Electromagnetism Worksheet Answers:

1.0:

Each electron has a small fraction of a Coulomb of charge, so if we have enough they will have 1 Coulomb in total. If we denote this number n_e, we have:

$$1C = n_e \times 1.6 \times 10^{-19}C$$
$$n_e = 1C / 1.6 \times 10^{-19}C$$
$$n_e = 6.25 \times 10^{18}\ electrons$$

1.1:

Since like charges repel, the spheres will accelerate away from each other. As they get further apart the force between them will decrease, meaning they accelerate less, but still experience some acceleration. The velocity will continually increase as they always experience an acceleration away from each other. In the absence of any other forces there is only the repelling force producing an acceleration and so continual (but not constant) increase in velocity.

1.2:

Since one has a positive charge and the other a negative, we know the force will be attractive. We can calculate the magnitude of the force from Coulomb's Law:

$$F = \frac{kQ_1Q_2}{r^2}$$
$$F = \frac{9 \times 10^9 \times 1.6 \times 10^{-19} \times 2 \times 10^{-6}}{(1 \times 10^6)^2}$$
$$F = \frac{9 \times 1.6 \times 2 \times 10^{-16}}{10^{12}}$$
$$F = 18 \times 1.6 \times 10^{-4}$$
$$F \approx 3mN$$

1.3:

- Work = $q(V_B - V_A)$ = 0.1(80 – 100) = 2 Joules

Note: due to the way it's defined the path the particle takes *doesn't matter* - it's a trick question!

1.4

Step 1: apply the right hand rule

- Remember, *v* is in the direction of *positive charge flow!*
  - x = direction of proton travel, so *v* points in +x direction
  - z = direction of the magnetic field.
- What direction will the magnetic force be in?

- Step 2: apply the correct formula
  - $F = qvB \sin\theta = qvB \times 1 = (1.6 \times 10^{-19})(2 \times 10^5) \times (1)$
  - $F = 3.2 \times 10^{-14}$
- What are the units and the direction?
  - Newtons, to the right relative to the direction of the proton's movement.

1.5:

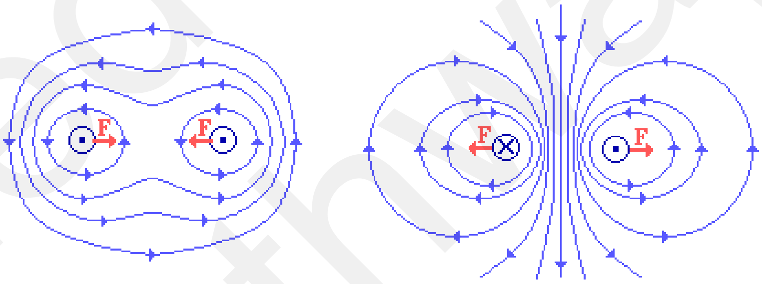
- Step 1: The Right Hand Grip Rule
  - Direction of *I* indicates *positive charge flow*
  - Gives direction of magnetic field, *B*

- Step 2: Apply the formula

$$B = \frac{\mu_0 I}{2\pi r} = \frac{4\pi\times10^{-7}\times10}{2\pi\times1\times10^{-3}} = 2\times10^{-3}\ \text{Tesla}$$

with an anti-clockwise direction facing *into* the current.

1.6
The two wires attract if their currents in the same direction.



Same direction   Opposite direction

1.7:
1. A

Use the right hand rule to determine the direction of the magnetic field. It is straightforward to see that the magnetic field must go into the page. To confirm this, place your thumb in the direction of the current (down the page), your palm in the direction of the force applied (to the right), and your fingers will point in the direction of the required magnetic field (into the page).

Using $F = ILB$, (the $\sin\theta$ term has been omitted, since the magnetic field is completely perpendicular to the current such that $\theta = 90^\circ$ leading to $\sin\theta = 1$

$$2.3 \times 10^6 = 7.5 \times 10^3 \times 3.0 \times B$$

$$2.3 \times 10^6 = 22.5 \times 10^3 \times B$$

$$B = \frac{2.3 \times 10^6}{22.5 \times 10^3}$$

$$B \approx \frac{2.25 \times 10^6}{22.5 \times 10^3} \text{ (low approximation)}$$

$$B \approx 0.1 \times 10^3 = 100 \text{ T}$$

This is a minor underapproximation, so the answer is A, 102 T, into the page.

2) D

The rails are essentially two parallel wires carrying current. Since the current in these wires flow in opposite (antiparallel) directions, there is a repulsive force between them i.e. they are being pushed apart.

This occurs since the current flowing through each wire produces its own magnetic field (right-hand grip rule). As the current flows through the second wire it is travelling through the field created by the first, and thus experiences a force of repulsion (right-hand slap rule).

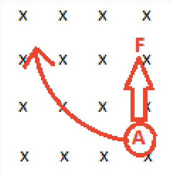
1.8:

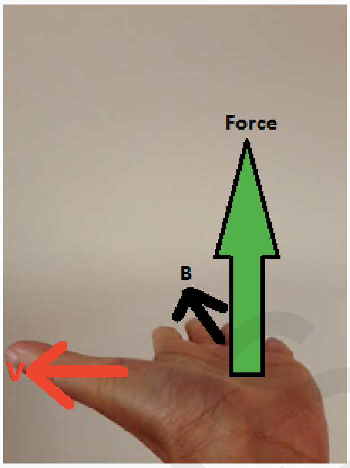
1) B

Particle A is travelling in a circular path in a magnetic field. This means that the magnetic field is exerting a force on particle A. As magnetic fields only exert forces on charged particles, particle A must be a charged particle. (Remember $F_B = Bvq$ where q is the charge on the particle.

To determine whether particle A is positively or negatively charged, use the right-hand and left-hand palm rule.

Note: the force is directed towards the centre of the circular path.





The left-hand palm rule correlates with an upward force exerted on the particle. As the left-hand palm rule is used for negatively charged particles, particle A is a negatively charged particle.

2) D

We can see from the diagram that particle C's path has a greater radius than that of particle A. The radius of the circular path travelled by charged particle in a magnetic field is

$$r = \frac{mv}{Bq}$$

This equation is derived from the fact that the magnetic force on a charged particle acts at right angles to its velocity. Therefore, the force exerted by the magnetic field acts as a centripetal force (a force that causes an object to travel in a circular path) on the charged particle.

$$F_c = \frac{mv^2}{r} \qquad F_B = Bvq$$

$$F_c = F_B$$

$$\frac{mv^2}{r} = Bvq \Rightarrow r = \frac{mv}{Bq}$$

For a given magnetic field strength, the radius of the circular path of the charged particle is determined by its mass, charge and velocity. Since this question does not give us this information about particles A and C, we cannot determine the exact reason why particle C travels in a larger circle than particle A. e.g. Particle A can be heavier and faster than particle C provided it has a much greater charge than particle C.

3) A

$$F_B = Bvq$$

$$F_B = 50 \times 10^{-6} \times 2.5 \times 10^{5} \times 5 \times 10^{-3}$$

$$F_B = 50 \times 2.5 \times 5 \times 10^{-6+5-3}$$

$$F_B = 50 \times 12.5 \times 10^{-4}$$

$$F_B = 625 \times 10^{-4}$$

$$F_B = 6.25 \times 10^{-2} \text{ N}$$

1.9:
1) A
Recall that an electron in a magnetic field is subjected to a force perpendicular to its motion. This causes it to move in a circle.
Apply the right hand rule:
Your thumb (velocity) points upwards in the direction of the movement of positive charge. Because the electron is a negative charge, your thump points opposite to the electron's direction of motion.
Your palm (force) points to the right, since we want to push the electron to the right so that it moves in a clockwise circle.
Your fingers (magnetic field) will be pointing into the page.
Alternatively, you can use your left hand for negative charges, and place your thumb in the direction of the electron's motion, not opposite. This is usually inadvisable as you have to be careful to only use your left hand for negative charges.

2) C
Lets consider the direction first. In Question 1, our electron moved upwards and moved in a clockwise circle. When it enters the bottom half of the cyclotron, the right hand rule (or left hand if you prefer) will show that the magnetic field does not have to change direction. As long as the magnetic field in this case is pointing into the page, the electron will move clockwise. Answers A and D are incorrect. Answers B and C seem like the same thing. Be careful of the wording. But first, the Physics. Each time the electron completes a half circle, it crosses the gap and accelerates. This means the velocity, v, increases. This alone is sufficient to increase the radius of motion, r. It's not necessary increase the magnitude of the magnetic field; in fact, if you increased B too much, you would end up decreasing the radius of motion.

Additonal Notes
Looking at the formula, if the velocity of the electron doubled each time it crossed the gap, but you quadrupled magnetic field, you would end up with a radius that is half the original one. Being able to infer general relationships between different variables in a formula is an excellent skill to have in Physics questions. It can save time and if neccessary, allow you to make educated guesses on questions when time is of the essence.

2.0:

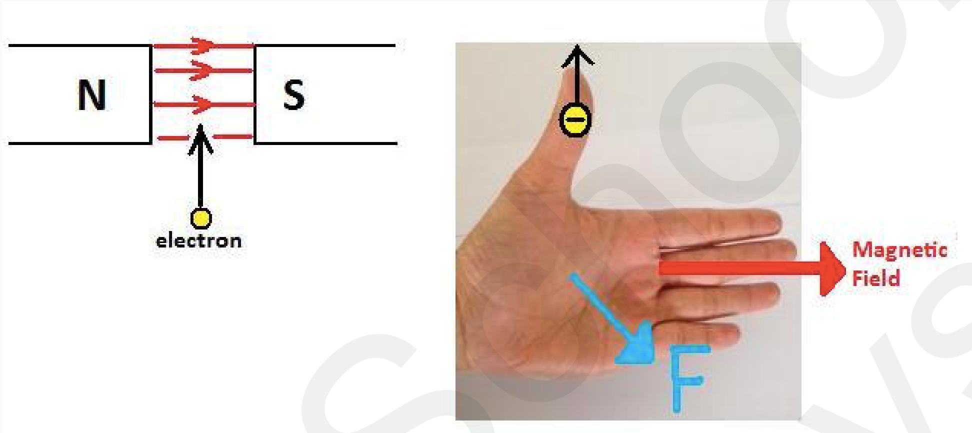
1) D

First, we need to identify that the direction of the magnetic field is always from North to South. So for this scenario, the direction of the magnetic field would be from left to right.

Secondly, we need to identify that an electron is a negatively charged particle.

Now, we can use the left-hand palm rule(meant for negatively charged particles) to find out the direction of force exerted on the electron by the magnetic field. Use your thumb to point to the direction of the electron's velocity, use your fingers to point to the direction of the magnetic field. The direction your palm is facing will be the direction of the magnetic field force on the electron.

In this question, the force acting on the electron is directed out of the page.



Note: the right hand palm rule uses the exact same concept **EXCEPT** that the thumb direction represents the direction of the **positive charge's velocity.** You may also use the right hand palm rule to solve this question by pointing the thumb to the OPPOSITE direction to the velocity of the electron(negatively charged). Use whichever rule that suits you best.

2) A

An alpha particle contains 2 protons and 2 neutrons (it is a helium nucleus) . This gives it an overall net charge of +2. Alpha particles can be expressed as ${}^4_2He^{2+}$ or ${}^4_2\alpha^{2+}$

A positron, ${}^{0}_{+1}e$ is a positively charged electron i.e. they have the exact same properties as electrons except for the positive charge. Giving it a +1 charge.

Since both the alpha particle and positron are positively charged, the direction of the force exerted on them by the magnetic field is the same(into the page).

3) B

The force exerted by a magnetic field on a charged particle is given by the equation: $F_B = Bvq$

B represents the magnetic field strength, ***v*** represents the velocity of the charged particle, and ***q*** represents the charge of the particle.

In this scenario, the magnetic field strength (***B***) and the velocity of the particles (***v***) is the same. The only difference is the charge of the particles. Because this question is just asking for the magnitude of the force we can ignore the type of charge(positive or negative) of the particles and focus on the size of the charge.

Alpha particles have a +2 charge (doubly positive), positrons have a +1 charge, electrons have a -1 charge.

The alpha particle has the greatest magnitude of charge of 2 and the positron and electron have the same magnitude of charge of 1.

Thus the force on the alpha particle will be greater than the force on the electron and positron. The force on the electron and positron is the same.

4) D

Because the magnetic force on a charged particle acts at right angles to its motion, it acts as a centripetal force (that causes an object to travel in a circular path).

$$F_c = \frac{mv^2}{r} \qquad F_B = Bvq$$

$$F_c = F_B$$

$$\frac{mv^2}{r} = Bvq \Rightarrow r = \frac{mv}{Bq}$$

Again, the magnetic field strength (***B***) and velocity (***v***) of the particles are the same. We know that the charge of the alpha particle (+2) is double that of the positron (+1). However, the mass of an alpha particle(2 protons + 2 neutrons) is far greater than that of a positron (has the same mass has an electron). Therefore, the radius of the curvature of the alpha particle is more than two times greater than the curvature of a positron.

2.1:

1) D

This question tests candidates' ability to interpret proportionality in the context of magnetic flux density. Induction is usually a difficult topic, however for this question, only a basic understanding is required.

From the introduction to this question we have the following association:

$$B \propto \frac{1}{R^3}$$

The distance between the target and the coil doubles, therefore:

$$B \propto \frac{1}{2^3} = \frac{1}{8}$$

So the magnetic flux decreases to $\frac{1}{8}$ of its original value. The correct answer is 'D'.

2) C

This question requires a basic understanding of Faraday's law, which states that current is induced in a conductor when the magnetic environment around that conductor changes. For example, a coil will produc a current when being moved closer to, or away from a magnet, but will not produce any current if it stationary to the magnet. In the context of the metal detector, this means that an induced current, and therefore magnetic field, will only be produced when the induction field around the target is changing. An oscillating induction field ensures that object inside the detection zone of the coil will always experience a changing magnetic environment.

If the induction coil did not change, then metal objects would only be detected as they moved towards or away from the detector.

The correct answer is 'C'

'A' is incorrect as the coil is not turning 'off and on', but alternating between polarities. Also, keep in mind that the question relates to electromagnetic induction, not power consumption. This should b a strong clue that this is not the answer you are looking for.

'B' is a nonsense answer.

'D' is an incorrect statement. The induced magnetic field of the target will always oppose the induction field.