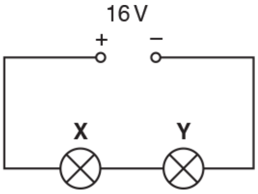
Power

1. Two filament lamps **X** and **Y** are connected in series with a 16 V d.c. supply. The supply has negligible internal resistance.



Lamp **X** emits a power of 2.0 W and lamp **Y** emits a power of 6.0 W.

What is the potential difference across the lamp **X**?

A 1.0 V
B 4.0 V
C 12 V
D 16 V

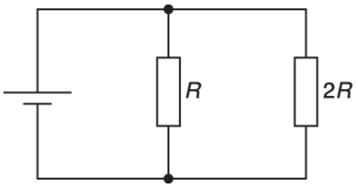
Your answer [1]

2. Which order of magnitude gives the best estimate for the wavelength in metres of microwave radiation just beyond the infra-red part of the electromagnetic spectrum?

A. 10^{3}
B. 1
C. 10^{-3}
D. 10^{-6}

Your answer [1]

3. A resistor of resistance *R* is connected in parallel with a resistor of resistance 2*R*. The combination of resistors is connected to a cell.



What is the ratio $\dfrac{\text{power dissipated in resistor of resistance } R}{\text{power dissipated in resistor of resistance } 2R}$?

A $\frac{1}{4}$ **B** $\frac{1}{2}$

C 1 **D** 2

Your answer [1]

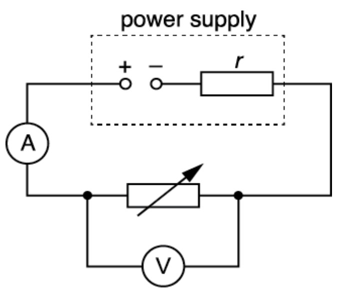
4. The potential difference across a lamp is 2.5 V. The current in the lamp is 20 mA.

What is the energy dissipated in the lamp in 3.0 hours?

A 0.050 J
B 0.15 J
C 9.0 J
D 540 J

Your answer [1]

5. A variable resistor is connected across the terminals of a power supply of constant e.m.f. and internal resistance *r*.



The resistance of the variable resistor is changed from zero to its maximum value.

Which of the following statements is/are correct?

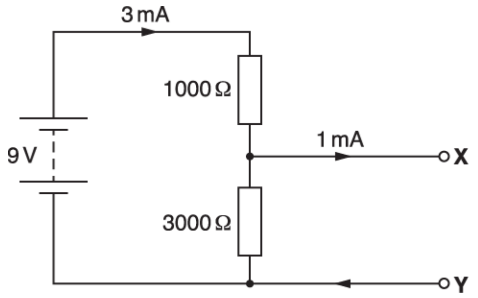
1 The current in the circuit decreases.
2 The p.d. across the internal resistance decreases.
3 A graph plotted of terminal p.d. against current has a negative gradient.

A Only 1
B Only 1 and 2
C Only 1 and 3
D 1, 2 and 3

Your answer

[1]

6. A 9V battery is connected to two resistors as shown. The terminals **X** and **Y** are connected to another circuit that draws a current of 1 mA. The current from the battery is 3 mA.



What is the power supplied to the circuit connected between **X** and **Y**?

A 6 mW
B 12 mW
C 18 mW
D 27 mW

Your answer

[1]

7. A small heater is connected to a power supply. The power supply is switched on for 100 s. The current in the heater is 3.0 A and it dissipates 1200 J of thermal energy.

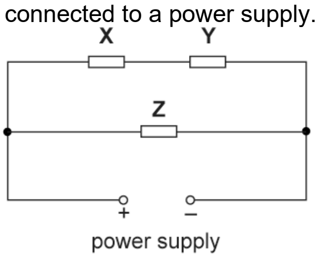
What is the potential difference across the heater?

A 0.25V
B 4.0V
C 12V
D 300V

Your answer

[1]

8. Three identical resistors **X**, **Y** and **Z** are connected to a power supply.



The power dissipated in the resistor **Z** is 24 W.

What is the power dissipated in the resistor **Y**?

A 6.0 W
B 12 W
C 24 W
D 48 W

Your answer **[1]**

9. Which is **not** a unit of energy?

A kW h
B eV
C J
D W

Your answer **[1]**

10. A student determines the power *P* dissipated in a resistor. The measured values of the current **I** in the resistor and the resistance *R* of the resistor are:

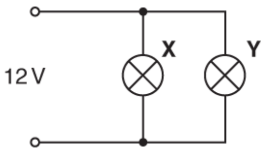
$$I = (4.0 \pm 0.2)\ \text{A and } R = (3.0 \pm 0.3)\Omega$$

The equation $P = I^2R$ is used to calculate *P*.
What is the percentage uncertainty in the value of *P*?

A 15%
B 20%
C 25%
D 30%

Your answer **[1]**

11. Two filament lamps **X** and **Y** are connected in parallel to a supply.
The power dissipated by lamp **X** is 24 W and the power dissipated by lamp **Y** is 6.0 W.
The supply has electromotive force (e.m.f.) 12 V and negligible internal resistance.



What is the total current drawn from the supply by the lamps?

A 0.4A

B 0.5A

C 2.0A

D 2.5A

Your answer [1]

12. The graph in **Fig. 20.1** below shows the variation of force with extension for a single spring.

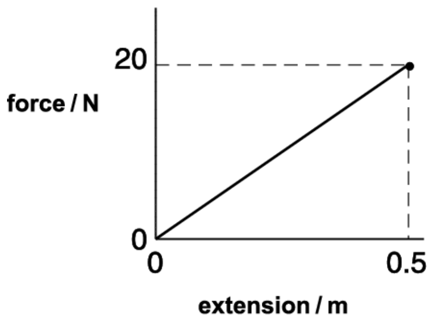


Fig. 20.1

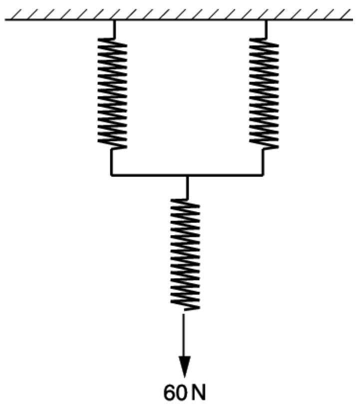


Fig. 20.2

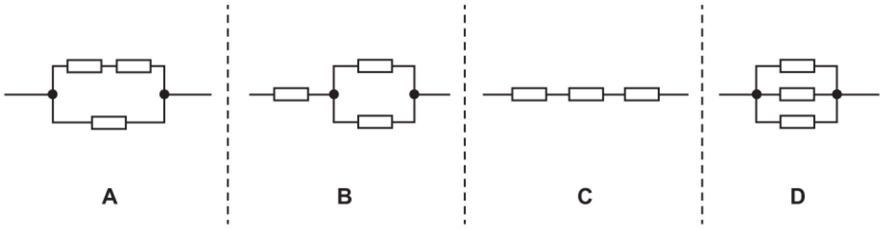
Three of these springs are joined together as shown in **Fig. 20.2** and a force of 60 N applied.
What is the distance moved by the 60 N force (to 2 s.f.)?

A. 1.5 m
B. 2.0 m
C. 2.3 m
D. 3.0 m

Your answer

[1]

13. Four electrical circuits are shown below.



All the resistors are identical.
Each circuit is connected to the same power supply.

Which circuit dissipates the **least** power?

Your answer [1]

14. The p.d. across a resistor is 12 V. The power dissipated is 6.0 W.

Which statement is correct?

A. The charge passing through the resistor in one second is 2.0 coulomb.
B. The resistor transfers 6.0 joule for each coulomb passing through the resistor.
C. The resistor transfers 12 joule in 2.0 second.
D. The resistor dissipates 6.0 joule when the current is 2.0 ampere.

Your answer

[1]

15. A battery of e.m.f. of 8.0 V and internal resistance 2.5 Ω is connected to an external resistor. The current in the resistor is 350 mA.

What is the power dissipated in the external resistor?

A. 1.9 W
B. 2.5 W
C. 2.8 W
D. 3.1 W

Your answer

[1]

16. A filament lamp is described as being 120 V, 60 W. The lamp is connected to a supply so that it lights normally.

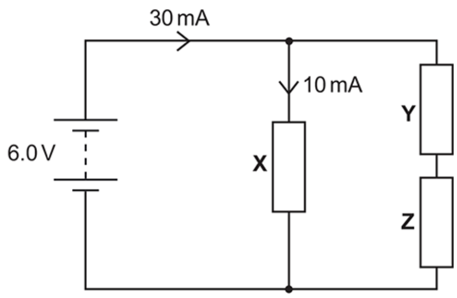
Which statement is correct?

A. The charge passing through the filament in one second is 2.0 coulomb.
B. The lamp transfers 60 joule for each coulomb passing through the filament.
C. The lamp transfers 120 joule in 2.0 second.
D. The supply provides 60 joule to the lamp when the current is 2.0 ampere.

Your answer

[1]

17. A battery of electromotive force (e.m.f) 6.0 V and of negligible internal resistance is used in the circuit below.



The current from the battery is 30 mA. The current in the resistor **X** is 10 mA.
The resistors **Y** and **Z** are identical.

What is the power dissipated in the resistor **Z**?

A 30 mW
B 60 mW
C 120 mW
D 180 mW

Your answer [ ] **[1]**

18. A wire **X** has length *L* and radius *r*. Another wire **Y** made of the same material as **X** has length 2*L* and radius 3*r*. The wires are connected in **parallel** to a battery.

What is the correct ratio of

$$\frac{\text{power dissipated in } \mathbf{Y}}{\text{power dissipated in } \mathbf{X}}?$$

A 0.22
B 1.0
C 4.5
D 6.2

Your answer [ ] **[1]**

19. A student is given two identical filament lamps. Each lamp is labelled as '12 V, 24 W'. The student connects the two lamps in series across a 12 V supply of negligible internal resistance.

Which of the following statements is / are true when the lamps are in **series**?

1 The resistance of each lamp is 6.0 Ω
2 The current in the circuit is greater than 1.0 A.
3 The potential difference across each lamp is 6.0 V.

A 1, 2 and 3
B Only 2 and 3
C Only 1 and 2
D Only 2

Your answer

[1]

20. The current in a lamp is 2.0 mA. The potential difference across the lamp is 6.0 V.

What is the energy transfer in the lamp over a period of 3.0 hours?

A 0.012 J
B 0.036 J
C 2.16 J
D 130 J

Your answer **[1]**

21. In a particle-accelerator electrons are accelerated through a potential difference of 120 kV. The electron beam current is 8.0 μA.

What is the total energy transferred to the electrons in a time of 2.0 hours?

A 0.96 J
B 120 J
C 1900 J
D 6900 J

Your answer **[1]**

22. A household is planning to change all their 60 W filament bulbs to 12 W LED bulbs.
The household has a total of 10 bulbs.
Each bulb will be used for about 2000 hours in one year.
The cost of 1 kWh is 15.4 p.

What would the annual saving be?

A £7.39
B £36.96
C £147.84
D £184.80

Your answer [ ] **[1]**

23. The cost of 1 kWh of energy is 16p.
Calculate the cost of using the heater for 5.0 hours.

cost = ... p **[2]**

24 (a). Some houses are heated by "night storage heaters" which use cheap electricity between the hours of midnight and 7.00 am.

Fig. 4.1 shows a circuit diagram of three identical 230 V, 3.5 kW storage heaters connected to a 230 V mains power supply of negligible internal resistance.

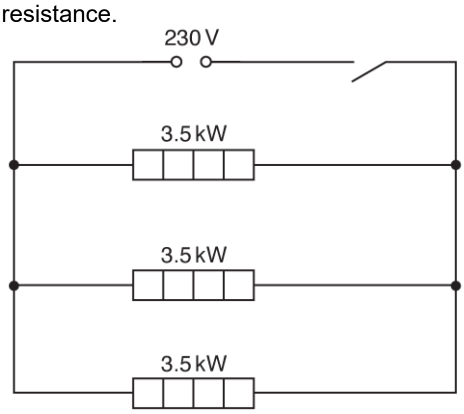


Fig. 4.1

i. Show that the resistance of each heating element is about 15 Ω when the heater is operating at 230 V.

[1]

ii. The heating element is constructed from a metallic wire of resistivity 1.6×10^{-6} Ω m.
The radius of the wire is 0.55 mm.
Determine the length L of the metallic wire in one heating element.

L = ... m **[3]**

iii. State and explain whether the heater obeys Ohm's law.

---

[2]

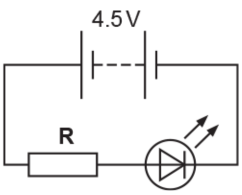
(b). The cost of 1 kW h of energy is 7.6 pence.

Calculate the cost of using the three storage heaters between midnight and 7.00 am every night for one week.

cost = £ .... **[2]**

25. A light-emitting diode (LED) emits red light when it is positively biased and has a potential difference (p.d.) greater than about 1.8 V.

An LED is connected into a circuit, as shown below.



The battery has electromotive force (e.m.f.) 4.5 V and negligible internal resistance.
The resistor **R** has resistance 150 Ω.
Assume the p.d. across the LED is 1.8 V.

Calculate the ratio $\frac{\text{power dissipated by LED}}{\text{power dissipated by resistor}}$.

ratio = ... **[2]**

26. Fig. 17.1 shows a resistor and a diode connected in series to a cell.

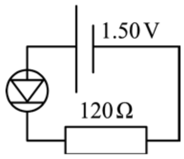


Fig. 17.1

The resistor has resistance 120 Ω. The cell has e.m.f. 1.50 V and negligible internal resistance. The potential difference across the diode is 0.62 V.

Calculate the total power dissipated in the circuit.

power = ... W **[3]**

27.

A student is investigating an unidentified component found in the laboratory.
The table shows the results from the lab book of the student.

V / V	**I / mA**
− 5.0	− 5.0
+ 5.0	+ 5.0
+ 10.0	+ 30.0

The potential difference across the component is *V* and the current through it is *I*.

i. Calculate the power dissipated by the component when *V* is +10.0 V.

power = W **[1]**

ii. Analyse the data in the table and hence identify the component.

----

[3]

28 (a). The International Space Station (ISS) orbits the Earth at a height of 4.1×10^5 m **above** the Earth's surface.

The radius of the Earth is 6.37×10^6 m. The gravitational field strength g_0 at the Earth's surface is 9.81 N kg^{-1}.

Both the ISS and the astronauts inside it are in free fall.

Explain why this makes the astronauts feel **weightless**.

---

[1]

(b).

i. Calculate the value of the gravitational field strength g at the height of the ISS above the Earth.

g = ... N kg^{-1} **[3]**

ii. The speed of the ISS in its orbit is 7.7 km s^{-1}. Show that the period of the ISS in its orbit is about 90 minutes.

[2]

(c). Use the information in **(b)(ii)** and the data below to show that the root mean square (r.m.s.) speed of the air molecules inside the ISS is approximately 15 times smaller than the orbital speed of the ISS.

- molar mass of air = 2.9×10^{-2} kg mol^{-1}
  temperature of air inside the ISS = 20 °C

[3]

(d). The ISS has arrays of solar cells on its wings. These solar cells charge batteries which power the ISS. The wings always face the Sun.

Use the data below and your answer to **(b)(ii)** to calculate the **average** power delivered to the batteries.

- The total area of the cells facing the solar radiation is 2500 m^2.
- 7% of the energy of the sunlight incident on the cells is stored in the batteries.
- The intensity of solar radiation at the orbit of the ISS is 1.4 kW m^{-2} outside of the Earth's shadow and zero inside it.
- The ISS passes through the Earth's shadow for 35 minutes during each orbit.

average power = ... W **[4]**

29 (a). The circuit diagram shows a battery of e.m.f. *E* and internal resistance *r* connected to a variable resistor *R*.

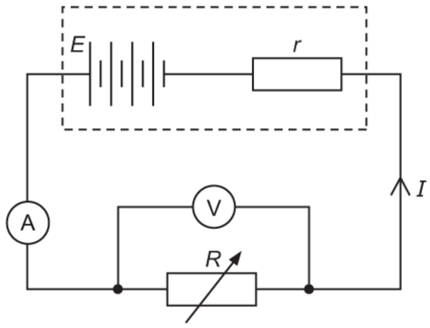


Fig. 5.1

The current *I* in the variable resistor is measured using an ammeter and the potential difference *V* across the variable resistor is measured using a voltmeter.

The resistance *R* of the variable resistor is varied. *I* and *V* are recorded for each value of *R*.
A graph of *V* (*y*-axis) against *I* (*x*-axis) is plotted.

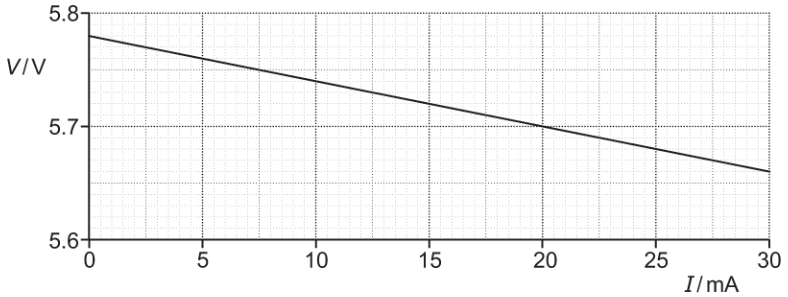


Fig. 5.2

Explain how values for *E* and *r* may be determined from the graph.
No calculations are required.

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[2]

(b). The resistance of the variable resistor is now fixed. The current is 25 mA.

i. Use the graph to determine the resistance *R* of the variable resistor.

R = ... Ω **[1]**

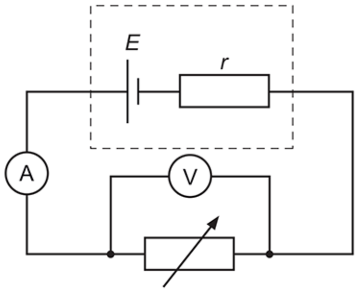
ii. Calculate the energy *W* dissipated in the variable resistor in 5.0 minutes.

W = ... J **[2]**

iii. Calculate the charge *Q* passing through the variable resistor in 5.0 minutes. Include an appropriate unit.

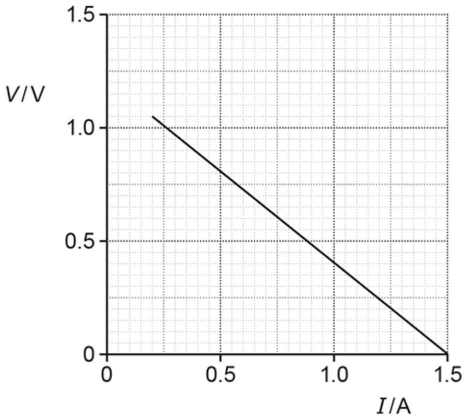
Q = ... unit .... **[2]**

30. A student is doing an experiment to determine the e.m.f. *E* of a cell and its internal resistance *r*.
The circuit diagram of the arrangement is shown below.



The student changes the resistance of the variable resistor. The potential difference *V* across the variable resistor and the current *I* in the circuit are measured.

The *V* against *I* graph plotted by the student is shown below.



V / V	I / A	R / Ω	P / W
0.20	1.25		
0.40	1.00		
0.60	0.75		
0.80	0.50		
1.00	0.25		

There is an incomplete table next to the graph.
R is the resistance of the variable resistor and *P* is the power dissipated by the variable resistor.

- Use the graph to determine E and r. Explain your reasoning.
- Calculate *R* and *P* to complete the table. Describe how P depends on R.

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[6]

31. This question is about an electric cooker, which consists of an oven and an electromagnetic induction hob.

The electromagnetic induction hob is shown in **Fig. 4.1.**

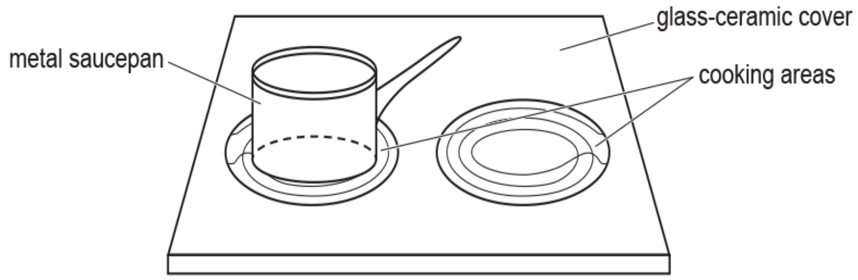

Fig. 4.1

Each cooking area has a coil below the glass-ceramic cover. When switched on, the coils carry a high-frequency **alternating** current.

A metal saucepan is placed above one of the coils. A large alternating current is induced in the saucepan base, and this causes the saucepan to heat up.

i. **Fig. 4.2**shows one of the coils at a time when the current is in the direction indicated by the arrows.

Fig. 4.2

On **Fig. 4.2**, sketch the magnetic field pattern for the current-carrying coil.

[2]

ii. **Fig. 4.3** shows the path of the large alternating current induced in the metal base of the saucepan

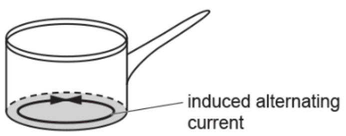

Fig. 4.3

Explain the origin of this large current.

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[2]

iii. Explain why it would be safe for a person to place a hand on the cooking area before the saucepan is put onto it.

[2]

32. A student wishes to determine experimentally the efficiency of a small low-voltage DC motor. The motor is used to lift light loads.

Describe with the aid of a suitable diagram how an experiment to determine the efficiency of the electric motor can be safely conducted, and how the data can be analysed.

----
[6]

33. A 150 W heater constructed from nichrome wire is switched on for 5.0 hours.

The wire has a cross-sectional area of 4.1×10^{-9} m^2.
The current in the wire is 1.5 A.
The number density of charge carriers in nichrome is 7.9×10^{28} m^{-3}.

Calculate

i. the resistance *R* of the heater

R = ... Ω **[2]**

ii. the number *N* of electrons passing through the heater in 5.0 hours

N = ... **[2]**

iii. the mean drift velocity *v* of the electrons (charge carriers) in the heater.

v = ... ms^{-1} **[2]**

34. A student is investigating a 230 V, 1.0 kW heating element. The heating element is shown in Fig. 1.2.

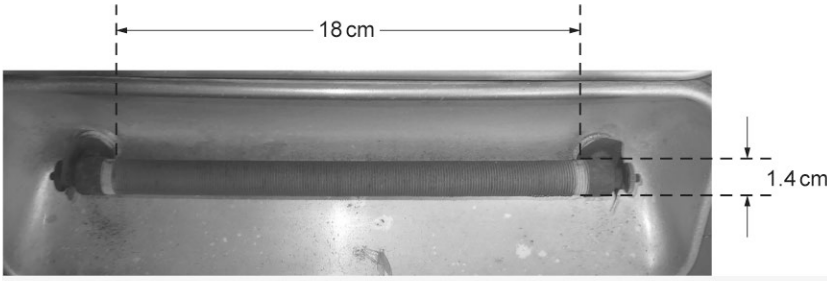


Fig. 1.2

A length of nichrome wire is wound in a spiral groove along 18 cm of a ceramic cylinder of diameter 1.4 cm. The distance between the centres of adjacent turns of the wire is 1.5 mm.

The numbers labelling the reels of loose wire on the laboratory shelf are the *imperial standard wire gauge* (swg). The student wishes to find out which reel holds the same wire as that wound on the heating element of Fig. 1.2.

The book of data gives the following information:

resistivity of nichrome at operating temperature = $1.1 \times 10^{-6}\ \Omega\ m$

swg	24	26	28	30	32
diameter of wire / 10^{-3} m	0.56	0.46	0.38	0.32	0.27
cross-sectional area / 10^{-6} m^2	0.25	0.16	0.11	0.08	0.06

i. Show that the resistance of the nichrome wire wound on the ceramic cylinder is 53 Ω.

[2]

ii. Show that the length of wire wound on the heating element is 5.3 m.

[2]

iii. Use the information given in **(i)** and **(ii)** to determine the swg number of the wire used as the heating element.

swg number = **[3]**

35 (a).

A student conducts an experiment to confirm that the uniform magnetic flux density B between the poles of a magnet is 30 mT.

A current-carrying wire of length 5.0 cm is placed perpendicular to the magnetic field.

The current I in the wire is changed and the force F experienced by the wire is measured. Fig. 22.1 shows the graph plotted by the student.

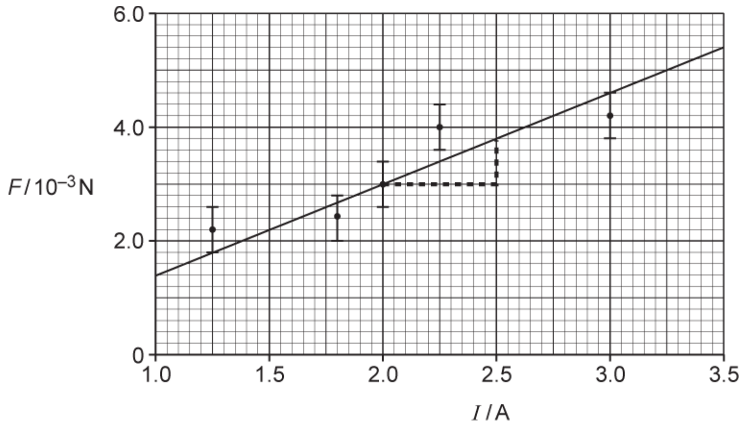


Fig. 22.1

The student's analysis is shown on the graph of Fig. 22.1 and in the space below.

$F = BIL$

$$\text{gradient} = BL = \frac{(3.8 - 3.0) \times 10^{-3}}{2.5 - 2.0} = 0.0016$$

$$B = \frac{0.0016}{0.05} = 0.032\ \text{T} = 32\ \text{mT}$$

This is just 2 mT out from the 30 mT value given by the manufacturer, so the experiment is very accurate.

Evaluate the information from Fig. 22.1 and the analysis of the data from the experiment. No further calculations are necessary.

[6]

(b). Fig. 22.2 shows a transformer circuit.

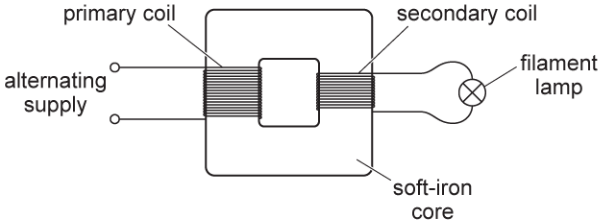


Fig. 22.2

The primary coil is connected to an alternating voltage supply. A filament lamp is connected to the output of the secondary coil.

i. Use Faraday's law of electromagnetic induction to explain why the filament lamp is lit.

[3]

ii. The primary coil has 400 turns and the secondary coil has 20 turns. The potential difference across the lamp is 12 V and it dissipates 24 W. The transformer is 100% efficient.

1. Calculate the current in the primary coil.

current = ... A **[2]**

2. The alternating voltage supply is replaced by a battery and an open switch in series. The switch is closed. The lamp is lit for a short period of time and then remains off. Explain this observation.

[2]

36. Fig. 1 shows a high-speed electric train.

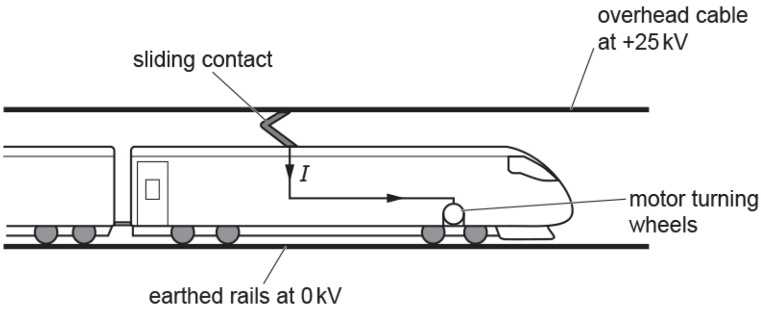


Fig. 1

The potential difference between the overhead cable and the rails on the ground is 25 kV.
The sliding contact on the top of the train constantly touches the overhead cable.
The overhead cable supplies a current I to the electric motor of the train.
The motor turns the wheels. The train experiences a **resultant** forward force *F*.

The total mass of the train is 2.1×10^5 kg.

The train accelerates from rest. The value of F is 190 kN for speeds less than 6.0 m s^{-1}.

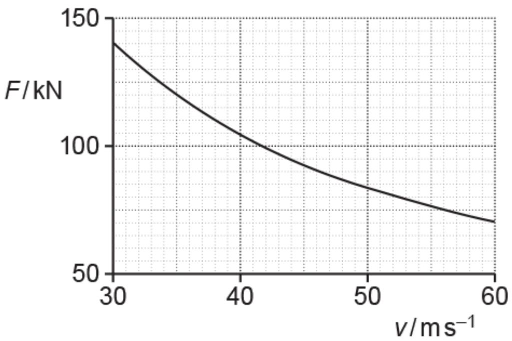
i. Show that the train's acceleration is about 1 m s^{-2}.

[1]

ii. Calculate the distance s that the train travels to reach a speed of 6.0 m s^{-1}.

s = ... m**[2]**

iii. The speed of the train is v.
During one period of its journey, the train accelerates from v = 30 m s^{-1} to v = 60 m s^{-1}.
The graph of *F* against v for this period is shown below.



1. Use the graph to show that output power of the electric motor during this period is constant at about 4 MW.

[3]

2. Calculate the current *I* in the electric motor when the train is travelling at 50 m s^{-1}.

I = ... A**[2]**

37. A filament lamp **X** is part of an electrical circuit. The circuit has a battery of electromotive force (e.m.f.) 6.0 V and negligible internal resistance. The potential difference across the lamp can be increased **continuously** from 0 to 6.0 V. This potential difference is measured using a voltmeter.
The lamp glows brightly at 6.0 V.

i. Draw a circuit diagram for this electrical arrangement.

[2]

ii. Describe and explain the variation of the resistance of this lamp as the potential difference across it is changed from 0 to 6.0 V.

[4]

iii. The filament lamp **X** is now connected in a different circuit as shown in Fig. 16.

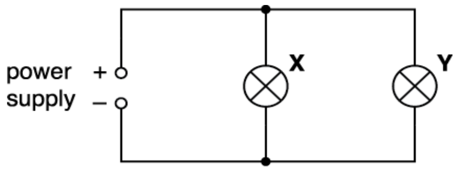


Fig. 16

The power dissipated in **X** is three times more than the power dissipated in the filamentlamp **Y**. The filament wire of lamp **X** has a diameter half that of lamp **Y**.
The filament wires of **X** and **Y** are made of the same material and are at the same temperature.

Calculate the ratio

$$\frac{\text{mean drift velocity of charge carriers in lamp } \mathbf{X}}{\text{mean drift velocity of charge carriers in lamp } \mathbf{Y}}.$$

ratio = ... **[3]**

END OF QUESTION PAPER