser from the table that emits visible radiation.

.................................................................................................................................................. 1

(ii) Name one type of laser from the table that emits ultraviolet radiation.

.................................................................................................................................................. 1

(iii) Give one medical use of ultraviolet radiation.

.................................................................................................................................................. 1

(b) A rhodamine laser can be adjusted to emit a range of wavelengths. What difference is observed in the light from this laser beam as the wavelength changes?

.................................................................................................................................................. 1

(c) The beam from the carbon dioxide laser is used to cut steel. A section of steel is cut in 10 minutes. Using information from the table, calculate the energy given out by the laser during this cutting process.

Space for working and answer

.................................................................................................................................................. 2
7. A student designs a lie detector using the following circuit.

Moisture detector:
- high resistance when dry
- low resistance when wet

(a) Name component Q.

(b) Suggest a suitable output device that could be used at P to produce an audible output.

(c) This lie detector is based on the fact that when a person tells a lie, the moisture on their skin increases. Initially, the person holds the moisture detector in dry hands and component R is adjusted until the output device is silent.

(i) What happens to the resistance of the moisture detector when the person holding it tells a lie?

(ii) Explain how the circuit operates as a lie detector.
8. An automatic vending machine accepts 1p, 2p and 5p coins. Four light sensors P, Q, R and S are arranged as shown in the coin slot.

When a coin passes between a lamp and its sensor, the light is blocked. Coins of different diameters block the light from different lamps.

The position of the sensors in relation to the diameters of coins is shown below.

The logic output of the sensors is as follows:

- light blocked – logic output 1
- light not blocked – logic output 0

(a) (i) Name a suitable input device to be used as a sensor.

(ii) Complete the truth table for the outputs of the sensors when each of the coins passes between the lamps and the sensors.
8. (continued)

(b) A washer is a metal disc with a hole in the middle. The machine is able to reject washers, when they are inserted instead of coins. A washer the same diameter as a 1p coin blocks the light from reaching sensors Q and S only.

Part of the circuit used is shown below.

(i) Name gate A.

(ii) Name gate B.

(iii) When a washer is inserted, the logic levels at P, Q, R and S are as shown below.

In the boxes on the diagram above, enter the logic levels at each position T, U, V, W and X.

(iv) When a washer is detected, this circuit activates an output device that pushes the washer to reject it.

Name a suitable device to be used as the output device.
9. A table from the Highway Code giving overall stopping distances for vehicles is shown.

The overall stopping distance is made up of:

the **thinking distance** – the distance travelled while the driver "thinks" about braking. This distance depends on the driver's reaction time.

**plus**

the **braking distance** – the distance travelled while braking.

<table>
<thead>
<tr>
<th>Speed of vehicle (m/s)</th>
<th>Overall stopping distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.9</td>
<td>6 6</td>
</tr>
<tr>
<td>13.4</td>
<td>9 14</td>
</tr>
<tr>
<td>17.8</td>
<td>12 24</td>
</tr>
<tr>
<td>26.7</td>
<td>18 55</td>
</tr>
</tbody>
</table>

(a) (i) How far does a vehicle travelling at 13.4 m/s travel while the driver thinks about braking?

.............................................................................................................................................. 1

(ii) Use information from the table to calculate the reaction time.

*Space for working and answer*
(b) A car travels along a road. The driver sees traffic lights ahead change from green and starts to brake as soon as possible. A graph of the car’s motion, from the moment the driver sees the traffic lights change, is shown.

(i) What is this driver’s reaction time?

(ii) Calculate the overall stopping distance.

Space for working and answer

(iii) Calculate the acceleration of the car from the time the driver applies the brakes.

Space for working and answer
10. A student runs along a diving platform and leaves the platform horizontally with a speed of 2.0 m/s. The student lands in the water 0.3 s later. Air resistance is negligible.

(a) (i) Calculate the horizontal distance travelled by the student before landing in the water.

*Space for working and answer*

(ii) The student has a vertical acceleration of 10 m/s². Calculate the vertical speed as the student enters the water.

*Space for working and answer*

(b) Later the student runs off the end of the same platform with a horizontal speed of 3.0 m/s. How long does the student take to reach the water this time? Explain your answer.

........................................................................................................................................

........................................................................................................................................

........................................................................................................................................

[3220/402] Page eighteen
10. (continued)

(c) The student climbs from the water level to a higher platform. This platform is 5.0 m above the water. The student has a mass of 50 kg.

(i) Calculate the gain in gravitational potential energy of the student.

Space for working and answer

(ii) The student drops from the edge of the platform and lands in the water.

Calculate the vertical speed as the student enters the water.

Space for working and answer

[Turn over]
11. A wind generator on a yacht is used to charge a battery at 12 V.

The graph shows the charging current at different wind speeds.

(a) The wind blows at a speed of 10 m/s.
(i) What is the charging current at this wind speed?
11. (a) (continued)

(ii) Calculate the electrical power produced by the generator at this wind speed.

Space for working and answer

(iii) The wind speed does not change.

Calculate the energy supplied to the battery in 3.5 hours.

Space for working and answer

(b) The yacht has a stand-by petrol powered generator to charge the battery.

Why is the petrol generator necessary, in addition to the wind generator?

............................................................................................................................................
............................................................................................................................................

[Turn over
12. A mains operated air heater contains a fan, driven by a motor, and a heating element. Cold air is drawn into the heater by the fan. The air is heated as it passes the heating element.

The circuit diagram for the air heater is shown.

(a) (i) What is the voltage across the heating element when the heater is operating?

....................................................................................................................................................... 1

(ii) What type of circuit is used for the air heater?

....................................................................................................................................................... 1

(b) The following data relates to the heater when the fan rotates at a particular speed.

- mass of air passing through per second: 0.2 kg
- energy supplied to air per second: 2000 J
- specific heat capacity of air: 1000 J/kg°C

(i) Calculate the increase in air temperature.

Space for working and answer

....................................................................................................................................................... 2
12. *(b) (continued)*

(ii) The motor is adjusted to rotate the fan at a higher speed. This draws a greater mass of air per second through the heater. Explain any difference this causes to the temperature of the hot air.

..............................................................................................................................

..............................................................................................................................

..............................................................................................................................

2

[Turn over]
13. Titan is the largest of Saturn’s moons. The gravitational field strength on Titan is 1.35 N/kg.

(a) (i) What is a moon?

........................................................................................................................................

........................................................................................................................................

1

(ii) What is meant by gravitational field strength?

........................................................................................................................................

........................................................................................................................................

1

(b) Early in 2005, a probe was released from a spacecraft orbiting Titan. The probe, of mass 318 kg, travelled through the atmosphere of Titan.

(i) Calculate the weight of the probe on Titan.

Space for working and answer

........................................................................................................................................

........................................................................................................................................

2

(ii) As the probe descended through the atmosphere, a parachute attached to it opened.

State why the parachute was used.

........................................................................................................................................

........................................................................................................................................

........................................................................................................................................

1
13. (b) (continued)

(iii) The probe carried equipment to analyse the spectral lines of radiation from gases in the atmosphere of Titan. These lines are shown. The spectral lines of a number of elements are also shown.

Spectral lines from gases in Titan's atmosphere

Helium

Hydrogen

Mercury

Nitrogen

Use the spectral lines of the elements to identify which elements are present in the atmosphere of Titan.

.................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................................. 2

[END OF QUESTION PAPER]
YOU MAY USE THE SPACE ON THIS PAGE TO REWRITE ANY ANSWER YOU HAVE DECIDED TO CHANGE IN THE MAIN PART OF THE ANSWER BOOKLET. TAKE CARE TO WRITE IN CAREFULLY THE APPROPRIATE QUESTION NUMBER.