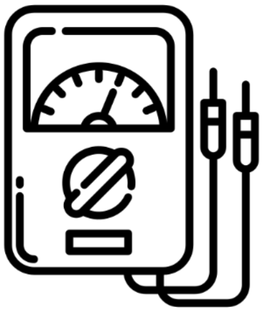
ESAT Physics Prep

Week 2 – Magnetism



ANSWERS

Week 1 – Electricity

Week 2 – Magnetism

Week 3 – Mechanics

Week 4 – Thermal physics

Week 5 – Matter

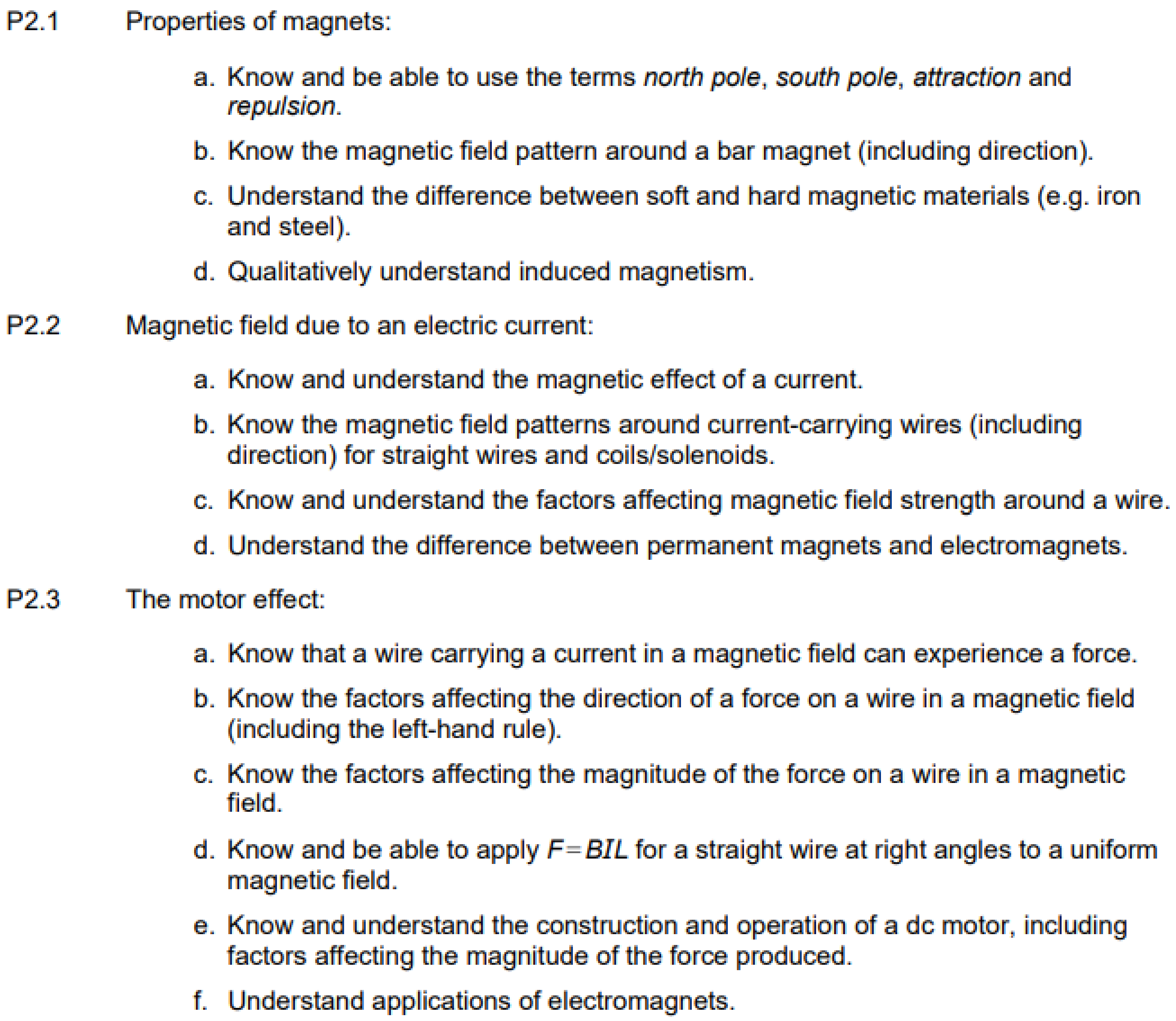
Week 6 – Waves

Week 7 – Radioactivity

There is one sample ESAT test – note that they use the same questions from NSAA 2020 specimen paper. Past NSAA & ENGAA questions are the most relevant.

There are no calculators in the ESAT.

Magnetism Spec



P2.1 Properties of magnets:

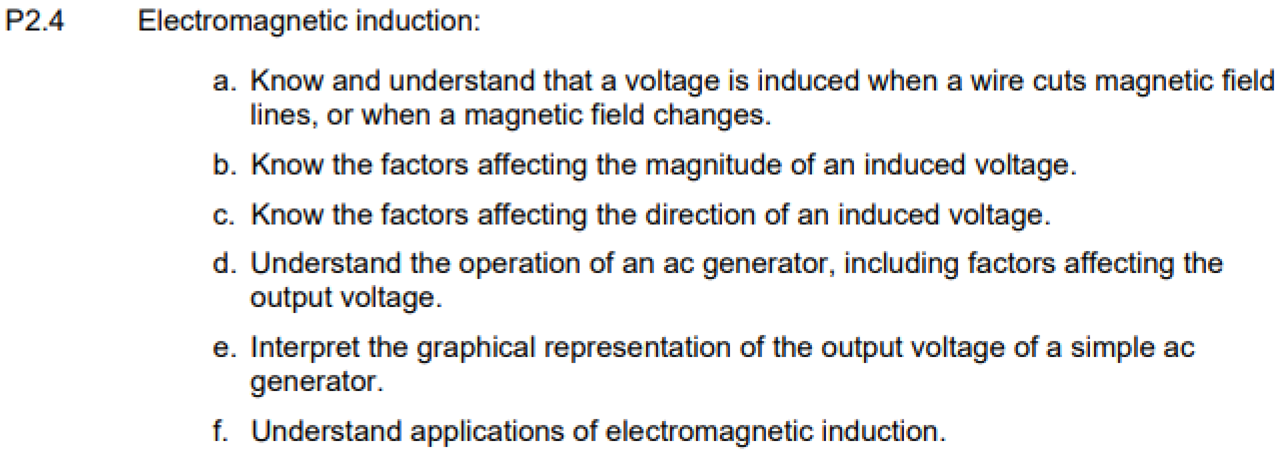
a. Know and be able to use the terms *north pole*, *south pole*, *attraction* and *repulsion*.
b. Know the magnetic field pattern around a bar magnet (including direction).
c. Understand the difference between soft and hard magnetic materials (e.g. iron and steel).
d. Qualitatively understand induced magnetism.

P2.2 Magnetic field due to an electric current:

a. Know and understand the magnetic effect of a current.
b. Know the magnetic field patterns around current-carrying wires (including direction) for straight wires and coils/solenoids.
c. Know and understand the factors affecting magnetic field strength around a wire.
d. Understand the difference between permanent magnets and electromagnets.

P2.3 The motor effect:

a. Know that a wire carrying a current in a magnetic field can experience a force.
b. Know the factors affecting the direction of a force on a wire in a magnetic field (including the left-hand rule).
c. Know the factors affecting the magnitude of the force on a wire in a magnetic field.
d. Know and be able to apply $F=BIL$ for a straight wire at right angles to a uniform magnetic field.
e. Know and understand the construction and operation of a dc motor, including factors affecting the magnitude of the force produced.
f. Understand applications of electromagnets.



P2.4 Electromagnetic induction:

a. Know and understand that a voltage is induced when a wire cuts magnetic field lines, or when a magnetic field changes.
b. Know the factors affecting the magnitude of an induced voltage.
c. Know the factors affecting the direction of an induced voltage.
d. Understand the operation of an ac generator, including factors affecting the output voltage.
e. Interpret the graphical representation of the output voltage of a simple ac generator.
f. Understand applications of electromagnetic induction.

P2.5 Transformers:

a. Know and understand the terms *step-up transformer* and *step-down transformer*.

b. Know and use the relationship between the number of turns on the primary and secondary coils, and the voltage ratio: $\frac{V_p}{V_s} = \frac{n_p}{n_s}$

c. Know that a consequence of 100% efficiency is total transfer of electrical power, and that this gives rise to the following relationship: $V_pI_p = V_sI_s$. Know and use this relationship to solve problems.

d. Understand power transmission, including calculating losses during transmission and the need for high voltage.

NSAA 2019 Q29

29 A U-shaped permanent magnet rests on a balance.

A straight, horizontal wire of length 5.0 cm is fixed in position between the poles of the magnet, perpendicular to the horizontal magnetic field.

There is a current of 2.0 A in the wire and the reading on the balance is 202 g.

When the direction of the 2.0 A current is reversed, the reading changes to 198 g.

What is the strength of the magnetic field?

(gravitational field strength = 10 N kg^{-1})

A 0.020 T

B 0.040 T

[✓ **C** 0.20 T]

D 0.40 T

E 200 T

F 400 T

change of 4g

mass of wire = 200g

Force due to current

$= 0.002 \times 10 = 0.02 N$

$F = BIL \Rightarrow B = \frac{F}{IL}$

$= \frac{0.02}{2 \times 0.05}$

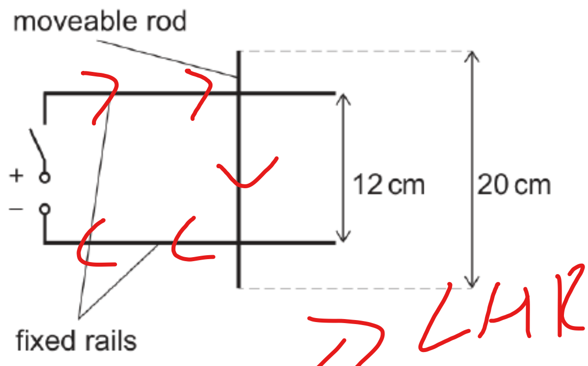
$= \frac{0.01}{0.05} = 0.2T$

NSAA 2020 Q30

30 Two fixed horizontal metal rails are side by side and 12 cm apart. The rails are connected to a dc power supply by a switch that is initially open.

A freely moveable metal rod of length 20 cm is placed on the rails as shown in the diagram. The diagram shows the arrangement seen from above.

The angle between the rod and the rails is 90°.



→ LHR ⇒ force to the right

The whole arrangement is placed in a uniform magnetic field of magnitude 0.50 T that is directed perpendicularly into the page.

The moveable rod has a weight of 0.40 N.

$$m = \frac{W}{g} = \frac{0.40}{10} = 0.04$$

The switch is now closed. As a result, there is a current of 2.4 A in the circuit and the rod moves.

What is the initial magnitude of the acceleration of the rod and what is its direction?

(gravitational field strength = 10 N kg^{-1})

	acceleration / m s^{-2}	*direction*
A	0.36	to the left ✗
B	0.36	to the right ✓
C	0.60	to the left ✗
D	0.60	to the right ✓
E	3.6	to the left ✗
[✓ **F**]	3.6	to the right ✓
G	6.0	to the left ✗
H	6.0	to the right ✓

$$F = BIL$$
$$= 0.50 \times 2.4 \times 0.12$$
$$= 1.2 \times 0.12$$
$$= 0.144\,N$$

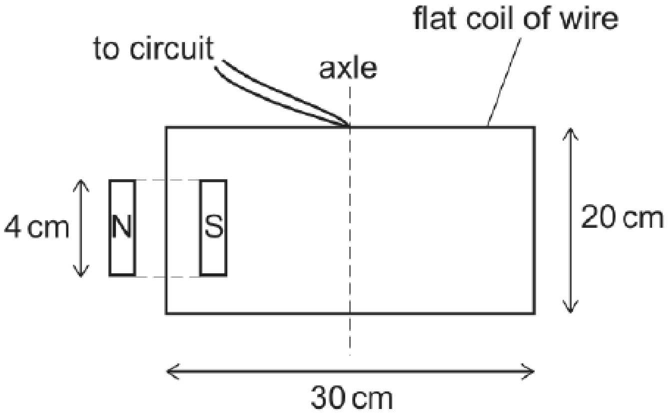
$$F = ma$$
$$a = \frac{F}{m} = \frac{0.0144}{0.04}$$
$$= 3.6\,m/s^2$$

ENGAA 2020 Q28

A flat rectangular coil of wire with sides of length 30 cm and 20 cm is freely pivoted about an axle. The axle passes through the middle of the sides of length 30 cm.

Part of the coil is between the poles of a U-shaped magnet as shown in the diagram. The poles are 4.0 cm long. The magnetic field can be considered uniform between the poles, and zero elsewhere.

The coil is connected to a power supply so that there is a current in it.



[diagram not to scale]

The current is 0.60 A and the magnetic flux density is 0.050 T. There are 50 turns of wire in the coil.

What is the moment about the axle, in N cm, produced by the magnetic force acting on the coil?

A 0.018 N cm

B 0.036 N cm

C 0.045 N cm

[✓ **D**] 0.90 N cm

E 1.8 N cm

F 2.25 N cm

G 4.5 N cm

$F = BIL \times n$

$= 0.050 \times 0.60 \times 0.04 \times 50$

$= 2.5 \times 0.60 \times 0.04$

$= 0.1 \times 0.60 = 0.06N$

$m = F \times d$

$= 0.06 \times 15$

$= 0.9$ Ncm

NSAA 2021 Q32

32 A uniform, horizontal magnetic field has magnetic field strength 0.60 T and a direction from west to east.

A horizontal wire is placed in a north–south direction, so that it is at 90° to the magnetic field.

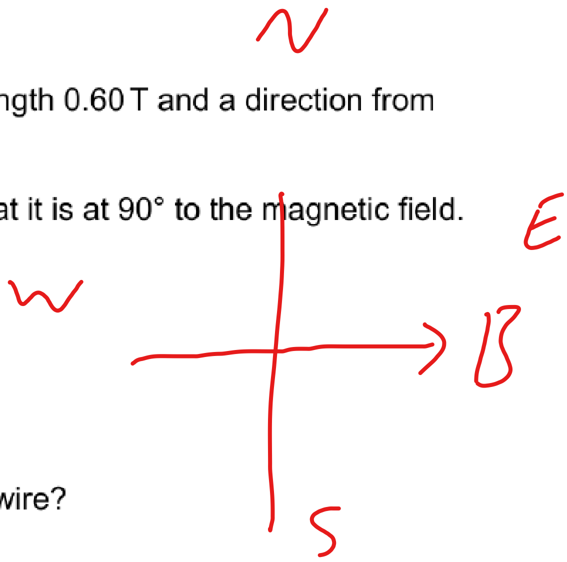
The wire carries a constant current.

The wire has length 0.40 m and mass 0.018 kg.

The resultant force acting vertically on the wire is zero.

What are the magnitude and direction of the current in the wire?

(gravitational field strength = 10 N kg^{-1})



Force up
(out of page)
FLHR says
I is N->S

	magnitude of current / A	direction of current
A	0.012 ✗	from north to south
B	0.012 ✗	from south to north
C	0.075 ✗	from north to south
D	0.075 ✗	from south to north
E	0.12 ✗	from north to south
F	0.12 ✗	from south to north
[✓ G]	0.75 ✓	from north to south ✓
H	0.75 ✓	from south to north ✗

$$mg = BIL$$

$$0.018 \times 10 = 0.60 \times I \times 0.40$$

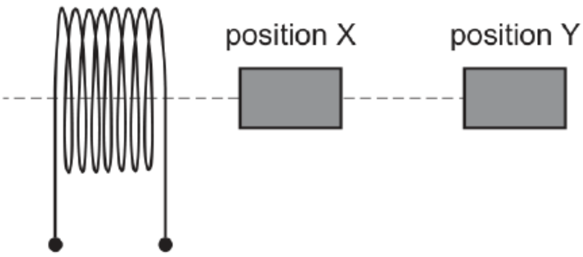
$$I = \frac{0.18}{0.60 \times 0.40} = \frac{0.18}{0.24}$$

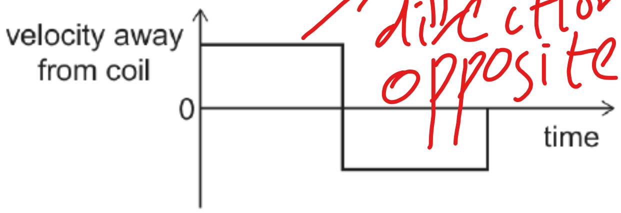
$$= 0.75 \text{ A}$$

NSAA 2022 Q36

36 A bar magnet is placed at position X close to one end of a coil and on the axis of the coil as shown.

The graph shows how the velocity of the magnet varies as it is then moved rapidly to position Y and back to position X.



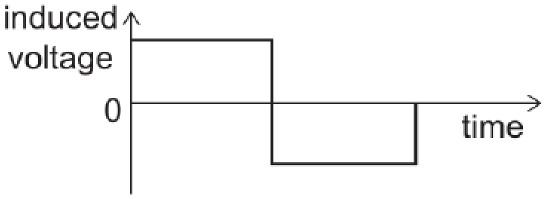


→ opposite direction so opposite emf

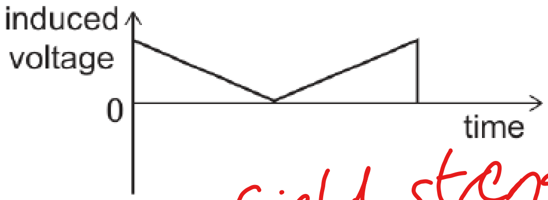
The magnetic field of the bar magnet still affects the coil when the magnet is at position Y.

Which graph represents how the induced voltage in the coil changes as the magnet moves?

A

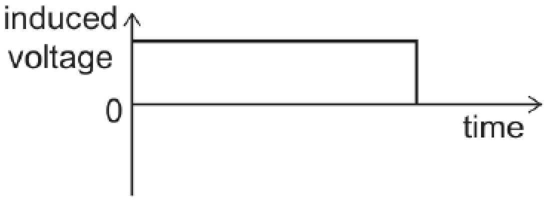


B

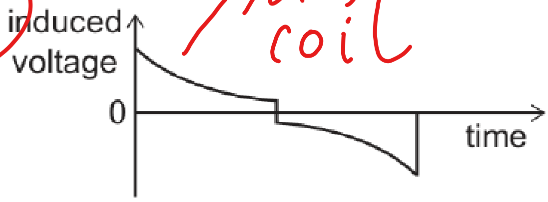


field strength decreases with → distance from coil

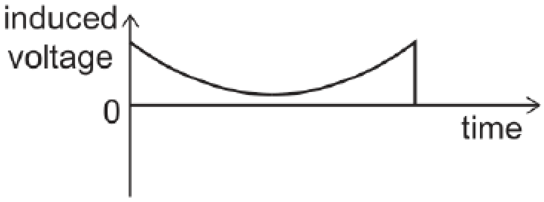
C



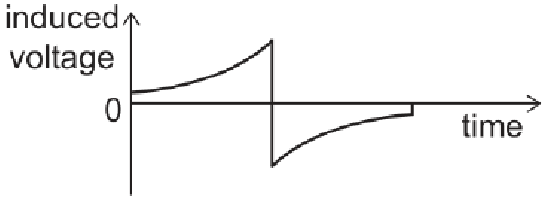
[✓ **D**]



E



F



$Q = It \Rightarrow I = \frac{Q}{t} = \frac{20}{90} = \frac{2}{9}\ A$

NSAA 2022 Q21

21 There is a constant current in a conducting wire. A charge of 20 C passes through the wire in 1.5 minutes.

An 18 cm straight section of this wire lies in a uniform magnetic field. This section of wire is perpendicular to the direction of the field. The magnetic field strength is 0.15 T.

What is the magnitude of the magnetic force on this section of wire?

[✓ **A**] 0.0060 N

B 0.36 N

C 0.60 N

D 0.81 N

E 36 N

F 49 N

G 81 N

H 4900 N

$$F = BIL$$
$$= 0.15 \times \frac{2}{9} \times 0.18$$
$$= 0.15 \times 2 \times 0.02$$
$$= 0.30 \times 0.02$$
$$= 0.0060 \checkmark$$

ENGAA 2022 Q2

2 There is a constant current in a conducting wire. A charge of 20 C passes through the wire in 1.5 minutes.

An 18 cm straight section of this wire lies in a uniform magnetic field. This section of wire is perpendicular to the direction of the field. The magnetic field strength is 0.15 T.

What is the magnitude of the magnetic force on this section of wire?

[✓ **A**] 0.0060 N

B 0.36 N

C 0.60 N

D 0.81 N

E 36 N

F 49 N

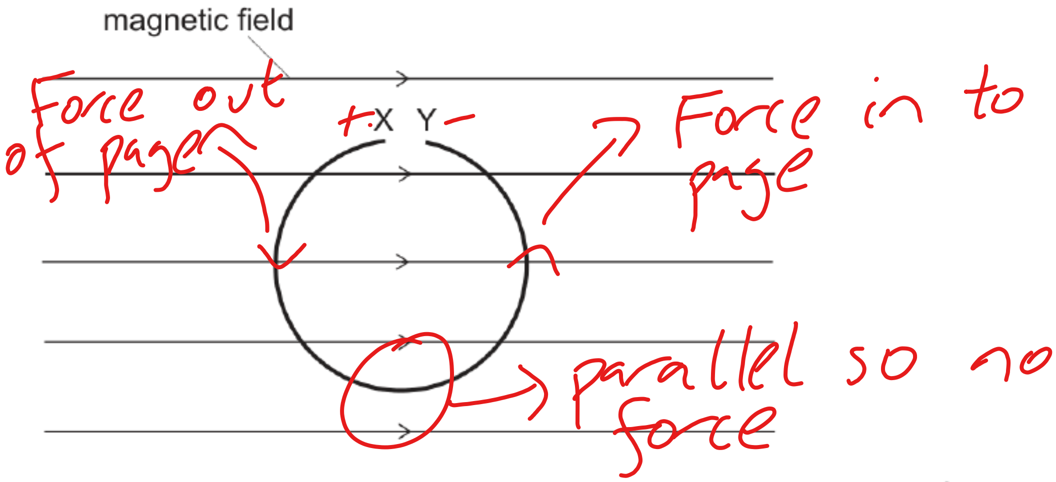
G 81 N

H 4900 N

same q as above!

NSAA 2023 Q37

37 A copper ring, with a small gap XY, rests in a uniform horizontal magnetic field. The ring lies in the plane of the page and the direction of the magnetic field is horizontal from left to right, as shown in the diagram.



A voltage is now applied across XY, such that X is connected to the positive terminal of the power supply and Y is connected to the negative terminal.

Which statement describes the motion of the ring immediately after the voltage is applied?

(Assume that the mechanism supporting the ring allows the ring to move freely and allows the voltage to be applied continuously.)

A The ring moves towards the bottom of the page.

B The ring moves towards the top of the page.

C The ring moves towards the left of the page.

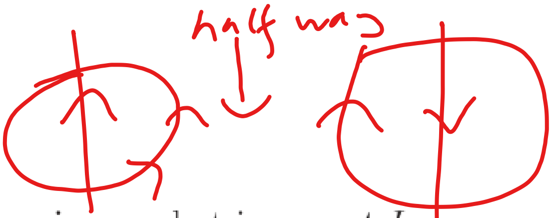
D The ring moves towards the right of the page.

E The ring rotates about an axis perpendicular to the plane of the page in a clockwise direction.

F The ring rotates about an axis perpendicular to the plane of the page in an anti-clockwise direction.

G The ring rotates about an axis that is in the plane of the page and parallel to the field.

[✓ **H**] The ring rotates about an axis that is in the plane of the page and perpendicular to the field.



PAT 2019 Q9

9. A long, thin, straight wire carrying an electric current I causes a magnetic field of flux density B at a perpendicular distance r from the wire. The magnitude of this flux density is given by the following relation:

$$B = \frac{\alpha I}{r}$$

where α is a constant. The magnetic field points circumferentially around the wire. A second, identical wire is placed parallel to the first one at a distance D. Find the current I_2 that has to flow in the second wire if the flux density at a line half way between and parallel to the wires is to double, compared to the flux density from only one wire at current I. [2]

A	B	C	[✓ D]	E
$I_2 = I$	$I_2 = 2I$	$I_2 = -2I$	$I_2 = -I$	$I_2 = -I/2$

PAT 2023 Q12

12. A device uses 3 kW of power at a voltage of 60 V. It is connected to a power supply via an ideal transformer. The transformer has N turns on the winding connected to the device and $20N$ turns on the winding connected to the power supply. What current flows in the winding connected to the power supply? [2]

$60 \times 20 = 1200V$

A	B	[✓ C]	D	E
1 mA	0.4 A	2.5 A	50 A	1 kA

$P = IV$

$$I = \frac{P}{V} = \frac{3000}{1200} = 2.5 A$$

ENGAA 2023 Q14

14 The voltage output of a power station is stepped up using a transformer before the power is transmitted to a distant town. The primary coil of this transformer has 300 turns and the secondary coil has 1500 turns.

In the town, a step-down transformer reduces the voltage supplied by the transmission cables to 33 000 V for distribution within the town. The step-down transformer supplies a current of 1500 A.

$P = IV = 33\,000 \times 1500$

The current in the transmission cables is 450 A and both transformers are ideal and 100% efficient.

What is the voltage output of the power station?

(Assume that the resistance of the transmission cables is negligible.)

A 1980 V

B 6600 V

[✓ **C**] 22 000 V

D 110 000 V

E 550 000 V

$$V = \frac{P}{I} = \frac{33000 \times 1500}{450}$$

$$= 33000 \times \frac{10}{3} = 110\,000 \checkmark$$

$$\frac{V_p}{V_s} = \frac{N_p}{N_s} = \frac{300}{1500} = \frac{1}{5}$$

$$V_p = \frac{1}{5} \times 110\,000 = 22000 \checkmark$$

ENGAA 2021 Q4

4 A **non-ideal** transformer has 100 turns on the primary coil and 25 turns on the secondary coil.

It is provided with 3.0 kW of electrical power at a current of 12.5 A.

The voltage output is the same as for an ideal transformer, but the current in the output coil is 40 A.

What is the efficiency of the transformer?

A 20%

B 25%

C 31%

D 69%

E 75%

[✓ **F** 80%]

G 91%

H 100%

$$V = \frac{P}{I} = \frac{3000}{12.5}$$

$$\frac{V_p}{V_s} = \frac{N_p}{N_s}$$

$$V_s = \frac{V_p N_s}{N_p} = \frac{3000}{12.5} \times \frac{1}{4}$$

$$= \frac{3000}{50} = 60V$$

$$P = I \times V = 40 \times 60$$

$$= 2400 W$$

$$\frac{2400}{3000} \times 100 = 80\%$$

ENGAA 2019 Q8

8 The secondary coil of an ideal, 100% efficient transformer is connected to a resistor by cables of total resistance 1500 Ω. The current in the primary coil is 4.0 A. There are 240 turns in the primary coil and 4800 turns in the secondary coil.

What is the power produced as heat in the cables?

[✓ **A** 60 W]

B 300 W

C 6000 W

D 24 000 W

E 120 000 W

F 9 600 000 W

$$\frac{N_p}{N_s} = \frac{I_s}{I_p}$$

$$I_s = \frac{240}{4800} \times 4.0$$

$$= \frac{1}{20} \times 4.0 = 0.2A$$

$$P = I^2R = 0.2^2 \times 1500$$

$$= 0.04 \times 1500 = 60W$$