17.   Coulomb's Law

The force, F, between two objects with charge q_1 and q_2, is given by:

$$F = -\frac{k\,q_1 q_2}{r^2}$$, where r = distance between the two charges in meters

k = Coulomb's constant = 9×10^9 Nm^2/C^2.

Example 1   Charges of 80×10^{-6} C and 70×10^{-6} C are 0.5 m apart. How much force repels these like-charges?[1]

Example 2   There is a direct relationship between quantity of charge and force of repulsion or attraction. What do we mean by that? Show mathematically and graphically.

Example 3   There is an inverse relationship between charge separation and force of repulsion or attraction. What do we mean by that? Show mathematically and graphically.

Example 4   By what factor would the attractive force between two oppositely charged objects increase if we decreased the distance between them to 1/3 of the original distance?

---

[1] -**201.6 N**   Note that sometimes the formula is shown without the negative sign. The (-) sign produces a positive(attractive) force. For like charges, the formula yields a negative(repulsive) force .

Example 5   The distance between two charges was doubled. And yet the force of attraction still tripled. What happened to one of the charges, if the other remained the same?

Exercises

1.   Charges of 5.0 X10^{-5} C (or 50 X 10^{-6} C = 50μC) and 70 X10^{-6} C are 0.30 m apart. How much force repels these like- charges?[2]

2.   What happens to the force between two charges if the distance separating them triples?

3.   What happens to the force between two charges if the amount of charge triples in each case?

4.   What happens to the force between two charges if one of the charges is replaced by one that is only half as charged and it is also twice as far from the original charge?

5.   If the repulsive force between two objects is to remain the same, and if one object's charge becomes sixteen times bigger, what distance should separate the charges?

6.   If the following is a graph of Coulomb's Law, what do x and y represent from the formula

$$F = -\frac{k\,q_1 q_2}{r^2}$$

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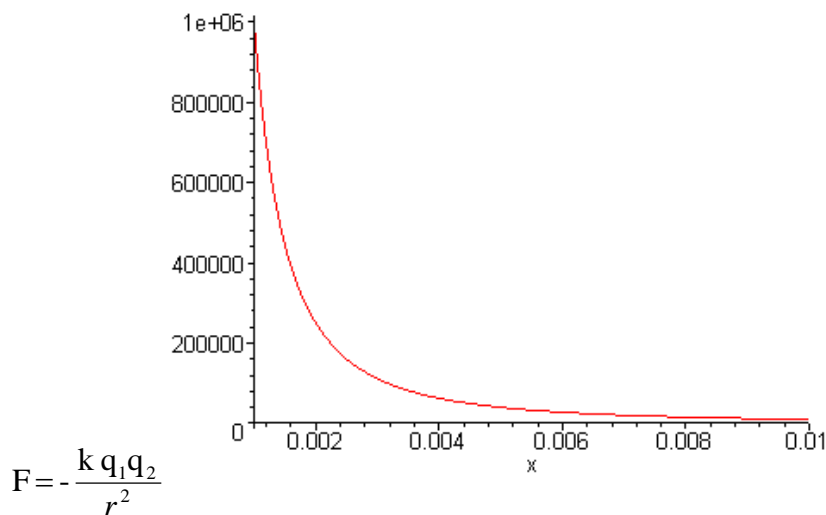
[2] **-350 N (Note: 50 X 10^{-6} or 50 microCoulombs is the same as = 5.0 X 10^{-5})**

18. **Kirchoff's Laws:** **A-** Parallel and Series Circuits

A summary of Simple Circuits:

Variable	Series	Parallel
resistance	$R_T = R_1 + R_2 + \ldots$	$1/R_T = 1/R_1 + 1/R_2 + \ldots$
voltage	$V_T = V_1 + V_2 + \ldots$	constant
current	constant	$I_T = I_1 + I_2 + \ldots$
Ohm's Law	$V_T = I\,R_T$	$V = I_T\,R_T$

Example 1
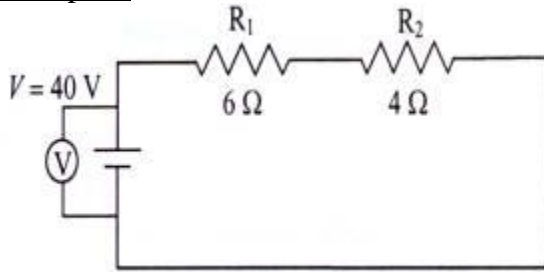
a. What is the total resistance of the circuit?

b. What current would be measured in between the two resistors?

c. What voltage (V_1) would be measured across R_1? Across R_2?

Example 2
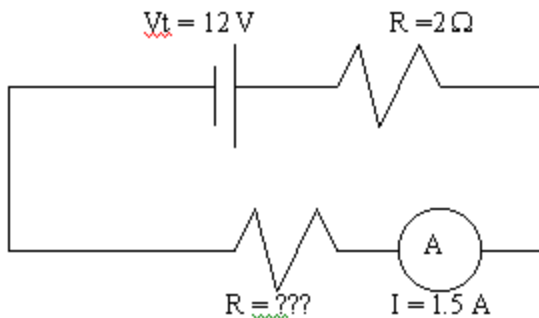
a. Find the missing resistance in the circuit shown, which consists of a 12 V battery hooked to two resistors.

b. If the two resistors represented two light bulbs, and one of the light bulbs was off, would you be able to turn the other bulb on?

Example 3

a. What is the total resistance of the circuit?

b. What is the total current?

c. What voltage (V_1) would be measured across each individual resistor?

d. What current is drawn out by each resistor?

Example 4

The drawing seems confusing, but note that it is a parallel circuit because the electrons have a "choice". At the junction (shown by the red dot) the electrons either follow the green route or the orange route.

Use $I_1 = 1A$; $I_2 = 0.5$ A; $R_1 = 10$ Ω.
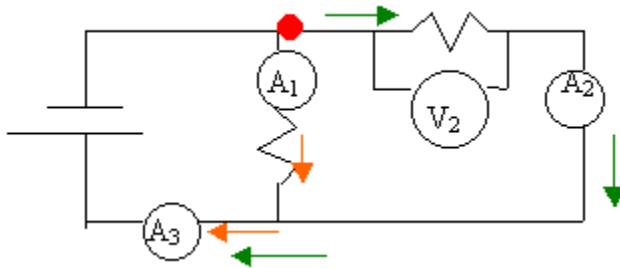
a. Find V_2.

b. Find R_2.

c. Use two methods to arrive at R_T.
d. Find the total resistance and the voltmeter reading at each resistor:

Exercises

Material World: Electricity

1. Find either the missing voltage or missing current

a)

50 Ω   A 0.50 A

40Ω   30 Ω

b)

10 Ω

10 Ω

40 Ω

100
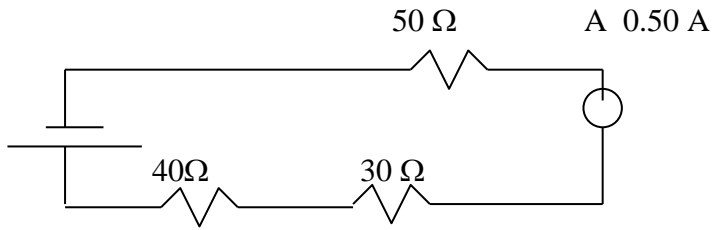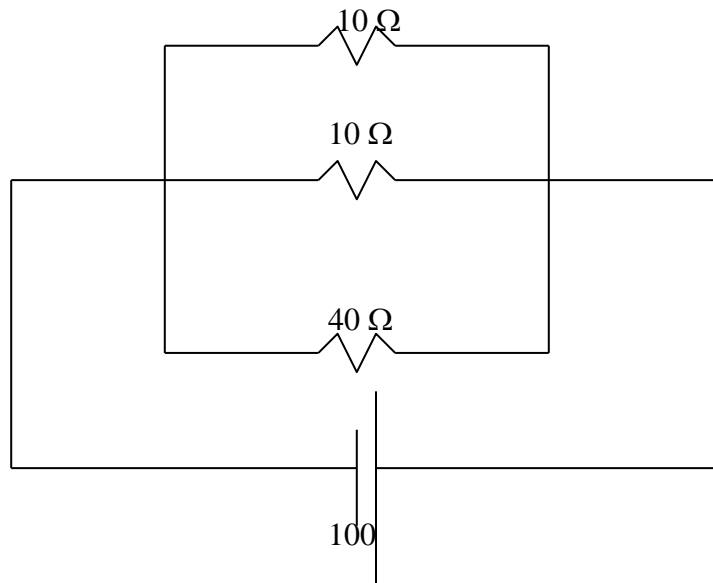
2. Two resistors are connected in parallel. Each draws 2.0 A of current. If the total voltage is 12 V, find R_1 and R_2.

3. Two resistors are connected in series. The total current is 0.500 A. The potential difference at the resistors is 2 V and 5V, respectively. Find R_1 and R_2.
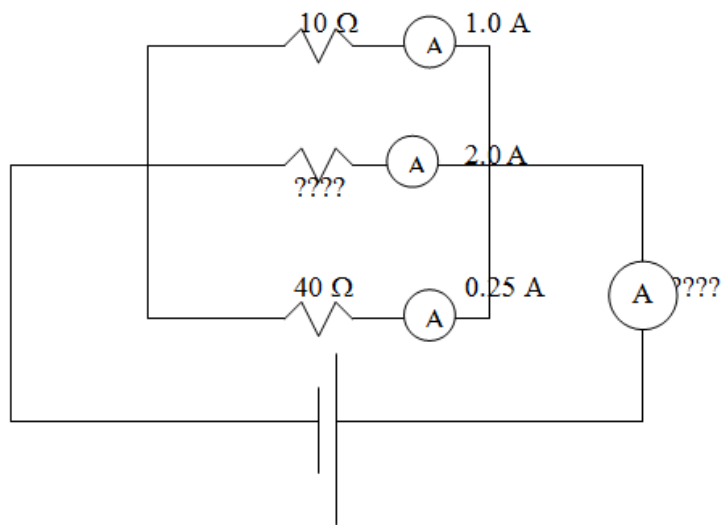
4. Find the missing voltage and resistance.

12V

??? Ω   A 3.0 A

??? V

2 Ω

5.   Find the missing voltage.

10 Ω

10 Ω

A

40 Ω   2.0 A

V = ??
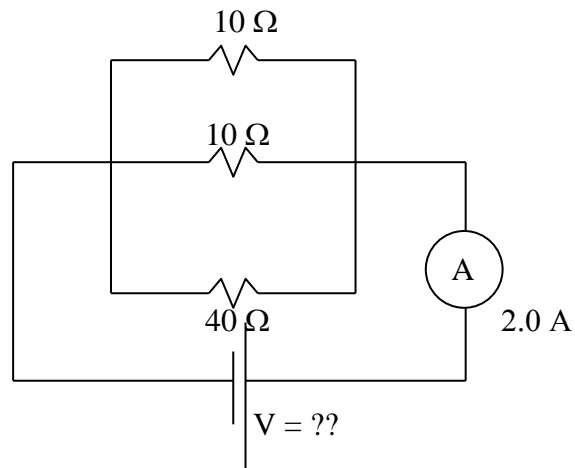
6.   Find the missing resistance, the total current, and the missing voltage

10 Ω   1.0 A
          A

          A   2.0 A
????

40 Ω   0.25 A   A ????
          A

7.   a.   In a series circuit, what measurement is constant at each resistor?
      b.   In a parallel circuit, what measurement is constant at each resistor?

STE's Circuit Subtleties

(1) a) What is the total resistance of this circuit? _____ Why? _____ .
_____
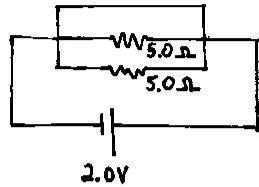
b) Can you show why algebraically?

2.0V

(2) a) Penelope's Question : find the missing resistance, x.

240 Ω
120 Ω
2.0A
120V
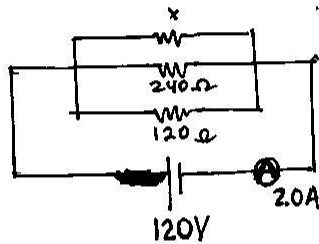
b) How you would you solve for x using Req (total resistance in parallel)?

(3) a) what happens to the current (calculate in each case) when you connect an additional 6 Ω resistor to the circuit.

Case 1

6Ω 6Ω

12 V

→

6Ω 6Ω 6Ω

12 V

b) Case 2

c) How much current does each 6Ω resistor receive (before & after)?

④ Solve for V using the fact that $1\,\Omega = 1\,\dfrac{Js}{C^2}$. Show all units & respect sig figs.

$$I = 1.50\,A$$
$$R = 2.00\,\Omega$$

⑤ Flashback Subtlety: How do you show, in a diagram, the difference between a strong & a weak electrolyte?

⑥

New T-shirt idea:

YOU

s mist?

B-   **Combination Circuits** combine the features of parallel circuits with those of series circuits. The key to surviving these is to keep in mind the distinctive features of those circuits in mind.

$\mathcal{E} = 12$ V
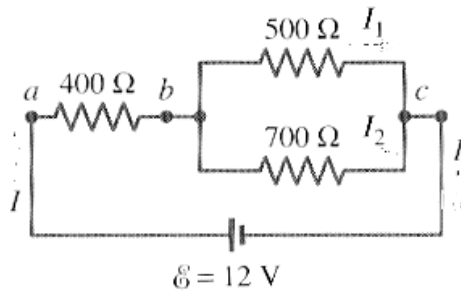
<u>Example 1</u>

a. What is the overall resistance of this circuit?

b. What is the potential difference measured from a to b?

c. What currents would be measured within the parallel branch? (see diagram for I_1 and I_2)

12 V
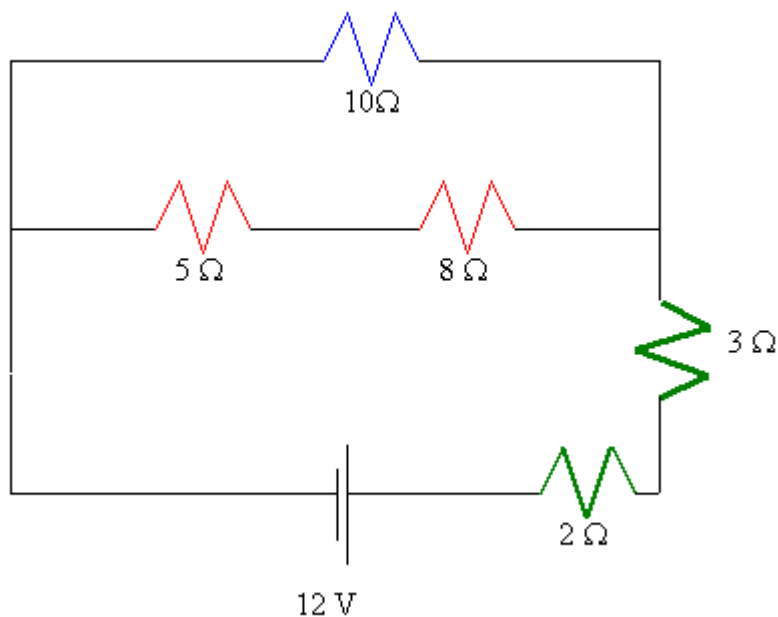
<u>Example 2</u>

a.   Find the total current in the following:

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First, we'll redraw the circuit to make sure we realized that the 5 and 8 Ω resistor are in series, but they in turn are in parallel to the 10 Ω resistor. The parallel branch is then series with both the 3 and 2 Ω resistors.
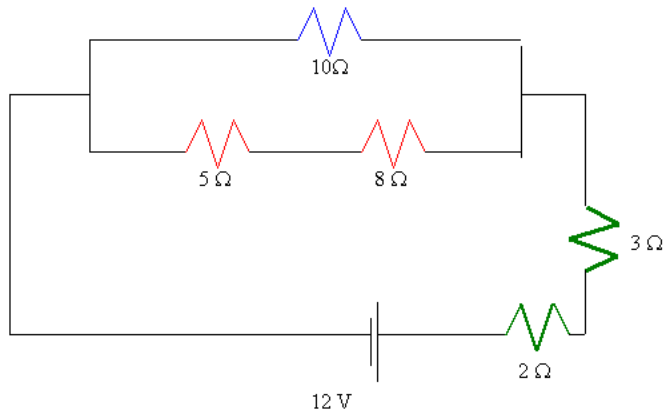
b.   What is the voltage drop across the 8 Ω resistor?

Example 3   Connect four 5Ω resistors in such a way that their total resistance is 5 Ω.

Exercises

1.   An electric circuit is illustrated below.

$R_1 = 4\Omega$
$R_2 = 6\Omega$
$R_3 = 6\Omega$
$R_4 = 6\Omega$
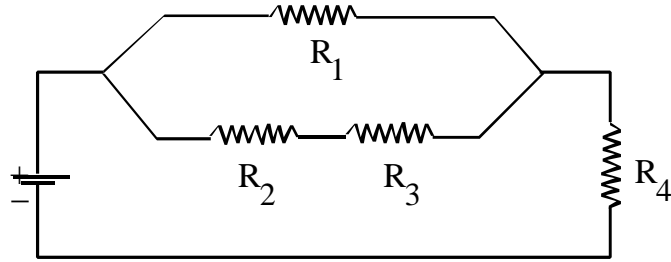
What is the equivalent resistance of this circuit?

2.   An electric circuit is illustrated below.
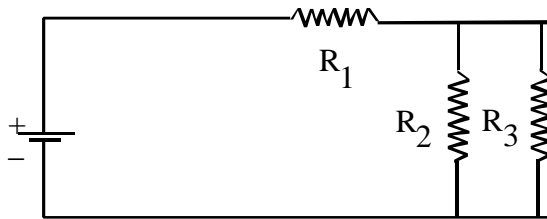
$R_1 = 15\Omega$
$I_1 = 2$ A
$I_2 = 1.5$ A
$V_2 = 90$ V

What is the value of resistor R_3?

3.   A series-parallel electric circuit is illustrated below.

Find R_T

126
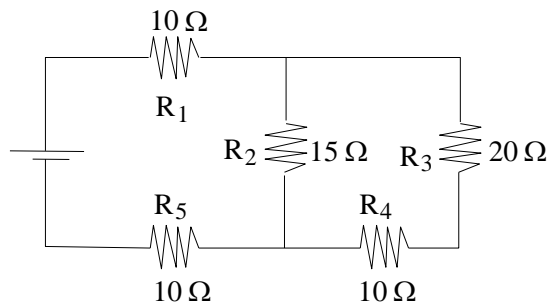
4.   A series-parallel electric circuit is illustrated below.
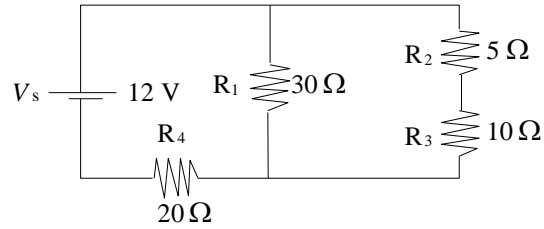
What is the potential difference across the terminal of resistor R_1?

5.   A series-parallel electric is illustrated below.
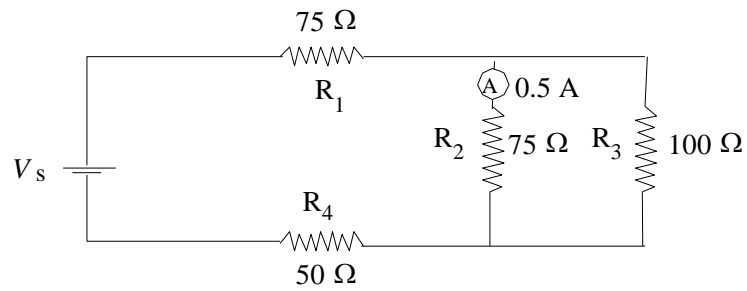
What is the intensity of the current flowing from the power source, I_s?

6.   The following electric circuit consists of a power supply, five resistors (R$_1$, R$_2$, R$_3$, R$_4$ and R$_5$) and an ammeter Ⓐ.
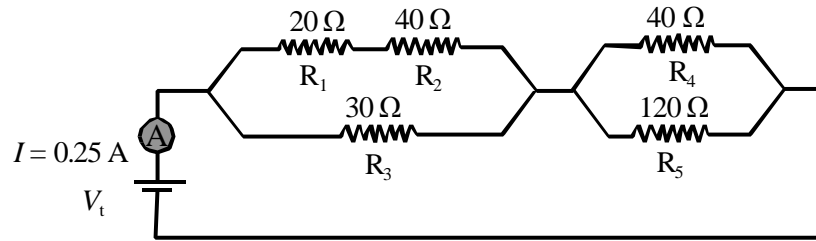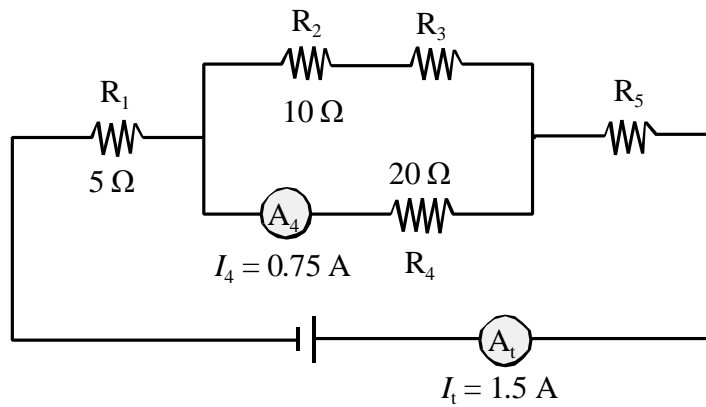

The ammeter reads 0.25 A.

a.   What is the potential difference (voltage), V_t, across the terminals of the power supply?
b.   What is the potential difference across R$_3$?
c.   What is the potential difference across R$_1$?
d.   What current flows through R$_5$?

7.   An electric circuit is illustrated below.
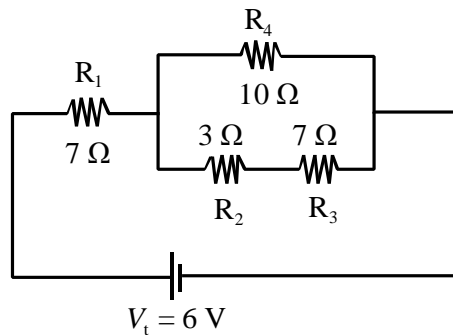
What is the current intensity, I, in resistors R_2 and R_3?

8.   The following electric circuit consists of a power source, five resistors (R$_1$, R$_2$, R$_3$, R$_4$ and R$_5$) and two ammeters Ⓐ$_4$ and Ⓐ$_t$.

What is the potential difference (voltage) across the terminals of resistors R_3?

9. The following circuit consists of a power source, two ammeters (A$_t$) and (A$_3$), a voltmeter (V) and three resistors (R_1, R_2 and R_3).
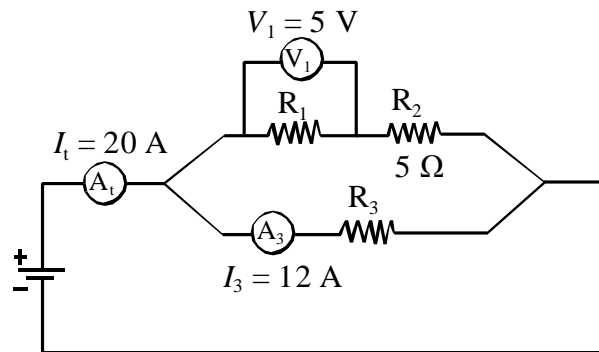
The total current intensity I_t is 20 A. Current intensity I_3 is 12 A. The potential difference (voltage) V_1 across the terminals of resistor R_1 is 5 V.

What is the resistance of resistor R_3?

10. A source with a potential difference of 30 V is connected to the circuit shown below.

R_1

$R_3 = 10 \ \Omega$

I_1

$I_2 = 1 \ A$ $R_2 = 10 \ \Omega$

I
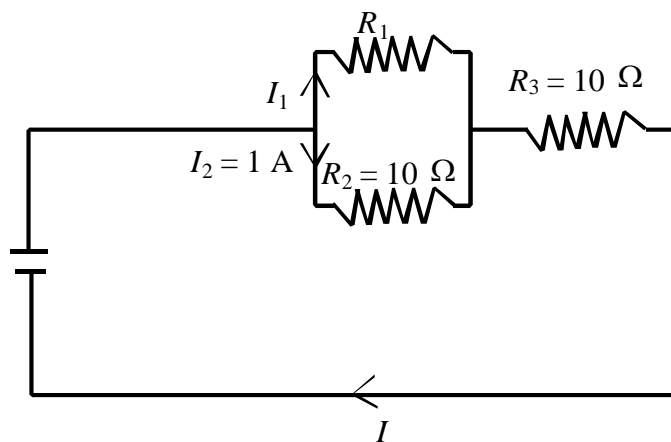
What is the current intensity I across the circuit?

11. The following electrical circuit consists of a power source, four resistors (R_1, R_2, R_3 and R_4) and a voltmeter V_4 ($V_s = V_{total}$).

$R_1 = 20\ \Omega$

(A)

$R_2 = 10\ \Omega$ $R_3 = 30\ \Omega$

$V_s = 100$ V

$R_4 = 20\ \Omega$

(V₄)

$V_4 = 60$ V
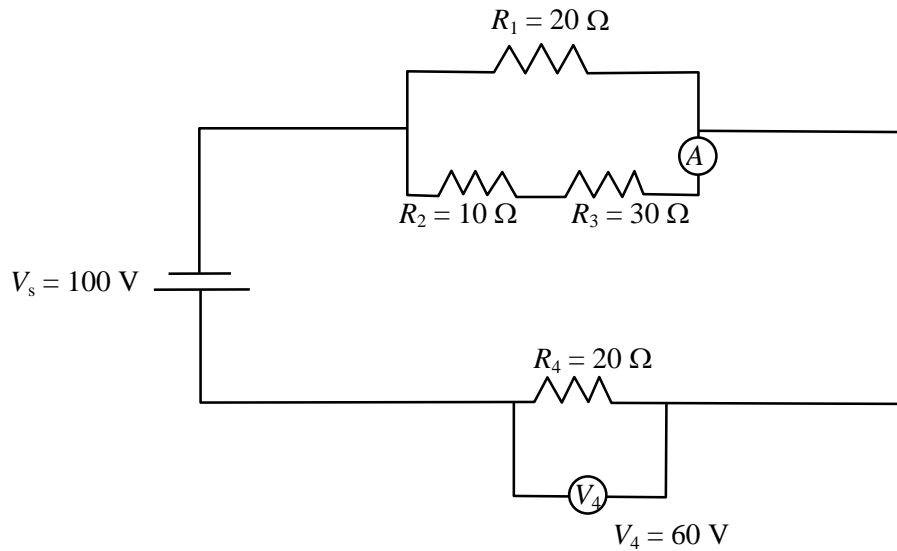
What is the current intensity (I_3) through R_3?

12. How can one 25 Ω and two 100 Ω resistors be connected so that their total resistance is 75 Ω?

13. How can four 1.0 Ω resistors and one 2.0 Ω combine to give a total resistance of 1.5 Ω?

14. Four identical resistors are connected as shown. If the total voltage is 12V, find the voltage across each resistor.

R_2

R_3

R_4

R_1
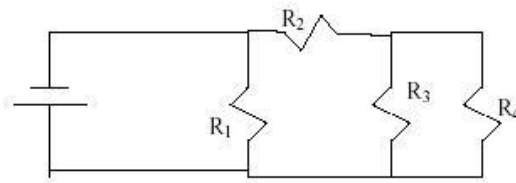
19.   Magnetic Field Induced By a Current

If a strong enough current moves through a straight wire it will create a magnetic field perpendicular to the direction of the current. The **first left hand rule** reveals whether the compass direction along the circle would be clockwise or counter clockwise. Notice that the thumb points in the direction of the electron flow.
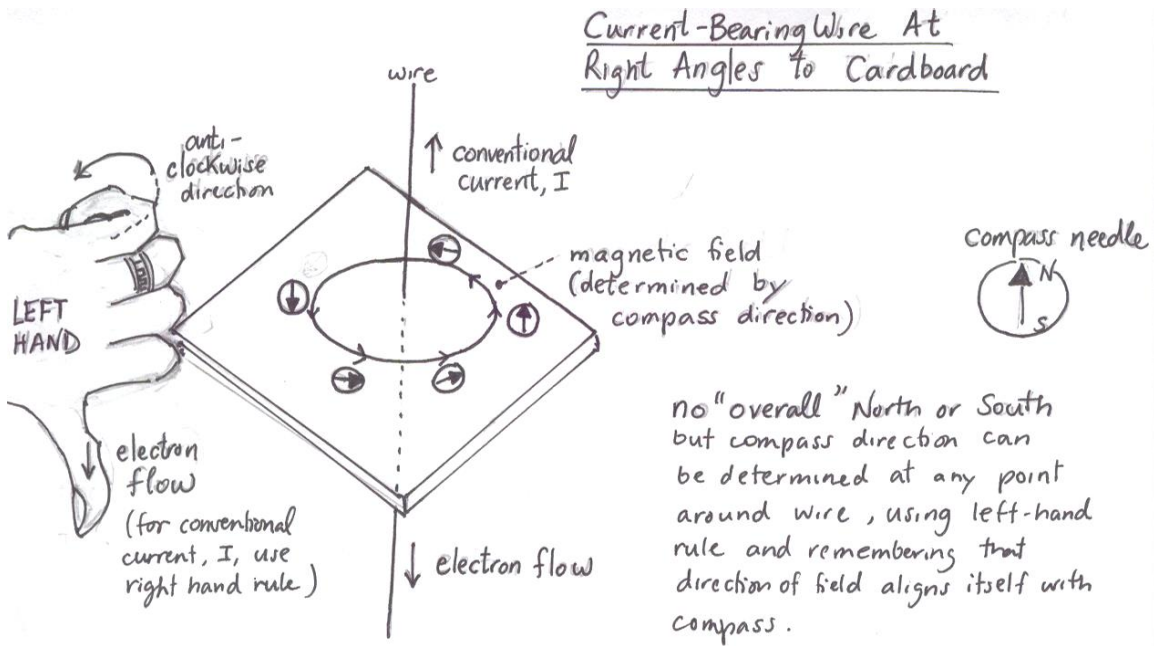
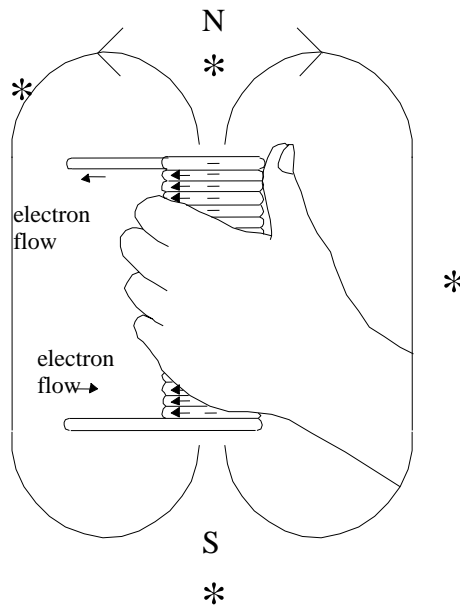Example 1   Draw the magnetic field in each case.

a.

(+)

(-)

b.

The X represents electrons moving into the paper.
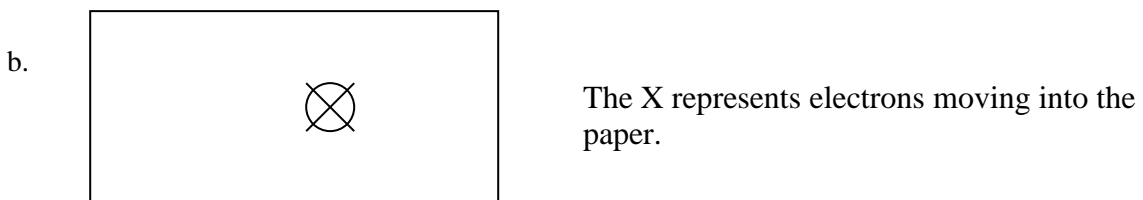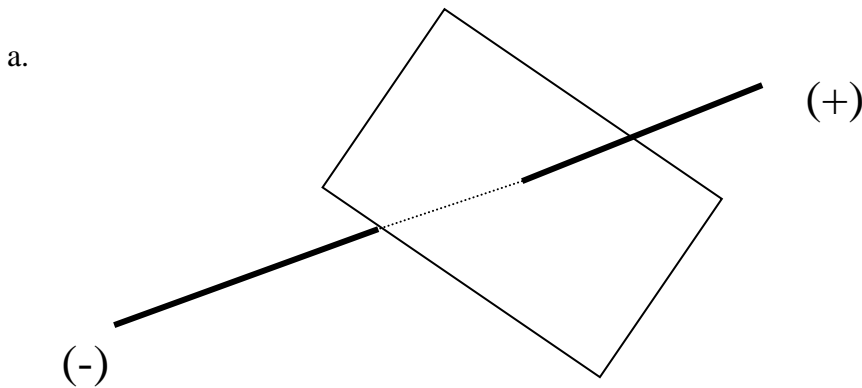
B.   Magnetic Field Induced By a Current in a Solenoid

When a solenoid is attached to a strong voltage source, an electromagnet can be created. Each of the circular magnetic field loops combine to create one overall field that resembles that of a bar magnet. The **second left-hand rule** reveals the North end of the magnetic field. Notice that the finger nails are pointing in the same direction as the electrons

Long Conductor Wound into a Coil With Many Loops (Solenoid)

electron flow
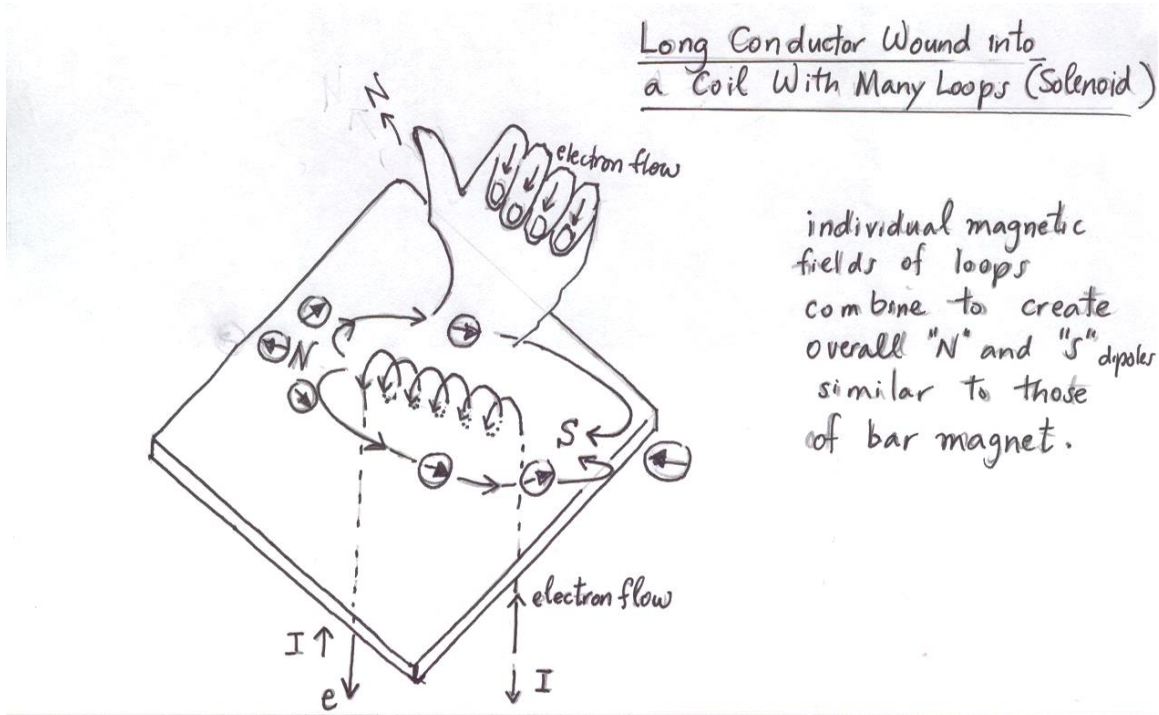
individual magnetic fields of loops combine to create overall "N" and "S" dipoles similar to those of bar magnet.

electron flow

Example 1   Draw what a compass would be behave like all along the magnetic field shown in the diagram. Draw a compass at each position marked by a *

N

*

*

electron flow

*

electron flow →

S

*

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Example 2   Draw the magnetic field around the following electromagnets.

a.
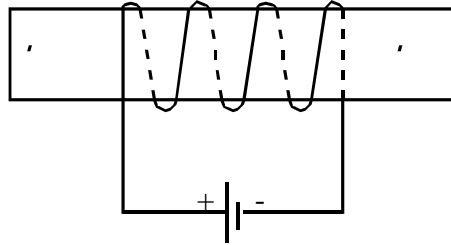
b.
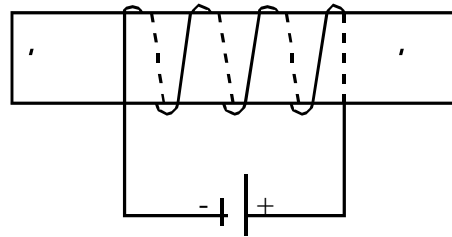
c.   Draw a solenoid in which the wire from the (-) end first slips under the coil, and then draw the magnetic field.

B.   Factors Affecting Electromagnets

The magnet's strength increases by…

(1) increasing the current
(2) increasing the number of loops
(3) and by placing a ferromagnetic material inside the coil.

Example: Elaborate on each of the above 3 factors.

Exercises (exact or varied forms of ministry exam questions)

1.   An electric current in a straight wire comes up through a sheet of paper. Four
         compasses are placed on the paper at different points around the wire.

Electric current
       comming out
     of the paper
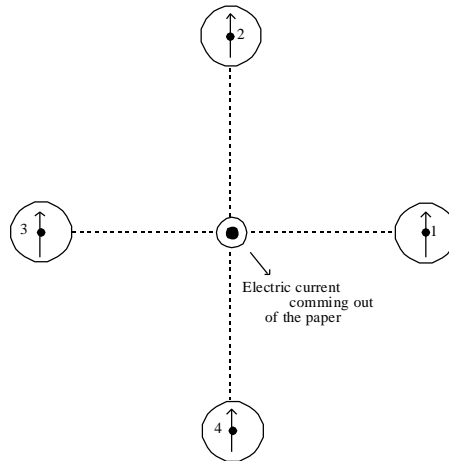
         Which arrow on the diagram correctly shows the direction of the needle of the
         compass at the location where it is placed?

2.   The four diagrams below represent electromagnets connected to the terminals of a
         battery.
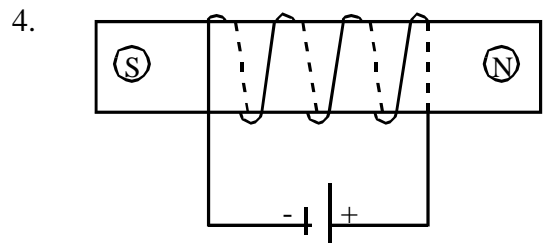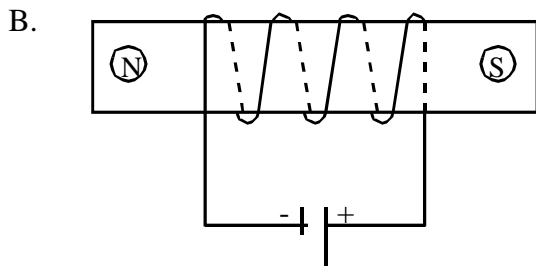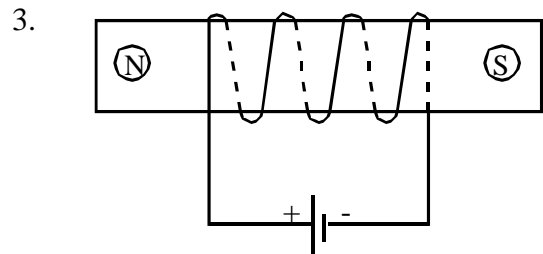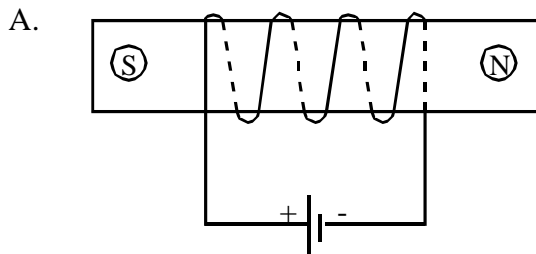
a.   In which diagrams are the magnetic poles of the electromagnet correctly
         indicated? _____ and _____
         b.   Redraw diagram (A) with a correct magnetic field.

3.   Electro-magnets are used in industry to attract metallic objects.
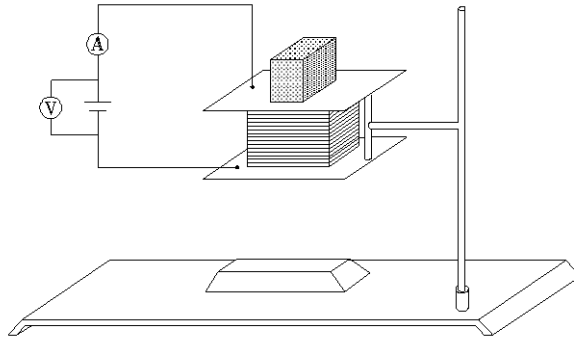
The diagram shows an electro-magnet with an iron core.

Which of the following changes would increase the strength of the electro-magnet? (yes or no)

a. Increase the potential difference of the power supply._____
b. Increase the temperature of the core._____
c. Use a core made of copper instead of iron._____
d. Increase the number of turns._____

4.   What does the magnetic field around a solenoid look like?

A)

C)

B)

D)
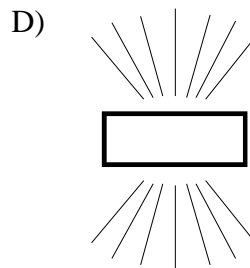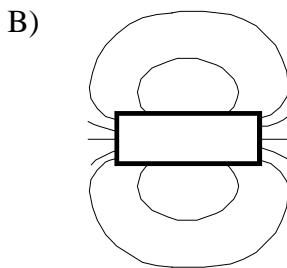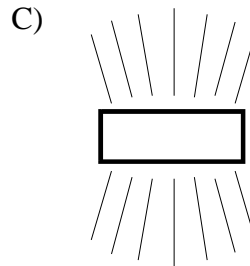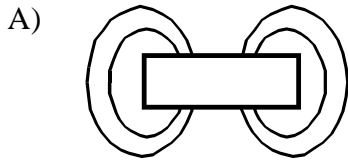
5.   The magnet in the diagram is constructed from an iron core and a coil of wire connected to a battery. When the switch is turned off, an electric current circulates through the wire.
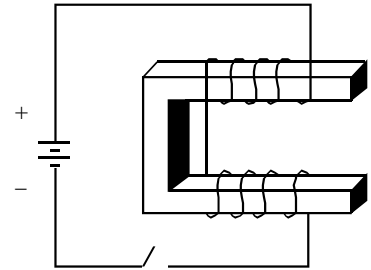
Which of the following diagrams correctly shows the magnetic field of this electromagnet?

A)

C)

B)

D)
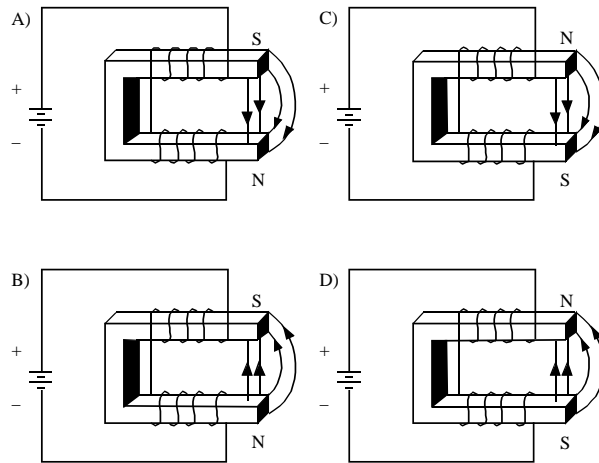
6.   Study the five diagrams below.

Which diagram(s) correctly show the relationship between a magnetic field and the electric current producing it?
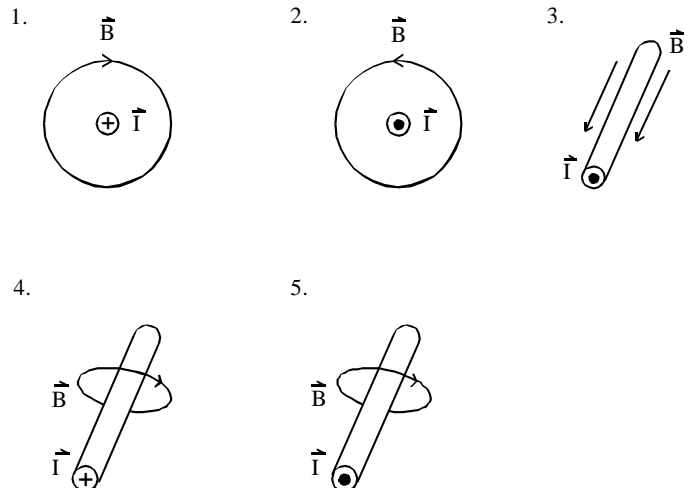
Legend :

⊙electron flow "out of the paper"

⊕electron flow "into the paper"

1.

2.

3.

4.

5.

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7. A solenoid connected to a battery is placed between the north pole and the south pole of a U-shaped magnet.
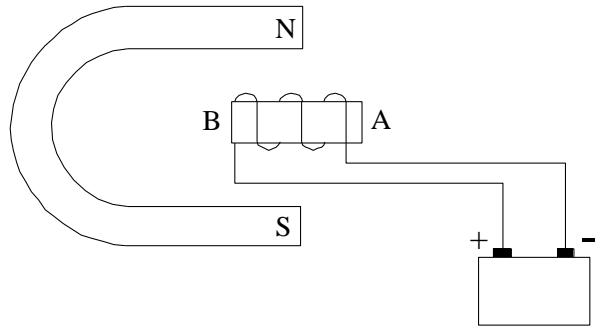
What effect does the magnet have on the solenoid?

8. Two of the following diagrams correctly represent the magnetic field created by an electric current flowing through a solenoid. *(careful: the diagrams' arrows are not representing electron flow but conventional current which ran in the opposite direction)*
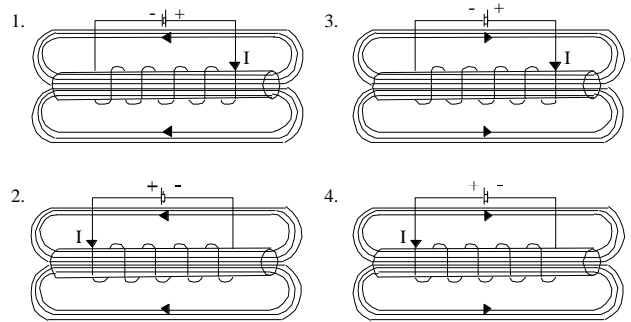
Which two diagrams are they?

9. A copper wire with a current flowing through it passes through a piece of cardboard as shown in the diagram to the right.
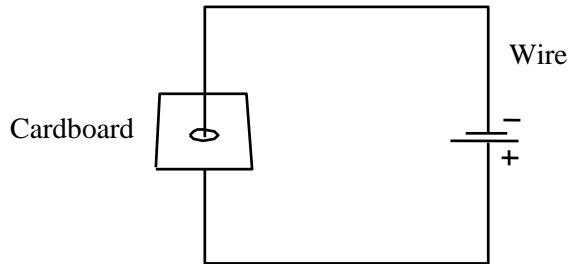
A magnetic compass is placed on the piece of cardboard near the wire. Draw where the compass would be pointing if it was placed at the

a.   12 o clock position on top of the cardboard
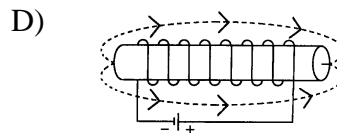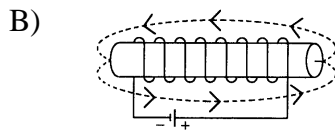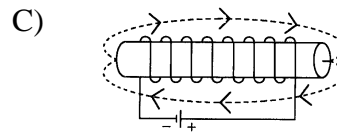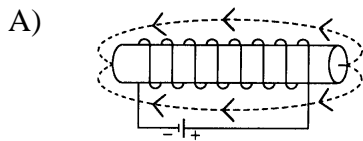b.   3 o clock position on top of the cardboard

10.   Which of the following electromagnets produces the strongest magnetic field?

A)   Wooden core

I = 5 A

C)   Wooden core

I = 10 A

B)   Iron core
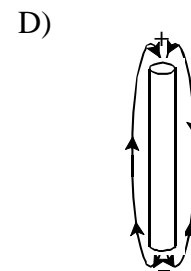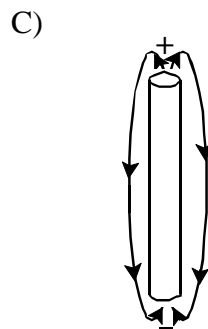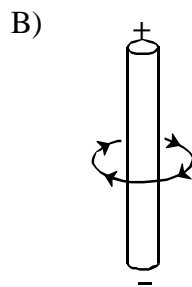
I = 5 A
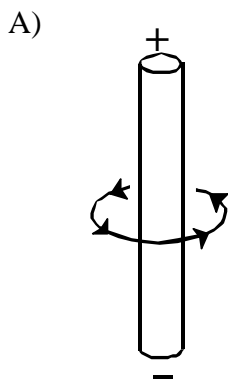
D)   Iron core

I = 10 A
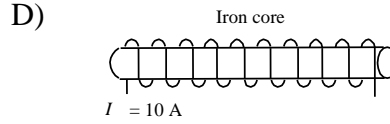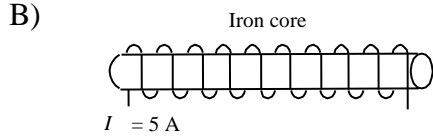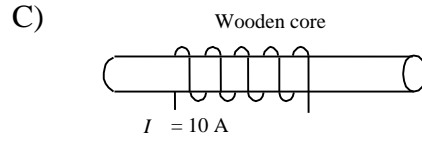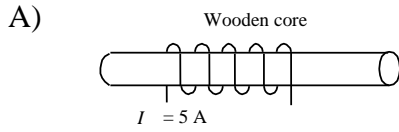
11.   An electric current flows through a solenoid.

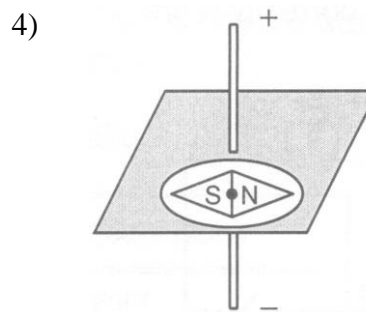Which diagram correctly illustrates the magnetic field produced by this solenoid?
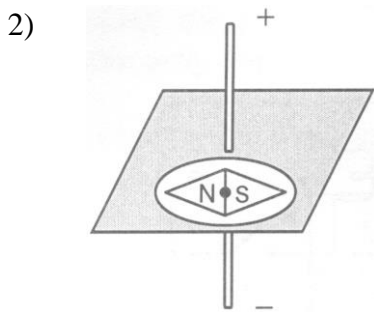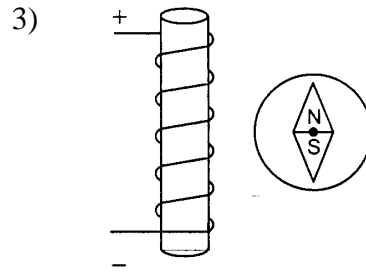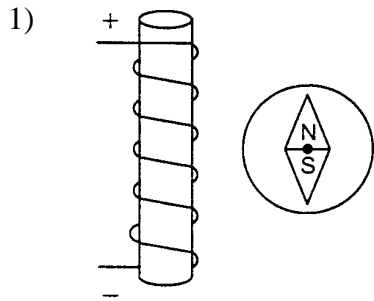
A)

C)

B)

D)

12.   An electric current flows through a *straight wire* and produces a magnetic field.

Which of the following diagrams correctly represents this magnetic field?

A)   B)   C)   D)

13.   The diagrams below illustrate a compass placed in magnetic field.

1)

3)

2)

4)

Which diagrams show the compass needle pointing in the correct direction?
_____ and _____

14.   A bar magnet is brought close to a current-bearing solenoid.

In which one of the following situations will there be repulsion?

A)

B)

C)

D)