1. Exam Skills

General comments on 2012 HSC examination

- Teachers and candidates should be aware that examiners may ask questions that address the syllabus outcomes in a manner that requires candidates to respond by integrating their knowledge, understanding and skills developed through studying the course and including the prescribed focus areas. It is important to understand that the Preliminary course is assumed knowledge for the HSC course.

- Candidates need to be aware that the marks allocated to the question and the answer space (where this is provided on the examination paper), are guides to the length of the required response. A longer response will not in itself lead to higher marks. Writing in excess of the space allocated may reduce the time available for answering other questions.

- Candidates need to be familiar with the Board’s Glossary of Key Words which contains some terms commonly used in examination questions. However, candidates should also be aware that not all questions will start with or contain one of the key words from the glossary. Questions such as ‘how?’ or ‘why?’ or ‘to what extent?’ may be asked or verbs may be used which are not included in the glossary, such as ‘design’, ‘translate’ or ‘list’.

- Teachers and candidates are reminded that mandatory skills content in Module 9.1 is examinable in both the Core and Option questions and that all objectives and outcomes, including the Prescribed Focus Areas, are integral to the Stage 6 Physics course.
General comments on Part (B) from the Marking Centre

- Better responses indicate that candidates had followed the instructions provided on the examination paper. In these responses candidates:
  (i) set out all working for numerical questions
  (ii) thought carefully about the units to be used and the quantities to be substituted into formulae, did not repeat the question as part of the response, looked at the structure of the whole question and noted that in some questions the parts follow from each other i.e. responses in part (a) lead to the required response in part (b) etc.
  (iii) used appropriate equipment, for example, pencils and a ruler to draw diagrams and graphs. (A clear plastic ruler helps candidates to plot points that are further from the axes and rule straight lines of best fit.)

Calculations

- In questions requiring numerical answers, you should **ALWAYS SHOW YOUR WORKING**. In calculation questions:
  - show the working in a clear and logical fashion
  - round-off answers at the end of the calculation instead of during the parts of the calculation
  - always write the appropriate units, if applicable

- If you have made a calculation mistake, you may still be awarded marks for your working, so it must always be clearly shown.

- Two marks are allocated in a simple calculation question.
  - 1 mark for correct formula and substitution and
  - 1 mark for the correct answer.
Common Mistakes

- Examiners provide reports after each HSC exam that indicates areas of strengths and weaknesses in student responses. From these common mistakes, it is clear that students generally can benefit by:
  - More precise and scientific use of terminology, especially that specified in the syllabus;
  - More precision with graphs and labelling of diagrams;
  - Avoiding answers that are too long or detailed or that use ambiguous terms;
  - Correct interpretation of questions, e.g. Listing instead of describing, or giving a description not an explanation;
  - Answering in specific terms, not generalities;
  - Ensuring all parts of multi-part questions are attempted;
  - Being able to clearly describe procedures, apparatus, etc. for mandatory practical activities as a first-hand experience.
Use of Tables

- HSC Marking Centre recommends the use of tables to answer questions involving **compare, assess, discuss and evaluate**.

- A sample response to a 2006 HSC question is given below. The question was “Assess the impact on society and the environment of the potential applications of superconductors.”

**Sample Response 1**

<table>
<thead>
<tr>
<th>Application of superconductor</th>
<th>Impact on Society</th>
<th>Impact on environment</th>
<th>Assessment</th>
</tr>
</thead>
</table>
| Maglev Trains                 | • Provides faster, more energy-efficient transport  
• More expensive to build - i.e. higher fares | • Less use of fossil fuels to power train, therefore less random emissions  
• Less coal needs to be mined for power stations | • Beneficial to both society and environment – however is costly |
| Transporting electricity     | • More efficient transportation  
• Zero power losses  
• Safer as DC is used  
• No need to have expensive transformers  
• Cheaper to transport  
• Smaller cables means more aesthetic benefits | • Less fossil fuels emitted into atmosphere – therefore, less air pollution  
• Reduced likelihood of acid rain | • Beneficial to society as cheaper and more efficient  
• Transportation takes place, less harm to society in the form of pollution |
| Superconducting generation of power | • More efficient power production  
• No need for AC and transformers  
• Cheaper electricity  
• Cleaner energy | • No fossil fuels used for power generation | • Less environmental impacts, society gets cheaper energy |
Sample Response 2

<table>
<thead>
<tr>
<th>Applications</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maglev Trains</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Society</td>
<td>• Frictionless form of transport allowing super-fast speeds</td>
<td>• The costs of implementation are detrimental</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Maintenance is a problem</td>
</tr>
<tr>
<td>Environment</td>
<td>• Does not use fossil fuels to provide transport</td>
<td>• The superconductors must be kept at a critical temperature which is difficult to maintain and uses a large amount of energy</td>
</tr>
<tr>
<td>Transformers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Society</td>
<td>• Allows for large scale distribution of energy without power loss as there is no resistance in cables</td>
<td>• Replacement of manual labour causing unemployment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Lack of technology to maintain a large distribution grid</td>
</tr>
<tr>
<td>Environment</td>
<td>• Power lines are unaesthetic</td>
<td>• Large amounts of energy used to keep cables at critical temperatures</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Costs and wastage of materials in creating cables for large scale supply</td>
</tr>
</tbody>
</table>
2. Drawing Scientific Graphs

- **What is a graph?**
  - A graph is a visual representation of a relationship between two variables, \( x \) (independent variable) and \( y \) (dependent variable).
  - The graphs make it easy to identify trends in data that we have collected.

- **How to Construct a Line Graph**

<table>
<thead>
<tr>
<th>Step</th>
<th>Action</th>
<th>Detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Identify the variables</td>
<td>Place your independent variable on the x-axis of your graph and the dependent variable on the y-axis.</td>
</tr>
<tr>
<td>2</td>
<td>Determine the variable range</td>
<td>Subtract the lowest data value from the highest data value</td>
</tr>
</tbody>
</table>
| 3    | Determine the scale of the graph | Determine a scale, (The numerical value for each square), that best fits the range of each variable. Use a scale so that your data is graphed as large as possible in the space provided.  
  |       |                               | **The range of each axis may be different.** They should each be large enough to cover the needed range without lots of extra space. They do not need to start at zero but it is recommended as this allows you to extrapolate.  
  |       |                               | **The scale of each axis may be different, but each one must be consistent.** If one box represents one metre at the beginning of the graph, one box always represents one metre |
| 4    | Number and label each axis      | Clearly label the x and y axes including the units of measurement.     |
| 5    | Plot the data points            | Plot each data value on the graph with a cross (x)                     |
| 6    | Draw the graph                  | Identify a trend or a relationship between the independent and dependent variables.  
  |       |                               | Remove any outliers for consideration.  
  |       |                               | Draw a curve or a line that best describes the identified trend. Most graphs of experimental data in Physics are linear and not drawn as "connect-the-dots"  
  |       |                               | If required to extrapolate (extending the graph, along the same slope, above or below measured data), use a dotted line. |
| 7    | Provide a descriptive title     | Your title should clearly tell what the graph is about.               |
Choice of Axis

- The value of the independent variable are plotted on the x-axis (the abscissa), and the values of the dependent variable are plotted on the y-axis (the ordinate), as shown in the figure below.

During an experiment, the independent variable is altered while the dependent variable is measured.

- It is not always clear which variable is the dependent which is the independent. Usually when time is involved it is the independent variable.

Scales

- In order to convey the desired information, the size of the graph should be LARGE, and this usually means making the graph fill as much of the graph paper as possible.
- Draw up the axes as large as possible. Leave enough space at the side and below the graph for the names of the axes.
- Choose a convenient scale that is easily subdivided. The scale must be large enough to cover all values to be plotted.
Labels

- Each axis is labelled with the **name and/or symbols** of the **quantity** plotted and the relevant unit used.
- For example:
  - current (A)
  - force (N)
  - time (s)

- The graph can also be given a **descriptive title** such as ‘graph showing the relationship between the pressure of a gas and its volume at constant temperature’.
Plotting the Points

- Points are plotted with a fine pencil with a cross. In many cases, error bars are required. These are short lines drawn from the plotted points parallel to the axes indicating the absolute error of the measurement.

Line of Best Fit

- When choosing the line or curve of best fit it is practical to use a transparent ruler. Position the ruler until it lies along the ideal line. The line or curve does not have to pass through every point.

- Do not assume that the line should pass through the origin as lines with an x-intercept or y-intercept are common.

A graph showing a relationship between $T^2$ and $L$ for a simple pendulum experiment
3. Magnetic Field (B), [T]

☐ What is a magnetic field?

- A magnetic field is a model used to explain the region of influence within which a magnetic force may exist.
  - Magnetic fields exist around a magnet and around current carrying conductors.
  - The unit of magnetic field is the Tesla, T.

- The flowchart below outlines the magnetic field phenomena.

- There are two methods of describing the magnetic field around a magnet and around current carrying conductors.
  (i) The value of \( \beta \) as an indication of the strength of the field at any particular point within the field. (Example: \( B = 0.1 \text{T} \))
  (ii) Magnetic field lines to illustrate the magnetic field pattern around a magnet or around a current carrying conductor.
Figure 1 shows magnetic field patterns around a bar magnet.

Figure 2 shows magnetic field patterns around two bar magnets with opposite polarities facing each other.
• Figure 3 shows magnetic field patterns around two bar magnets with same polarities facing each other.

![Figure 3](image)

• Figure 4 shows magnetic field patterns around a long straight current carrying conductor.

![Figure 4](image)
Plotting Magnetic Field Lines

Magnetic field lines show you two things:
1. **The direction of force on a North magnetic pole (e.g. compass needle)**, indicated by an arrow on the magnetic field lines.
2. **The strength of the magnetic field**, indicated by the density of the magnetic field line.

*Magnetic field lines* can be plotted using magnetic compasses.
- The north pole of a compass needle will always point in the same direction as the magnetic field at a point. See diagram below.

- The photograph below shows compass needles aligning itself in the same direction as the magnetic field.
The Earth’s magnetic field

- The Earth’s magnetic field is created by currents in its core of molten iron.
- The Earth’s magnetic axis is tilted by 11 degrees from the axis of rotation.

When freely suspended, magnets will align with the Earth's magnetic field.
- The end of the magnet pointing north is called the north-seeking pole or N pole.
- The part of the magnet pointing south is the south-seeking pole or S pole.

Magnetic field lines leave the north pole of a magnet and enter its south pole. The north geomagnetic pole is thus in reality a south (magnetic) pole, and the south geomagnetic pole is a north pole.
4. Long Straight Current Carrying Conductor

- Magnetic Fields around a Long Straight Conductor
  - The magnetic field formed by straight wire are concentric circles around the wire as shown in the figure below.

- If the direction of the current is inversed, the direction of the magnetic field line is also inversed.

- Plan view of the magnetic field of a long straight current carrying conductor is shown below.
Determining the Direction of a Magnetic Field - Right Hand Grip Rule

- The figure below shows the configuration of the magnetic fields around a LONG STRAIGHT current carrying conductor.

- The direction of the magnetic field around a long straight current-carrying wire is determined by the Right Hand Grip Rule.

  “Grasp the wire with the right hand so that the thumb points in the direction of the current. The curled fingers of the right hand point in the direction of the magnetic field.”
Calculating the Magnitude of a Magnetic Field

- The strength of the magnetic field formed by a current carrying conductor depends on:
  - The magnitude of the current. A stronger current will produce a stronger magnetic field around the wire.
  - The distance from the wire. The strength of the field decreases as you move further out.

The magnitude of the field $B$, a distance $d$ from a wire carrying a current $I$, is given by

$$B = \frac{kI}{d}$$

- $k = \frac{\mu_0}{2\pi} = \frac{4\pi \times 10^{-7}}{2\pi} = 2 \times 10^{-7}$ Tm/A is known as magnetic force constant.
- $\mu_0 =$ permeability of the medium in which the magnetic field exists $= 4\pi \times 10^{-7}$ Tm/A for air (or vacuum).

Note to students

As the formula for magnetic field strength around a long straight conductor is not provided in the exam. Questions relating to this formula will be qualitative and not quantitative.
When magnetic fields from two different current carrying conductors interact with each, the resultant magnetic field will change in direction and magnitude.

- If the two magnetic fields are in the same direction, then the resultant magnetic field will increase in magnitude:
  \[ B_{\text{Total}} = B_1 + B_2 \]

- If the two magnetic fields are in the opposite direction, then the resultant magnetic field will decrease in magnitude:
  \[ B_{\text{Total}} = B_1 - B_2 \text{ or } B_2 - B_1 \]

Let’s investigate this by considering the magnetic field interaction by two parallel current carrying conductors placed near each other as shown in the diagram below.

- Indicate the direction of the magnetic field produced by wire A at point P.
- Indicate the direction of the magnetic field produced by wire B at point P.
- Comment on the direction and magnitude of resultant magnetic field due to the interaction between magnetic field produced by wire A and B at point P.\(^1\)

- Can you guess the direction of the resultant magnetic field at point Q?
Concept Check 1.1

(a) Using dots (out of the page) and crosses (into the page), indicate the direction of the magnetic fields around a long straight wire

(i)  

(ii)  

(iii)  

(iv)  

Concept Check 1.2

Two parallel wires carry currents of 4 A and 5 A respectively, as shown below. Point P is midway between the wires.

What is the direction of the magnetic field, at point P, midway between the two wires?
Concept Check 1.3

Two current carrying wires are placed parallel to each other as shown below. Wire A is carrying a current of 3 A and Wire B is carrying a current of 2 A in the same direction. The two wires are separated by a distance of 1 m.

The magnetic field lines around the wires are shown in the figure below.

(i) Determine the magnitude and the direction of the magnetic field produced by wire A at point P. 

2
(ii) Determine the magnitude and the direction of the magnetic field produced by wire B at point P.  

(iii) Hence determine the **resultant** magnetic field strength at point P.  

(iv) Determine a point at which the resultant magnetic field strength would be equal to zero. (Hint: Let this position be x metres from wire A).
Magnetic Fields around Two Long Parallel Conductors

- The figures below show two parallel wires at a distance $d$ apart with the currents $I_1$ and $I_2$ respectively.

**Figure 1**: The current in the two parallel wires is flowing in the same direction. The magnetic field strength between the conductors is **weaker** than the magnetic field strength outside the conductors due to the interaction between the fields produced by the wires.

**Figure 2**: The current in the two parallel wires is flowing in opposite directions. The magnetic field strength between the conductors is **greater** than the magnetic field strength outside the conductors due to the interaction between the fields produced by the wires.

**Note To Students:**
Magnetic field lines do not cross each other!
5. A Circular Loop of Wire

- Magnetic fields Around a Circular Loop of Wire

  - The magnetic field around a circular loop of wire has the configuration as shown in figure below.

Plan view of magnetic fields generated by a circular loop of wire
**Solenoid**

- A solenoid is a coil of wire in the form of a helix. It is composed of a number of ‘turns’ (n or N).

- The magnetic field of a solenoid resembles that of the long bar magnet, and it behaves as if it has a North Pole at one end and a South Pole at the other.

Magnetic properties of a solenoid are outlined below:

- If the turns are close together and the solenoid is long relative to its diameter, then the magnetic field within it is **UNIFORM AND PARALLEL** to its axis except near the ends.
- The direction of the field inside a solenoid is given by the same right hand coil rule. The magnetic field of all the individual coils just add up.
- The magnetic field in the interior of a hollow solenoid of length \( l \), that has \( N \) turns of wire and carries the current \( I \) has the magnitude of

\[
B = \frac{\mu_0 NI}{l}.
\]
Right hand coil rule (RHCR)

- The direction of the B in a coil is given by the Right Hand Coil Rule.

“Grasp the loop so that the curled fingers of the right hand point in the direction of the current. The thumb of the right hand then points in the direction of B.”

To determine the direction of the magnetic field produced by a solenoid:

Step 1: Draw the current flowing in the wire below.

Step 2: Indicate whether the current is flowing into or out of the page at the top and bottom of the solenoid.

Step 3: Use the Right Hand Curl Rule to find the magnetic field in and around the solenoid.
- **Ferromagnetic substances**
  - The magnetic field produced by a current carrying solenoid is affected by the materials inside the coil.
  - Oxygen and aluminium slightly **INCREASE** the strength of the magnetic field (such substances are called paramagnetic).
  - Mercury and bismuth slightly **DECREASE** the strength of the magnetic field (diamagnetic substances).

  - A few substances yield a **LARGE INCREASE** in **MAGNETIC FIELD STRENGTH** when placed in a solenoid (these are called **FERROMAGNETIC** substances).
  - Figure (a) shows a solenoid with an air core. Figure (b) shows a solenoid with a ferromagnetic core.

  ![FIGURE (a): WITHOUT IRON CORE](image1)

  ![FIGURE (b): WITH IRON CORE](image2)

  - Compare the magnetic field strength between a solenoid without an iron core (Figure a) and a solenoid with an iron core (Figure b).\(^ \text{6} \)

  - Substances that increase the strength of a magnetic field by hundreds or thousands of times when inserted inside a solenoid are called **FERROMAGNETIC. IRON** is the most common example.
Concept Check 1.4

A coil is wound on a hollow cylindrical iron pipe. The ends of the wire are connected to a battery, producing magnetic field in and around the coil.

(i) On the diagram, sketch the magnetic field pattern produced by the coil.

(ii) Compare, qualitatively the size and direction of the field at points P and Q.

(iii) What would the effect be of using a cardboard cylinder rather than an iron cylinder? Explain.

Concept Check 1.5 (2011 HSC Q12 Modified)

The diagram represents a DC electric motor.

On the diagram, indicate the polarity of the magnetic pole at X and Y.
6. Magnetic force on a moving charge

☐ Electromagnetic Force

- A moving charged particle in a magnetic field experiences a magnetic force. The magnitude of the magnetic force depends on:
  
  (i) The magnitude of the velocity of the particle \( v \)
  
  (ii) The magnitude of the charge \( q \)
  
  (iii) The magnitude of the external magnetic field \( B \)
  
  (iv) The angle between the velocity and magnetic field \( \theta \)

- The magnitude of the magnetic force is calculated using the formula:

\[
F = qvB \sin \theta
\]

  - When the velocity vector makes an angle \( \theta \) with the magnetic field, the magnetic force acts in a direction perpendicular to both \( v \) and \( B \).

  - The direction of the magnetic force can be determined using Right Hand Palm Rule.

Note To Students

The angle in the formula \( F = qvB \sin \theta \) represents the angle between the velocity vector and the magnetic field vector. If the angle given in an exam question does not represent this angle then you will need to find the appropriate angle before you can apply the equation to solve the problem.
When a charged particle moves in a direction PERPENDICULAR to the magnetic field vector, the magnetic force $F$ on the charge is MAXIMUM and is given by the formula $F = qvB$.

$$F = qvB \sin \theta = qvB \sin 90^\circ = qvB$$

When a charged particle moves in a direction PARALLEL to the magnetic field vector, the magnetic force $F$ on the charge is ZERO.

$$F = qvB \sin \theta = qvB \sin 0^\circ = 0$$
Right Hand Palm Rule

- The direction of the magnetic force is determined by using Right Hand Palm Rule (RHPR)
  - Open your right hand so that the fingers are together and the thumb sticks out.
  - When your thumb is in the direction of v and, your fingers are in the direction of B then your palm faces in the direction of F

- Note that the F, v and B vectors are perpendicular to each other.

- The magnetic force on a NEGATIVE CHARGE is in the OPPOSITE direction to the force on a POSITIVE CHARGE moving in the same direction.

Did you know?
For negatively charged particles such as electrons moving in magnetic field, you can use 'Left Hand Palm Rule.'
Concept Check 6.1

In each case state the direction of the force acting on the moving charge.

(i) 

(ii) 

(iii)
Concept Check 6.2
In each case state the direction of the force acting on the moving charge P and Q

(i)

Q = Negative charge

(ii)

Q = Negative charge

P = Positive charge

P = Positive charge
Concept Check 6.3

(i) A proton moves in a region whose magnetic field strength is 1.0 T with a velocity of $1 \times 10^5$ m s$^{-1}$ at a right angle to the direction of the magnetic field. Determine the magnitude and direction of the magnetic force experienced by the proton. 

(ii) An electron moves in a region whose magnetic flux density is 2.0 T with a velocity of $2 \times 10^3$ m s$^{-1}$ at an angle of 30° to the direction of the magnetic field. Determine the magnitude and direction of the magnetic force experienced by the electron.
The Path of a Charged Particle

- A particle of charge $Q$ moving with a velocity, $v$ at **RIGHT ANGLES** to a uniform magnetic field experiences a force of magnitude: $F = qvB$

- The path of the particle in a uniform magnetic field is **CIRCULAR**. The direction of the force is determined by using the **RHPR**.
  - It shows that the direction of the electromagnetic force is always towards the centre of the circle and is **PERPENDICULAR** to the direction of the velocity.
  - Hence the electromagnetic force provides the particle with the **CENTRIPETAL FORCE** that result in a uniform circular motion.

- Mathematically: $\sum F = ma$
  - The net force acting on the particle is the magnetic force, $F = qvB$.
  - The acceleration of the particle in a uniform circular motion is $a = \frac{v^2}{r}$
  - Therefore, $qvB = \frac{mv^2}{r}$
    $$ qB = \frac{mv}{r} $$
  - Hence, the radius of the path of the charged particle is
    $$ R = \frac{mv}{qB} $$
The properties of a proton and an electron are tabulated below.

<table>
<thead>
<tr>
<th>Proton</th>
<th>Electron</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass (Kg)</td>
<td>$1.673 \times 10^{-27}$</td>
</tr>
<tr>
<td>Charge (C)</td>
<td>$+1.602 \times 10^{-19}$</td>
</tr>
</tbody>
</table>

- Calculate the mass to charge ratio of proton and electron.

- A proton and an electron are moving at the same speed and enter a region of uniform magnetic field. Compare the radius of curvature of path for proton and electron.

  - Since $v$ and $B$ are constant and same for both charged particles:

    $$ R = \left( \frac{v}{B} \right) \left( \frac{m}{q} \right) = k \times \frac{m}{q} $$

  - Mass to charge ratio for a proton is greater than mass to charge ratio for an electron:

    $$ \left( \frac{m}{q} \right)_p = 1837 \left( \frac{m}{q} \right)_e $$

  - Therefore,
Concept Check 6.4 [HSC]

This question refers to the following diagram

A negatively charged particle, P, moves in a circular path in a magnetic field. The magnetic field is directed into the page.

(i) Explain why the path of the particle is circular.  

Note to students:

- What is the condition required for an object to undergo circular motion?
- To answer question involving the key verb 'explain', student must make reference to a relevant law of Physics.

(ii) On the diagram, draw to the same scale the path and direction of motion of a positively-charged particle of the same mass and speed but twice the charge magnitude.
Concept Check 6.5  (2012 HSC Q30)

The diagram shows the paths taken by two moving charged particles when they enter a region of uniform magnetic field

(i) Why do the paths curve in different directions?

(ii) Why are the paths circular?

(iii) How do the properties of a particle affect the radius of curvature of its path in a uniform magnetic field?
Concept Check 6.6 [HSC]

This question refers to the diagram below.

A proton of mass $1.673 \times 10^{-27}$ kg is projected horizontally with a velocity of $1 \times 10^3$ ms\(^{-1}\) into a magnetic field of strength $1.4 \times 10^{-4}$ T which is directed vertically upwards.

(i) On the diagram, indicate the likely path of the proton (direction).\(^{11}\) 1

(ii) Calculate the magnitude of the force on the proton.\(^{12}\) 2

(iii) Calculate the acceleration of the proton.\(^{13}\) 2

(iv) Calculate the radius of the path.\(^{14}\) 2
(v) What electric field strength applied vertically on the page would exactly balance the force due to the magnetic field? State the direction of the electric field.

Note to students:
- What is the net force acting on the particle if the forces are ‘balanced’?
ANSWERS

1. Vertically down. $B_{\text{total}} > B_A$ or $B_B$. $B_{\text{total}} = B_A + B_B$
2. $B = 1.2 \times 10^{-6}$ T into the page
3. $B = 8 \times 10^{-7}$ T out of the page
4. $B = (1.2 \times 10^{-6} T - 8 \times 10^{-7} T)$ into the page $= 4 \times 10^{-7}$ T into the page
5. $B_A = B_B$

\[
\frac{kI_A}{x} = \frac{kI_B}{2 - x}
\]
\[
x = \frac{1}{1 - x}
\]
\[
x = 0.6 \, m
\]

6. The new field is hundreds or thousands of times greater in magnitude.

7. Magnetic field strength at P is greater than at Q. The directions of magnetic fields are opposite at P and Q.

8. When replaced with a cardboard, the magnetic field strength would be significantly lower as cardboard is not a ferromagnetic substance and therefore does NOT increase the strength of the magnetic field.

9. $F = 1.602 \times 10^{-14}$ N up
10. $F = 3.204 \times 10^{-16}$ N perpendicular and out of the page

11. Circular path bending downwards
12. $F = 2.2428 \times 10^{-20}$ N
13. $a = \frac{F_{\text{net}}}{m} = 1.3406 \times 10^6 \, m/s^2$
14. $R = 0.0750 \, m$
15. $Q \mathbf{E} = Q \mathbf{v} \mathbf{B}$

\[
E = vB = 0.14 \, N/C \text{ vertically up.}
\]