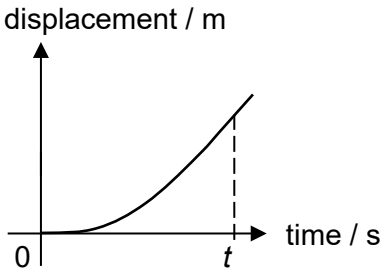
Section A [30 marks]

Four possible answers **A**, **B**, **C** and **D** are given for each question. Choose the **most appropriate answer** and shade your answers in pencil on the OTAS answer sheet provided.

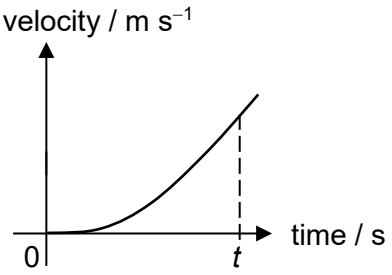
1 Which option consists of a pair of SI base unit?

A	ampere	joule
B	newton	second
C	kilogram	kelvin
D	metre	coulomb

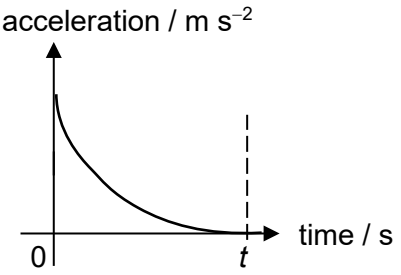
2 A box is dropped from a tall building. As the box falls, air resistance has a noticeable effect on its motion.



Graph 1



Graph 2

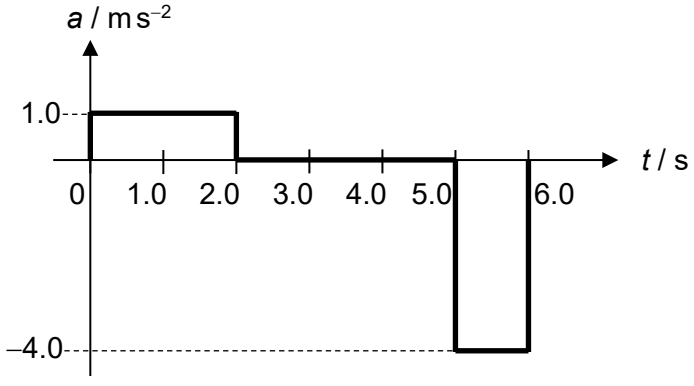


Graph 3

How many graph(s) correctly describe(s) the motion of the box from time 0 s to time *t*?

A 0 **B** 1 **C** 2 **D** 3

3 An object is moving with an initial velocity of 6.0 m s^{-1} to the right when it undergoes acceleration for a duration of 6.0 s as shown. Take displacement to the right as positive.



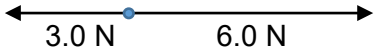
What is the velocity of the object after 6.0 s?

A –2.0 m s^{-1} **B** 2.0 m s^{-1} **C** 4.0 m s^{-1} **D** 8.0 m s^{-1}

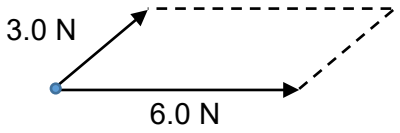
4 Forces of 3.0 N and 6.0 N act at a point.

Which vector diagram shows a resultant of 6.0 N?

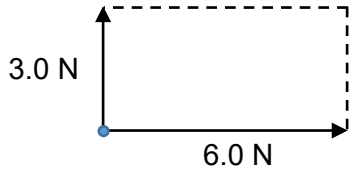
A



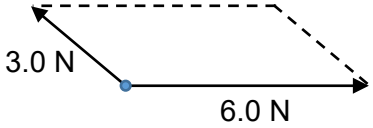
B



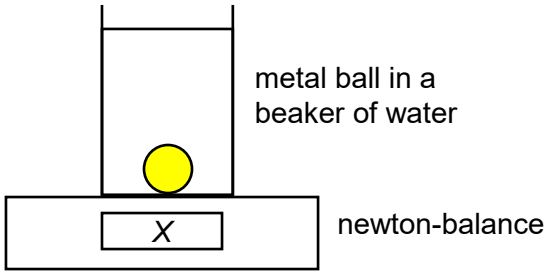
C



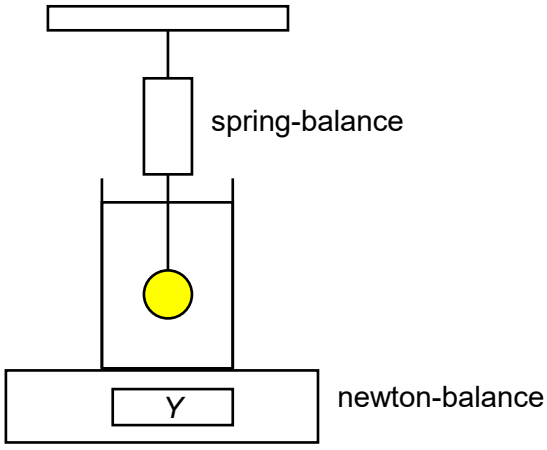
D



5 When a metal ball of weight *W* is placed inside a beaker of water, the newton-balance reads *X*.



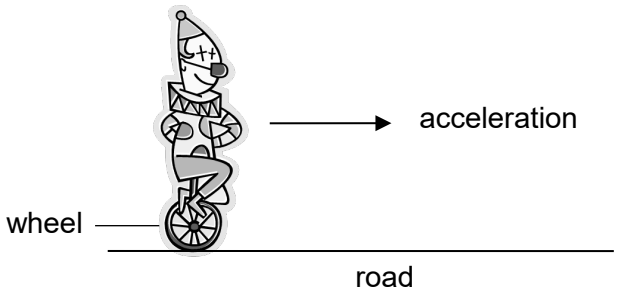
When the immersed metal ball is suspended by a spring-balance, the newton-balance reads *Y*.



What is the reading of the spring balance?

A $X - W$ **B** $X - Y$ **C** $Y - W$ **D** Y

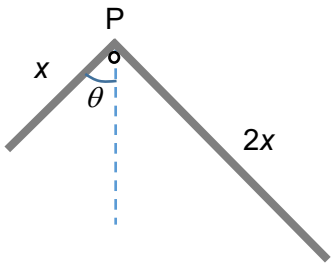
6 A clown on a unicycle accelerates to the right as shown.



What is the direction of the frictional force acting on the wheel?

A ← **B** → **C** ↖ **D** ↗

7 An L-shaped bar of uniform density and uniform cross-sectional area is hung on a frictionless pin P at its right-angle corner as shown. The lengths of the sides are x and $2x$ respectively.



What is the angle θ that the shorter arm makes with the vertical?

A 14° **B** 27° **C** 63° **D** 76°

8 An object of mass 2.0 kg is falling at a speed of 3.00 m s^{-1} at one particular instant. It experiences an average resistive force of 1.0 N as it falls .

What is the gain in kinetic energy of the object after it falls a further distance of 15.0 m?

A 279 J **B** 288 J **C** 294 J **D** 303 J

9 A scientist is shown a collection of electric cars. He is provided with only four measuring instruments and tasked to determine which of the cars has the greatest power.

Which instrument will be the least useful to the scientist?

A industrial weighing scale
B speedometer
C stopwatch
D voltmeter

10 Which information cannot be determined from the displacement-time graph of a wave?

A amplitude
B frequency
C period
D wavelength

11 A ship emits an ultrasound of wavelength 7.10×10^{-2} m to determine the depth of the sea. The time interval between emitting the ultrasound and detecting the echo is 38500 times the period of the ultrasound.

What is the depth of the sea?

A 1370 m
B 2730 m
C 5470 m
D 5.42×10^{5} m

12 Which factor will not affect the rate of evaporation?

A depth of liquid
B humidity of surrounding air
C temperature of liquid
D pressure of surrounding air

13 A student mixes 0.200 kg of water at 0 °C with ice at −10.0 °C at standard atmospheric pressure.

specific heat capacity of water,	c_w	= 4200 J/kg.°C
specific heat capacity of ice,	c_i	= 2100 J/kg.°C
specific heat capacity of steam,	c_s	= 2000 J/kg.°C
specific latent heat of fusion of ice,	l_f	= 3.34×10^{5} J/kg
specific latent heat of vaporization of water,	l_v	= 2.26×10^{6} J/kg

What is the minimum mass of ice needed to turn the water into ice?

A 0.200 kg
B 1.59 kg
C 2.00 kg
D 3.18 kg

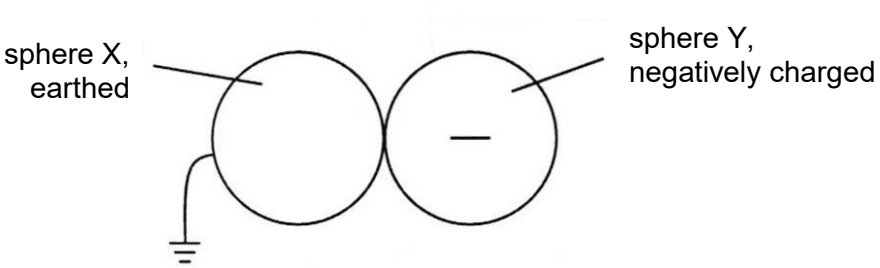
14 A positively charged ball A attracts ball B.

Which statement(s) about ball B is/are possible?

1. It has a smaller net positive charge than ball A.
2. It is neutral.
3. It is earthed.

A statement 2 only
B statement 3 only
C statements 2 and 3 only
D All the statements are possible.

15 The diagram shows two spheres X and Y of unknown materials touching each other. Sphere X is earthed and sphere Y is negatively charged.

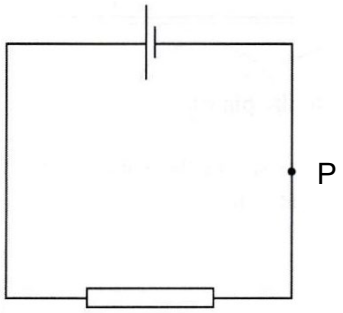


The earth connection is removed from sphere X and then the spheres are separated. Sphere X is found to be positively charged and sphere Y remains negatively charged.

Which of the following describes the nature of the materials of the spheres?

	sphere X	sphere Y
A	insulator	insulator
B	insulator	conductor
C	conductor	insulator
D	conductor	conductor

16 In the circuit below, n charge carriers pass through point P in time t. Each charge carrier has charge q.



What is the current in the circuit?

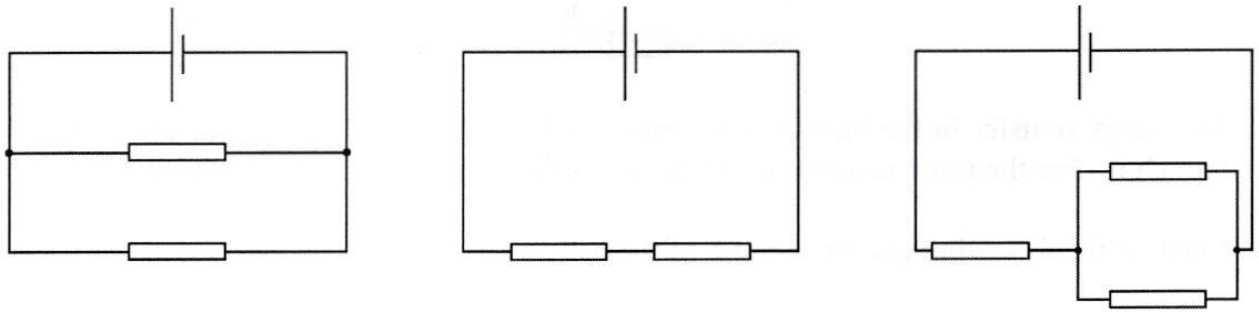
A $\frac{q}{t}$ **B** $\frac{nq}{t}$ **C** $\frac{qt}{n}$ **D** nqt

17 When the potential difference across an ohmic conductor is V, its resistance is R.

What is the resistance of the ohmic conductor when the potential difference across it is $\frac{V}{2}$?

A $\frac{R}{2}$ **B** R **C** $2R$ **D** $4R$

18 The cells in circuits X, Y and Z have the same e.m.f. and zero internal resistance. The resistors in the circuits have the same resistance.

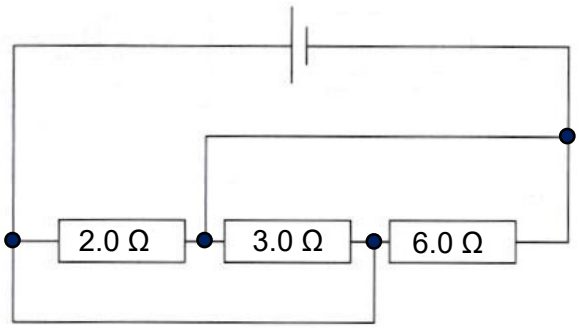


circuit X circuit Y circuit Z

Which of the following gives the current through the cells in increasing order?

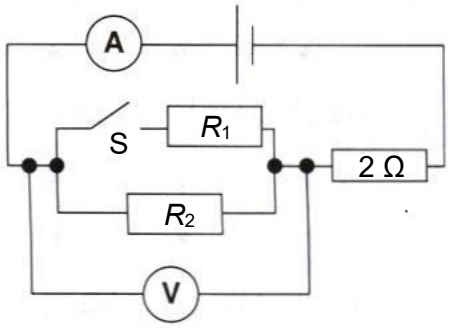
	lowest current	→	highest current
A	X	Z	Y
B	Z	Y	X
C	Y	Z	X
D	Y	X	Z

19 What is the effective resistance of the circuit below?



A 1.0 Ω
B 2.0 Ω
C 4.0 Ω
D 11 Ω

20 Resistors of resistances R_1 and R_2 are connected in a circuit as shown below. When switch S is opened, the ammeter reads 1.5 A and the voltmeter reads 9.0 V. When switch S is closed, the ammeter reads 3.0 A and the voltmeter reads 6.0 V.



What are resistances R_1 and R_2?

	R_1 / Ω	R_2 / Ω
A	2.0	6.0
B	3.0	6.0
C	2.0	8.0
D	3.0	8.0

21 The table below shows the cost of using solar energy to power a 100 W heater for 24 hours each day.

price of solar panel and installation	maintenance fee per year
$ 2500	$ 100

The estimated cost of purchasing electricity from an electrical retailer is $0.40 per kWh for the next 20 years.

What is the minimum number of years before the cost of using solar energy is totally recovered?

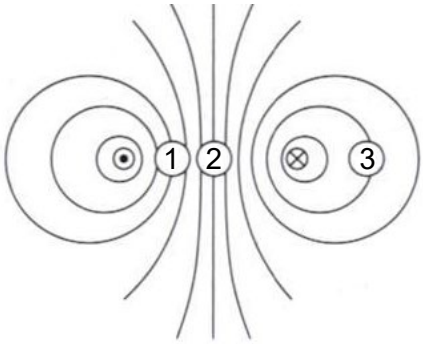
A 5 years
B 10 years
C 15 years
D 20 years

22 A 10 Ω resistor and a 20 Ω resistor are connected in parallel to a battery.

What is the ratio of the power dissipated by the 10 Ω resistor to the power dissipated by the 20 Ω resistor?

A 1 : 2
B 1 : 4
C 2 : 1
D 4 : 1

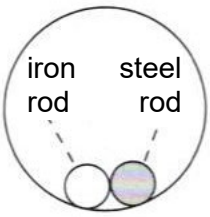
23 The diagram below shows the magnetic field lines due to two current-carrying wires that are perpendicular to the plane of the paper.



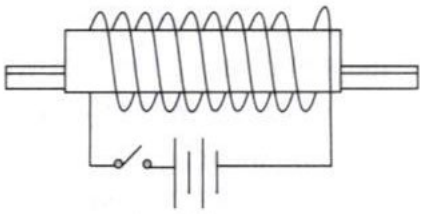
Which set of compasses shows the correct directions of the needles at positions 1, 2 and 3?

	position 1	position 2	position 3
A	↑	↑	↓
B	↑	↓	↓
C	↓	↓	↑
D	↓	↑	↓

24 An iron rod and a steel rod are placed inside a solenoid that is connected to a d.c. supply.



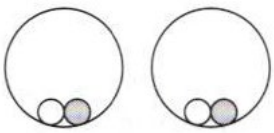
side view



front view

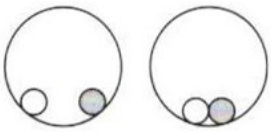
Which diagram shows the side view of the rods when the circuit is switched on for a while, before it is switched off again?

A



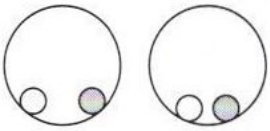
on off again

B



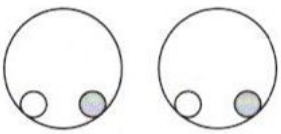
on off again

C



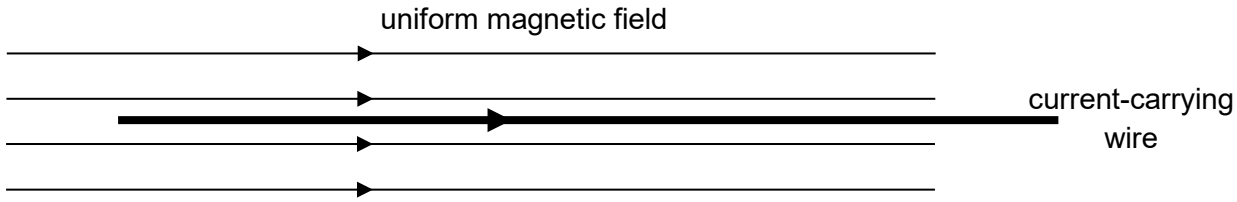
on off again

D



on off again

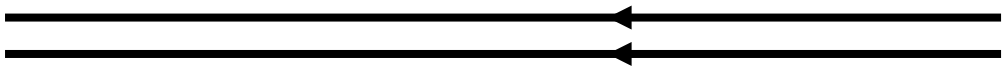
25 The diagram shows a current-carry wire in a uniform magnetic field.



Which modification will increase the magnetic force acting on the wire?

A increase the strength of the magnetic field
B increase the current
C reverse the direction of the magnetic field
D none of the above

26 The diagram shows two current-carrying conductors parallel to each other near the surface of the earth. The two conductors are initially held at rest, one above the other. The lower conductor is then released.



There are five possibilities with regard to the initial acceleration of the lower conductor immediately upon release. Take downward acceleration as positive.

- Initial acceleration is negative.
- Initial acceleration is zero.
- Initial acceleration is greater than zero but less than gravitational acceleration.
- Initial acceleration is equal to gravitational acceleration.
- Initial acceleration is greater than gravitational acceleration.

How many of these five possibilities may occur?

A 1 **B** 2 **C** 3 **D** 4

27 Which design aspect will not improve the efficiency of a transformer?

A using a steel core instead of an iron core
B using a laminated core
C using thicker copper wires
D using a special core design to completely link the magnetic field from the primary coil to the secondary coil

28 A transformer has a turns ratio of 4.0, and the current in the primary coil is 20.0 A.

What is the current in the secondary coil, if the efficiency of the transformer is 60.0%?

A 3.0 A **B** 8.3 A **C** 48 A **D** 130 A

29 Diagram 1 shows the oscilloscope trace produced by an input of maximum voltage 4.0 V and frequency 20.0 Hz.

Diagram 2 shows the trace from a second input on the same oscilloscope with the controls set at the same value.

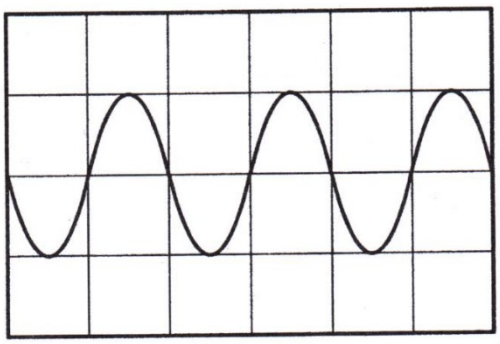


diagram 1

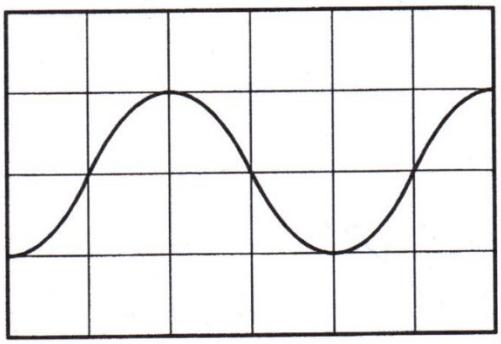
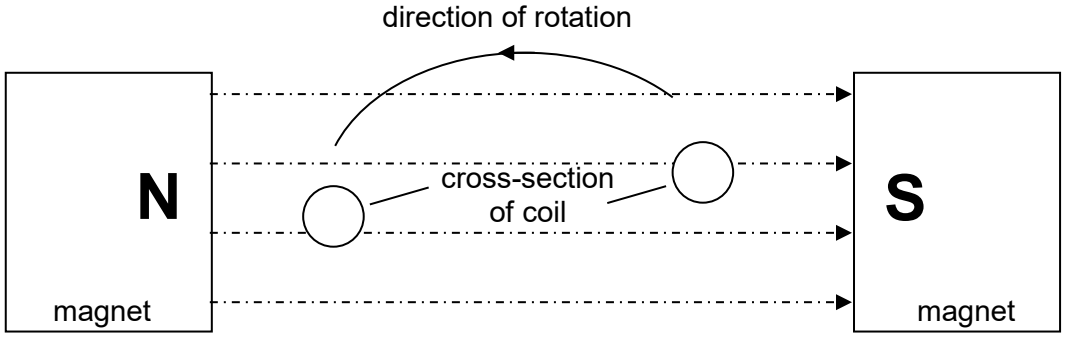


diagram 2

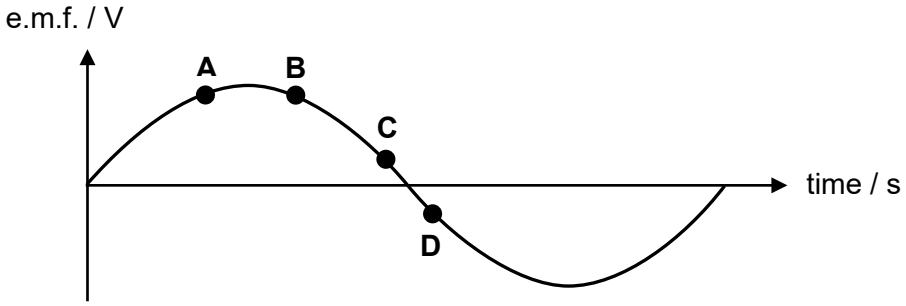
What are the values of maximum voltage and frequency of the second input?

A 2.0 V and 20.0 Hz
B 4.0 V and 10.0 Hz
C 4.0 V and 40.0 Hz
D 8.0 V and 20.0 Hz

30 The diagram shows the cross-section of a simple a.c. generator. The coil is at a position where it is slightly inclined to the horizontal. The coil is rotating anticlockwise.



Which point on the graph below best represents the induced e.m.f. in the coil at this position?



End of Section A

Section B [50 marks]

Write your **answers to Questions 31 to 41 in the spaces provided in each question**. Show your workings clearly where necessary. All quantitative answers should include appropriate units and be quoted to a suitable number of significant figures.

Question 34(c) indicated with an * is optional and will count towards your total marks. Your total marks will remain limited to a maximum of **80 marks**.

31 The mathematical expression describing the viscous force F acting on a sphere of radius r moving with speed v in a stationary fluid of viscosity η was determined by the physicist George Stokes as

$$F = 6 \pi \eta r v$$

Determine the SI base units of viscosity η.

SI base units of viscosity η = ... [2]

32 **(a)** A body is moving with an initial velocity u. After undergoing an acceleration a for a duration of time t, the body has a displacement s given by

$$s = ut + \frac{1}{2}at^2$$

State two conditions that must be satisfied for the above equation to be valid.

.....

.....

..... [2]

(b) A hot air balloon carrying two sand-bags P and Q rises vertically at a constant velocity of 10.0 m s^{-1}, as shown in Fig. 32.1.

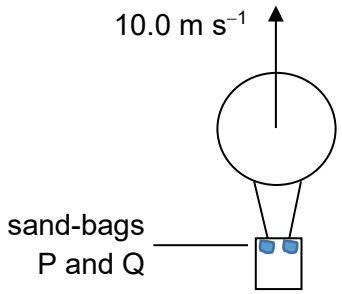


Fig. 32.1

In mid-flight, sand-bag P is released from the hot air balloon.

Assume that the hot air balloon continues to rise at the constant velocity of 10.0 m s^{-1} and that air resistance is negligible.

After a duration of 4.00 s, determine

(i) the displacement of sand-bag P from its point of release,

displacement of sand-bag P = ... [1]

(ii) the distance between sand-bag P and the hot air balloon.

distance between sand-bag P and hot air balloon = ... [2]

(c) A wind of speed 3.0 m s^{-1} starts to blow continuously towards the right.

(i) Calculate the magnitude and direction of the resultant velocity of the hot air balloon.

magnitude of resultant velocity = ...

direction of resultant velocity = ... [2]

(ii) With the wind still blowing horizontally towards the right, sand-bag Q is released from the hot air balloon. Sand-bag Q takes time *t* to reach the ground.

State the changes to the time *t*, if any, in the absence of the wind.

.....

..... [1]

33 A uniform rod of weight 5.00 N and length 10.0 m rests on two supports A and B placed 1.00 m and 2.00 m respectively from each end, as shown in Fig. 33.1.

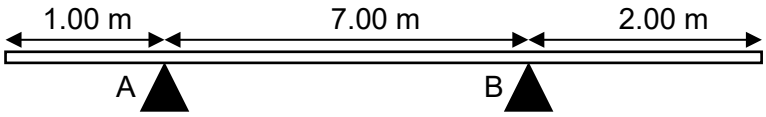


Fig. 33.1 (not drawn to scale)

(a) By taking moments about support A, determine the contact force due to support B acting on the rod.

contact force due to support B = ... [2]

(b) By considering forces in equilibrium, or otherwise, determine the contact force due to support A acting on the rod.

contact force due to support A = ... [1]

34 It is common for high-speed trains to utilize electromagnetic induction brakes to decelerate. Eddy currents are induced in the metal wheels through electromagnetic induction.

(a) A train with a total mass of 2.79×10^5 kg decelerates uniformly from 35.0 m s^{-1} to 15.0 m s^{-1}.

Calculate the loss of kinetic energy of the train.

loss of kinetic energy = ... [2]

(b) The kinetic energy of the train is converted to thermal energy in the metal wheels. Different metals are being considered as the material for the wheels. The volume of metal used will be the same regardless of the metal chosen. The properties of the four different metals A, B, C, and D are shown in Fig. 34.1.

metal	density / kg m^{-3}	melting point / K	specific heat capacity / J kg^{-1} K^{-1}
A	7500	1533	450
B	7800	1703	500
C	2700	930	900
D	4500	1940	544

Fig. 34.1

Using Fig. 34.1, state and explain which metal is the most suitable material for the wheels.

.....

.....

..... [2]

***(c)** For the comfort of the passengers, trains are usually limited to the following:

- maximum acceleration of 1.25 m s^{-2}
- maximum deceleration of 0.80 m s^{-2}
- maximum speed of 40.0 m s^{-1}

One train is making a journey on a straight horizontal track from one town to another. The total distance of the journey is 5.00 km. However, due to safety concerns, a region of 1.00 km as indicated in Fig. 34.2 requires the train to move at a maximum speed of 21.0 m s^{-1}. The train starts from rest at the start point and comes to rest at the end point.

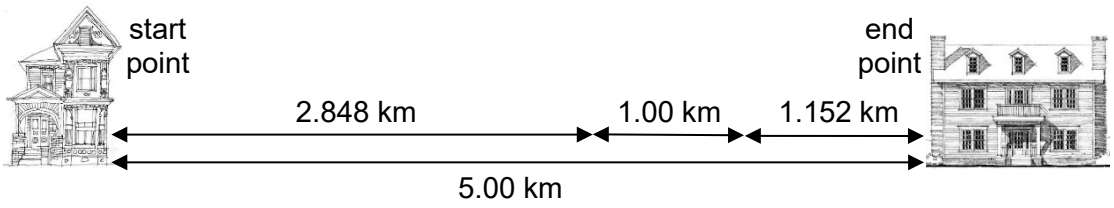


Fig. 34.2

Calculate the shortest time for the 5.00 km journey.

shortest time = ... [3]

35 Explain why a neutral body can be attracted to a positively charged body.

.....

.....

..... [2]

36 Fig. 36.1 shows a NTC thermistor and a fixed resistor of resistance 8.00 kΩ connected to a 12.0 V power supply.

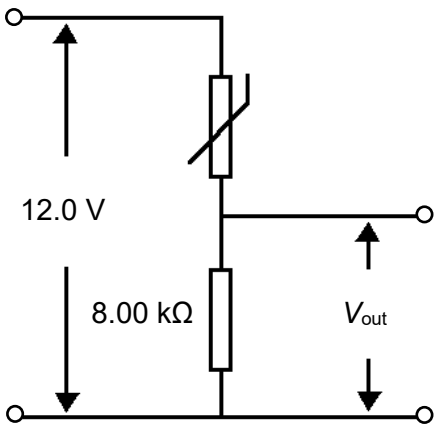


Fig. 36.1

(a) The thermistor has a resistance of 600 Ω at a temperature of 300 °C.

Calculate the output voltage V_{out} when the thermistor is at this temperature.

V_{out} = ... [2]

(b) When the temperature of the thermistor is 25 °C, V_{out} is 8.0 V.

At this temperature, determine

(i) the potential difference across the thermistor,

potential difference = ... [1]

(ii) the resistance of the thermistor.

resistance = ... [1]

(c) A device connected across V_{out} in Fig. 36.1 switches on when V_{out} exceeds 8.0 V.

Name one such device and explain how it works.

.....

.....

.....

..... [2]

37 Fig. 37.1 shows the specifications of two kettles.

	input electrical power / kW	potential difference / V	efficiency / %	capacity / litre
kettle A	2.80	230	70	4.0
kettle B	3.00	230	60	4.0

Fig. 37.1

Explain which kettle boils water, initially at room temperature, in a shorter time. Show your working.

.....

.....

.....

..... [2]

38 Describe an electrical method to demagnetize a bar magnet.

.....

.....

.....

..... [2]

39 Fig. 39.1 shows the cross-section of a rectangular copper coil (represented by two circles) and magnets, as part of a simple d.c. motor.

The dotted circle represents the path traced by the coil as it rotates about its axis X.

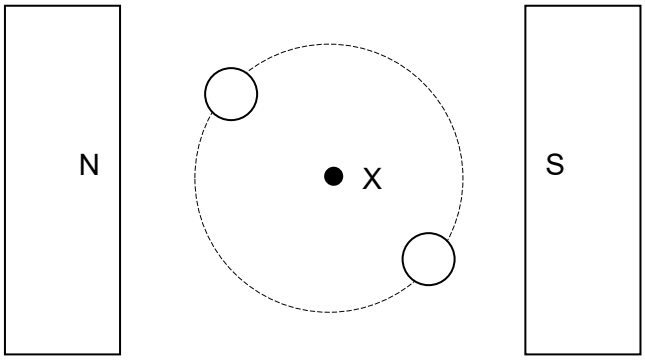


Fig. 39.1

(a) State three ways to increase the turning effect of the coil.

.....

.....

..... [2]

(b) The coil is in a position where the turning effect is the greatest. The direction of the current causes the coil to rotate in a clockwise direction.

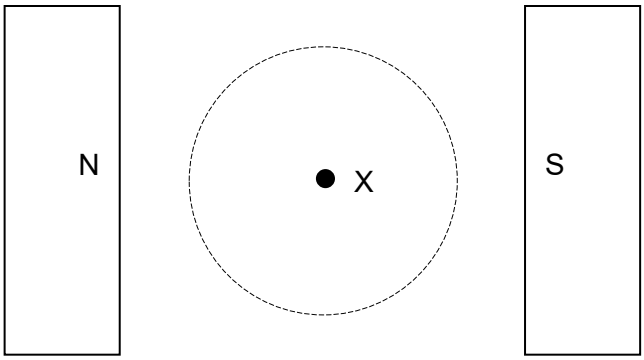


Fig. 39.2

In Fig. 39.2, draw the position of the cross-section of the rectangular coil (represented by two circles) and indicate the directions of flow of current in the coil. [2]

40 Fig. 40.1 shows a bar magnet oscillating vertically above a solenoid.

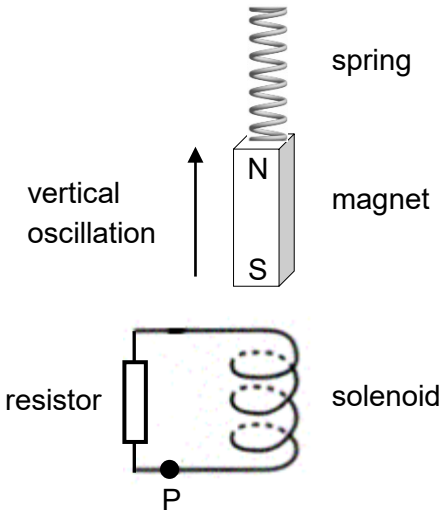


Fig. 40.1

(a) At one instant, the magnet is moving upwards at its greatest speed.

(i) State the polarity (North or South) of the top of the solenoid.

..... [1]

(ii) State the direction of the induced current flowing through point P.

..... [1]

(b) As the magnet oscillates vertically at a frequency of 10.0 Hz, an electromotive force (e.m.f.) is induced in the solenoid.

In Fig. 40.2, draw a variation of the e.m.f. with time in the solenoid for one cycle. Let the initial displacement of the magnet be at the highest point of the oscillation.

Fig. 40.2 [2]

(c) **(i)** The solenoid and spring are removed. Two horizontal conducting wires are placed near the magnet as shown in Fig. 40.3. The wires form part of a closed circuit.

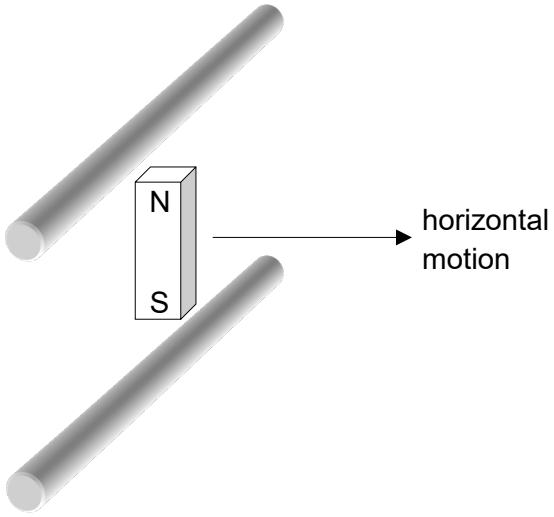


Fig. 40.3

In Fig. 40.3, draw the directions of the induced currents in both wires when the magnet is moved to the right, perpendicular to the wires. [2]

(ii) Describe the changes to the induced currents, if any, when the magnet is moved vertically instead of horizontally.

.....

..... [1]

41 Some students are tasked to design and conduct an experiment to determine the specific latent heat of vaporization of water under standard atmospheric pressure. They set up the apparatus as shown in Fig. 41.1.

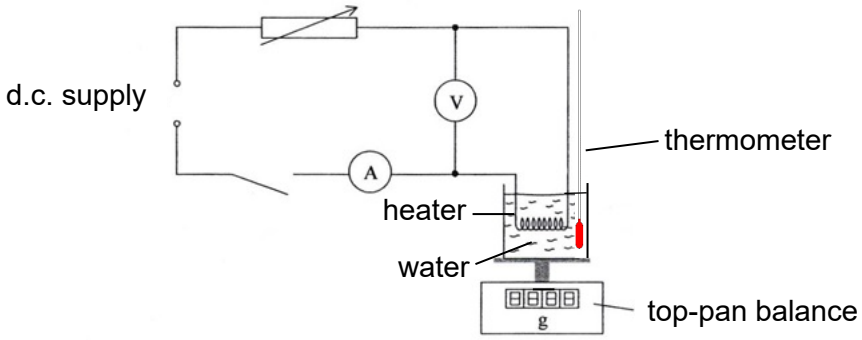


Fig. 41.1

The switch is closed and the current is kept constant using the variable resistor. The readings of the voltmeter and ammeter are recorded. When the water is boiling steadily, the reading of the top-pan balance is recorded and a stopwatch is started simultaneously. The reading of the top-pan balance is taken again after 200 seconds.

(a) **(i)** Define *specific latent heat of vaporization*.

.....

..... [1]

(ii) Suggest how the students know that the water is boiling.

.....

..... [1]

(iii) Using the kinetic model of matter, explain your answer in **(a)(ii)**.

.....

.....

..... [2]

(b) The students repeat the experiment for different powers supplied to the heater. Fig. 41.2 shows the graph of the power of the heater against the mass of water lost in 200 seconds (the change in the balance reading).

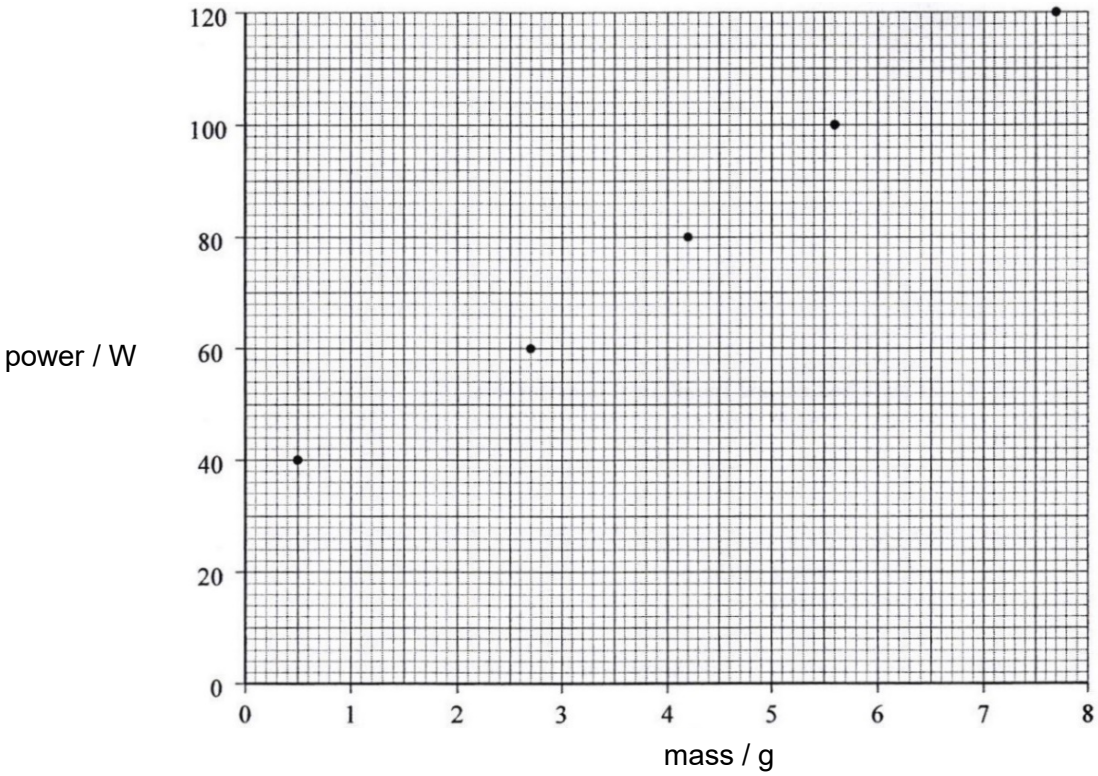


Fig. 41.2

(i) The relationship between the power of the heater and the mass of water lost is linear.

On Fig. 41.2, draw the best-fit line for the plotted points. [1]

(ii) Determine the gradient of the best-fit line.

gradient = ... W / g [2]

(c) In order to find a value for the specific latent heat of vaporization L of water, the students used the equation

$$P = M\,L,$$

where P is the power of the heater and M is the mass of water lost per unit time.

Using your answer to **(b)(ii)**, determine L.

L = ... [2]

(d) Theory suggests that the graph should pass through the origin. Explain why the graph in Fig. 41.2 does not pass through the origin.

.....

..... [1]

End of Section B