Pure Physics

GCE 'O' Levels

Mock Examination · Total: 100 marks · Generated 30/08/2026

Question 1

[10 marks]

KINEMATICS

2 In this experiment, you will investigate the speed of a glass ball rolling down an inclined track.

You have been provided with:

- a support
- two metre rules
- a glass ball
- a stopwatch
- Blu-Tack
- a 30 cm ruler
- a piece of cloth to act as a stop

Set up the apparatus as shown in Fig. 2.1. In Fig. 2.1 the two metre rules lie side by side to form a narrow channel; their 3 cm marks rest on a small block support so that the rules slope gently down to their 100 cm ends on the bench, where a cloth stop is held with Blu-Tack.

Place the support on the bench with the side marked Top facing upwards. Place the two metre rules on the support. Use a small piece of Blu-Tack for each metre rule to prevent them from moving on the support.

The metre rules should be placed on the support at the 3 cm marks and 5 mm apart. Ensure that the gap between the metre rules is 5 mm along the length of the metre rules. Fix the metre rules to the bench at the 100 cm ends with Blu-Tack.

(a) Measure the height h of the lower surface of the metre rules above the bench at the 0 cm mark, as shown in Fig. 2.2, a side view of the sloping track with h marked at the raised 0 cm end and the stop at the 100 cm end.

(b) Place the centre of the glass ball at the 1 cm mark on the metre rules. Release the ball and immediately start the stopwatch. The time taken for the ball to reach the end of the track is t_0.

Determine an accurate value for t_0. **[2]**

(c) The average speed of the ball is calculated using the formula shown.

$$\text{average speed} = \frac{\text{distance travelled}}{\text{time taken}}$$

In **(b)** the ball travels 99.0 cm. Calculate the average speed v_0 of the ball for this distance. **[1]**

(d) Replace the ball at the 1 cm mark. Reset the stopwatch to zero. Release the ball and start the stopwatch. Stop the stopwatch when the ball reaches the 51.0 cm mark on the track. The reading on the stopwatch is t_1. Record your value for t_1.

Calculate the average speed v_1 of the ball for this distance. **[1]**

(e) It is suggested that v_0 should be equal to v_1. Explain whether your values of v_0 and v_1 support this suggestion. **[1]**

(f) Plan an experiment to investigate the relationship between average speed and height h. Your plan should include

- the quantities that you should keep constant,
- a detailed description of how you would perform the experiment,
- a suitable table in which to display your measurements and calculated values (you do not need to enter any data into the table),
- a statement of the graph that you would plot to test the relationship.

[5]

[Total: 10]

Question 2

[5 marks]

PHYSICAL QUANTITIES, UNITS AND MEASUREMENT

A certain virus has a diameter of 3.0×10^{-8} m. A red blood cell has a diameter of 2.0×10^{-5} m.

(a) Express the diameter of the virus in nanometres. [1]

(b) Express the diameter of the red blood cell in micrometres. [1]

(c) Estimate how many of these viruses could be placed side by side across one diameter of the red blood cell. [2]

(d) State the difference, in orders of magnitude, between the diameter of the red blood cell and the diameter of the virus. [1]

Question 3

[10 marks]

CURRENT OF ELECTRICITY

In this experiment, you will determine the resistivity of the wire PQ.

You have been provided with

- a power supply
- a fixed resistor
- a switch
- an ammeter
- a voltmeter
- a length of resistance wire PQ on a metre rule
- a jockey (crocodile clip)
- a digital micrometer screw gauge
- seven connecting leads

Assemble the circuit as shown in Fig. 2.1. In Fig. 2.1 the power supply, a switch, an ammeter and a fixed resistor are joined in series with the resistance wire PQ, which is laid out horizontally along a metre rule. A jockey touches the wire a distance L from end P, and a voltmeter is connected between P and the jockey so that it measures the potential difference across the length L of the wire.

Adjust the position of the jockey along the wire PQ so that $L = 80.0$ cm. With the switch closed,

(a) (i) record the ammeter reading I. [1]

(ii) record the voltmeter reading V. [1]

(iii) Given that the resistance $R = V/I$, calculate the resistance R of the wire when $L = 80.0$ cm. [1]

(b) (i) Using the digital micrometer screw gauge, record the average diameter D of the wire PQ. [1]

(ii) The resistivity of the wire, ρ, is given by the formula

$$\rho = \frac{\pi R D^2}{4L}$$

Using the values from **(a)** and **(b)(i)**, determine the resistivity of the wire PQ. [1]

(c) Plan

The circuit is now assembled as shown in Fig. 2.2, in which the jockey has been removed so that the whole length of the wire PQ, from P to Q, is connected in series with the power supply, switch, ammeter and fixed resistor, with the voltmeter connected across the full wire PQ.

It is suggested that the relationship between V and D is

$$\frac{1}{V} = \frac{a}{D^2} + b$$

where a and b are constants.

Using resistance wires with different diameters and the apparatus in Fig. 2.2, plan an experiment to investigate the relationship.

Your plan should include

- the quantities that you should keep constant,
- a detailed description of how you will perform the experiment,
- a suitable table in which to display your measurements and calculated values (you do not need to enter any data into the table),
- a statement of the graph that you would plot to test the relationship,
- a sketch of the graph that you would obtain if the suggested relationship is correct,
- an explanation of how you would obtain a value of the constant b from your graph. [5]

Question 4

[10 marks]

PRACTICAL ELECTRICITY

9 An electric kettle is marked 230 V, 2000 W. When connected to a 230 V mains supply it heats 1.5 kg of water from $25\ ^{\circ}$C to $100\ ^{\circ}$C in 5.0 minutes. The specific heat capacity of water is 4200 J kg^{-1} K^{-1}.

(a) For normal operation, calculate

(i) the current in the heating element, [1]

(ii) the resistance of the heating element. [1]

(b) Calculate the electrical energy supplied to the kettle during the 5.0 minutes. [1]

(c) Determine the efficiency of the kettle in heating this water. [3]

(d) At a time of heavy demand the mains supply falls to 220 V. Taking the resistance of the element to be unchanged, calculate the power of the kettle at this supply voltage and state the effect on the time taken to boil the same mass of water. [2]

(e) The kettle has a plastic body and is joined to the mains by a two-core cable containing only a live wire and a neutral wire. Explain why the absence of an earth wire does not make this kettle unsafe. [2]

[Total: 10]

Question 5

[1 marks]

PRESSURE

Two vessels **S** and **T** are filled to the same level with the same liquid. The base area of **S** is less than that of **T**.

Which statement is correct?

A The force on the base of **S** is greater than the force on the base of **T**.

B The force on the base of **S** is the same as the force on the base of **T**.

C The pressure on the base of **S** is greater than the pressure on the base of **T**.

D The pressure on the base of **S** is the same as the pressure on the base of **T**.

Question 6 [1 marks]

RADIOACTIVITY

37 A nucleus of $^{232}_{90}Th$ captures a slow neutron. The nucleus that is formed then emits two β^- -particles.

Which nucleus is left at the end of this sequence?

- **A** $^{233}_{92}U$
- **B** $^{232}_{92}U$
- **C** $^{233}_{90}Th$
- **D** $^{229}_{88}Ra$

Question 7 [6 marks]

DYNAMICS

2 Fig. 2.1 shows a 5.0 kg object being pulled by a string at an angle of 60° to the horizontal. The string exerts a constant tension on the object, causing it to slide on the smooth horizontal surface at a constant acceleration of 0.50 m/s^2. Air resistance can be ignored.

Fig. 2.1 shows a rectangular block resting on a horizontal surface, with a string attached at its top right corner running upwards to the right at 60° to the horizontal.

(a) Calculate the resultant force acting on the object. [1]

(b) In the space below, draw a labelled diagram to show the resultant of all the forces acting on the object. Determine the magnitude of the tension of the string. [3]

(c) A student suggests that since the object is moving horizontally, the vertical component of the tension of the string must be equal to the weight of the object. Explain why in this situation, the weight of the object is larger than the vertical component of the tension. [1]

(d) After pulling the object for a certain distance, the string snaps. State and explain the subsequent motion of the object. [1]

Question 8

[7 marks]

ELECTROMAGNETIC INDUCTION

Fig. 8.1 shows the structure of a simple a.c. generator model. The rectangular coil ABCD is manually rotated between the poles of a magnet, with S on the left and N on the right, so that the plane of the coil is parallel to the magnetic field at the instant shown. The ends of the coil are connected through the component labelled Y to the terminals P and Q.

(a) When the coil is rotated at the position shown in Fig. 8.1, a maximum induced e.m.f. of E_0 is induced in the coil.

Explain why the value of induced e.m.f. E_0 is a maximum at this position. [2]

(b) (i) The a.c. generator is connected to an external circuit and an induced current flows through the a.c. generator.

On Fig. 8.1, draw the direction of the induced current flowing in the coil. [1]

(ii) State the purpose of the component labelled as Y. [1]

(c) Explain why in real power stations, a.c. is produced rather than d.c. [1]

(d) Fig. 8.2 shows a graph of the induced e.m.f. across PQ against time as the coil rotates for one complete rotation from the initial position shown in Fig. 8.1. The graph starts at $+E_0$, falls to $-E_0$ at half a rotation and returns to $+E_0$ at time T.

Assume that the magnetic field within which the loop rotates is uniform and the time taken for one complete rotation is T.

In Fig. 8.2 above, sketch a new graph in dotted lines to show the change when the coil is rotated in the **opposite** direction and at two times the speed within T. [2]

Question 9

[1 marks]

GENERAL PROPERTIES OF WAVES

23 An electronic synthesizer produces two pure notes A and B as shown.

The graph plots displacement against time. Trace A and trace B are drawn on the same axes and complete the same number of cycles in the same time, but trace A has a noticeably larger amplitude than trace B.

Which of the following statement about A and B is **wrong**?

- **A** B is softer than A.
- **B** Pitch of A is higher than B.
- **C** A and B has the same speed.
- **D** B has a lower wavelength than A.

Question 10

[5 marks]

MAGNETISM

Fig. 12.1 shows two identical magnets placed close to each other. The two bar magnets lie end to end in a horizontal line with a gap between them. Magnet A on the left has its S pole at the left-hand end and its N pole at the right-hand end. Magnet B on the right has its N pole at the left-hand end and its S pole at the right-hand end, so the two North poles face each other across the gap.

(a) On Fig. 12.1, draw the magnetic field around and between the two magnets. [3]

(b) State and explain what happens when a small piece of soft iron is placed equidistant from the North poles of both magnets. [2]

Question 11

[8 marks]

ELECTROMAGNETIC SPECTRUM

During the opening of the 1996 Olympic Games in Atlanta, USA was televised live around the world, including Singapore. The television signal was carried by electromagnetic waves via a satellite positioned $35\,700$ km above the surface of Earth, as shown in Fig. 6.1.

(a) Name the electromagnetic wave used in the signal transmission from Atlanta to Singapore and state another application of this electromagnetic wave. **[2]**

(b) The frequency of the signal used was 12 GHz.

(i) Determine the period of the television signal. **[2]**

(ii) Calculate the wavelength of the electromagnetic wave used in the transmission. **[2]**

(c) Due to occasional loss in transmission, an upset viewer from Singapore proposed two alternatives to the type of transmission used by the satellite — laser light and ultrasound.

(i) Identify one difference between laser light and ultrasound. **[1]**

(ii) Suggest a reason why using ultrasound in satellite transmissions is not a good idea. **[1]**

Question 12

[1 marks]

THERMAL PROPERTIES OF MATTER

Paper 1 Q9 A beaker of liquid is placed under a bell jar. The pressure of the air above the liquid is reduced and some liquid evaporates. This causes the liquid to become colder. Why does the temperature of the liquid fall?

- **A** The air molecules blow away the liquid molecules.
- **B** The air molecules cool down the liquid.
- **C** The higher energy molecules leave the liquid.
- **D** There are fewer molecules of liquid in the beaker.

Question 13

[1 marks]

TURNING EFFECT OF FORCES

Which of the following is the correct SI unit for the moment of a force?

A N

B N m

C N/m

D N m^2

Question 14

[1 marks]

ENERGY

A windmill raises water from a well. The depth of the well is 6 m. The windmill raises 500 kg of water every day.

What is the power extracted from the wind to perform this task? Assume the windmill is 100 % efficient.

- **A** 0.035 W
- **B** 0.35 W
- **C** 2.1 W
- **D** 21 W

Question 15

[10 marks]

LIGHT

9 OR

(a) Define critical angle. [1]

(b) Given that the refractive index of diamond is 2.4, calculate the critical angle of diamond. [1]

(c) A ray of light is incident on a diamond at point O on the upper left facet, as shown in Fig. 9.3. The angle of incidence is 30°. The diamond is drawn as a brilliant cut, with a flat horizontal top facet, sloping upper facets and two long lower facets meeting at a point below.

(i) Calculate the angle of refraction of the light ray after it is refracted at point O. [2]

(ii) Hence, on Fig. 9.3, construct the path of the light ray in the diamond after refraction at point O. [1]

(iii) Extend the ray that you constructed in **(ii)** until it meets another surface. Determine if the ray is refracted or totally internally reflected, and construct the path of the light ray accordingly. [2]

(iv) The light ray eventually emerges from the diamond. Describe and explain how the intensity of the light ray changes as it enters the diamond until after it exits the diamond. [2]

(v) Explain why some facets of a diamond may appear to be coloured even though it is placed under white light. [1]

Question 16

[1 marks]

ELECTROMAGNETISM

Paper 1 Q37 Four metal rods A, B, C and D are placed in turn inside a coil carrying a current, and the paper clips they pick up are recorded, both while the current flows and after it is switched off. Which rod would be the most suitable to use for the core of a coil in a circuit breaker?

metal rod	clips picked up (current on)	clips still attracted (current off)
A	1	0
B	6	6
C	6	0
D	3	1

Question 17

[1 marks]

THERMAL PROCESSES

Different surfaces reflect different proportions of energy from the sun. The bar chart shows the percentage of thermal energy reflected by three surfaces P, Q and R: P reflects 70%, Q reflects 55% and R reflects 10%.

Which of the following best describes the type of surface?

	White washed	**Red brick**	**Black tar**
A	P	R	Q
B	Q	R	P
C	R	Q	P
D	P	Q	R

Question 18

[5 marks]

STATIC ELECTRICITY

8 (a) A silk cloth is rubbed against a glass rod several times. The glass rod is then observed to repel a positively charged gold foil.

Explain how the glass rod could have become charged. [2]

(b) (i) Describe an example where electrostatic charging is a potential hazard. [2]

(ii) Suggest a solution to mitigate the hazard mentioned in **(b)(i)**. [1]

[Total: 5]

Question 19

[10 marks]

KINETIC PARTICLE MODEL OF MATTER

Fig. 11.1 shows a syringe with a stopper over the nozzle so that gas is trapped inside, while a force pushes the piston in.

(a) Explain, in terms of molecules, why the piston can be pushed in slowly while the stopper stays in position.

(b) Explain how the gas exerts pressure on the walls of the syringe.

(c) Explain why the pressure is the same at all points on the inside walls of the syringe.

(d) State how the pressure exerted by the gas changes when its volume is reduced by half at constant temperature, and explain your answer.

(e) State one assumption for your answer in part (d).

(f) Explain the changes in the motion of the gas molecules when the gas is heated.

Question 20

[6 marks]

D.C. CIRCUITS

A battery of e.m.f. $18\ \mathrm{V}$ and negligible internal resistance is connected in series with a $6.0\ \Omega$ resistor. This resistor is joined to a parallel combination of a $12\ \Omega$ resistor and a second resistor of unknown resistance R. The current delivered by the battery is $2.0\ \mathrm{A}$.

(a) Calculate the potential difference (p.d.) across the $6.0\ \Omega$ resistor. [1]

(b) Determine the effective resistance of the parallel combination. [2]

(c) Determine the resistance R. [2]

(d) State how the current delivered by the battery would change if the resistor of resistance R were replaced by one of greater resistance. [1]

Answers

Question 1

(a) h measured with the 30 cm ruler to the correct precision and with a unit, for example h = 5.1 cm.

(b) Time the run at least twice and average the readings to reduce random timing error: for example 2.76 s and 2.84 s giving $t_0 = 2.80$ s (sensible value, 2 decimal places, unit s).

(c) $v_0 = \dfrac{99.0}{2.80} = 35.4$ cm/s (3 significant figures, unit cm/s).

(d) The ball travels from the 1.0 cm mark to the 51.0 cm mark, so the distance is 50.0 cm. With t_1 = 1.80 s, $v_1 = \dfrac{50.0}{1.80}$ = 27.8 cm/s.

(e) The values do not support the suggestion, because $v_0 \neq v_1$: here 35.4 cm/s compared with 27.8 cm/s. The ball accelerates as it rolls down, so its average speed over the whole track is greater than its average speed over the first half.

(f) Keep constant at least two of: the distance travelled by the glass ball, the mass (and size) of the glass ball, the surface and separation of the metre rules, and the way the ball is released so that its initial speed is zero each time.

Method: set the support to give a measured height h at the 0 cm mark. Release the glass ball from rest at the 1 cm mark and start the stopwatch immediately; stop it when the ball reaches the end of the track. Repeat the timing for the same h and calculate the average time t_{ave}. Calculate the average speed from $v = 99.0/t_{ave}$. Record the values in a table. Change the height by using supports of different thickness and repeat for at least five different values of h, keeping all other quantities constant.

h / cm	t1 / s	t2 / s	tave / s	v / (cm/s)

Graph: plot average speed v (y-axis) against height h (x-axis) and use the shape of the line obtained to decide whether the suggested relationship holds.

Question 2

(a) $1 \text{ nm} = 10^{-9}$ m, so $3.0 \times 10^{-8} \text{ m} = 30$ nm.

(b) $1\, \mu\text{m} = 10^{-6}$ m, so $2.0 \times 10^{-5} \text{ m} = 20\, \mu\text{m}$.

(c) Number = $\dfrac{2.0 \times 10^{-5}}{3.0 \times 10^{-8}} \approx 6.7 \times 10^{2} \approx 670$.

(d) 10^{-5} compared with 10^{-8} differs by a factor of 10^{3}, i.e. 3 orders of magnitude.

Question 3

(a)(i) I = 0.14 A, recorded to 2 decimal places with unit (values such as 0.13 A or 0.10 A also accepted).

(a)(ii) V = 1.65 V, recorded to 2 decimal places with unit (values such as 1.70 V or 1.50 V also accepted).

(a)(iii) $R = V/I = 1.65/0.14 = 11.8$ Ω (accepted range 11 Ω to 15 Ω). The resistance of the fixed resistor must not be subtracted.

(b)(i) At least two micrometer readings must be recorded and averaged, e.g. $D = (0.285 + 0.285)/2 = 0.285$ mm.

(b)(ii) Substituting into $\rho = \pi R D^2/(4L)$ with the diameter converted to metres and $L = 0.800$ m:

$$\rho = \frac{\pi \times 13.6 \times (0.29 \times 10^{-3})^2}{4 \times 0.800} = 1.12 \times 10^{-6}$$

so $\rho = 1.12 \times 10^{-6}$ Ω m, which is close to the accepted value of 1.10×10^{-6} Ω m for swg32 nichrome wire. All lengths must be in metres and the unit Ω m must be stated.

(c) Independent variable: diameter D. Dependent variable: voltmeter reading V.

Quantities kept constant (any two): the length of each resistance wire connected across PQ; the material of the wires; the e.m.f. of the power supply and the resistance of the fixed resistor.

Method:

1. Set up the circuit as shown in Fig. 2.2.
2. Connect the wire of smallest diameter across PQ, keeping its length and the fixed resistor unchanged.
3. Close the switch and record the voltmeter reading V.
4. Using the digital micrometer screw gauge, take readings at several points along the wire and record the average diameter D.
5. Calculate $1/V$ and $1/D^2$.
6. Repeat steps 2 to 5 for six wires of different diameters.

Precautions: do not leave the switch closed for long, as the wire heats up and its resistance changes; do not touch the bare wire PQ as it may become hot.

Table of results, with units in the headings:

D / mm	V / V	1/V / V^{-1}	1/D^2 / mm^{-2}

Graph: plot $1/V$ on the vertical axis against $1/D^2$ on the horizontal axis.

Sketch: if the relationship is valid the graph is a straight line that does not pass through the origin, with a positive gradient a and a positive intercept b on the $1/V$ axis.

Constant b: b is the value of $1/V$ where the line of best fit cuts the vertical axis, that is the value of $1/V$ when $1/D^2 = 0$.

Question 4

(a)(i)

$$I = \frac{P}{V} = \frac{2000}{230} = 8.70\text{ A}$$

(a)(ii)

$$R = \frac{V}{I} = \frac{230}{8.70} = 26.5\ \Omega$$

(equivalently $R = \frac{V^2}{P} = \frac{230^2}{2000} = 26.5\ \Omega$)

(b)

$$E = Pt = 2000 \times (5.0 \times 60) = 6.0 \times 10^5\text{ J}$$

(c) Useful energy gained by the water:

$$E_{\text{water}} = mc\Delta\theta = 1.5 \times 4200 \times 75 = 4.725 \times 10^5\text{ J}$$

$$\text{efficiency} = \frac{4.725 \times 10^5}{6.0 \times 10^5} = 0.79$$

The efficiency is about 79%; the rest of the energy heats the kettle body and is lost to the surroundings.

(d)

$$P = \frac{V^2}{R} = \frac{220^2}{26.5} = 1.83 \times 10^3\text{ W} \approx 1.8\text{ kW}$$

Energy is now supplied at a lower rate, so the water takes a longer time to boil (about 5.5 minutes instead of 5.0 minutes).

(e) The kettle is double insulated. All the live parts, including the heating element and its connections, are enclosed within a casing of insulating plastic, and no metal part that the user can touch is connected to the live wire. Even if a live connection worked loose inside, the insulating casing prevents it from making any accessible part live, so there is no conducting path from the live wire through the user to earth. An earth wire is therefore unnecessary.

Question 5

D

Liquid pressure depends only on depth, density and g: $p = h\rho g$. The two vessels hold the same liquid filled to the same height, so the pressure on each base is the same.

Since force = pressure × area and **S** has the smaller base area, the force on the base of **S** is smaller, ruling out **A** and **B**.

Question 6

A

A neutron carries no charge, so capture raises the nucleon number by 1 and leaves the proton number unchanged: $^{232}_{90}\text{Th}$ becomes $^{233}_{90}\text{Th}$.

Each β^- emission turns a neutron into a proton, so the proton number rises by 1 while the nucleon number is unchanged.

After two such emissions the proton number is $90 + 2 = 92$ and the nucleon number is still 233, giving $^{233}_{92}\text{U}$.

Question 7

(a) $F = ma = 5.0 \times 0.50 = 2.5$ N, acting horizontally in the direction of motion.

(b) The labelled diagram shows the weight of 50 N acting vertically downwards, the normal contact force acting vertically upwards, and the tension acting along the string at 60° above the horizontal; the resultant of all of these is a single horizontal arrow of 2.5 N in the direction of motion. Resolving horizontally, $T\cos 60° = 2.5$, so $T = \frac{2.5}{0.5} = 5.0$ N.

(c) The smooth surface also pushes upwards on the object with a normal contact force. Vertical equilibrium requires the normal contact force together with the vertical component of the tension to balance the weight, so the weight must be larger than the vertical component of the tension by itself.

(d) The object moves in a straight line at constant velocity, keeping the speed it had at the instant the string snapped, because the surface is smooth and air resistance is ignored, so there is no longer any horizontal force and hence no acceleration.

Question 8

(a) At this position the plane of the coil is parallel to the magnetic field, so the sides AB and CD cut the field lines at the fastest possible rate. The rate of change of magnetic flux linkage is therefore a maximum, and by Faraday's law the induced e.m.f. is a maximum, E_0.

(b)(i) Using Fleming's right-hand rule on the sides moving through the field, the induced current flows anticlockwise around the coil, in the sense A to B to C to D.

(b)(ii) Y is the pair of slip rings. They keep continuous electrical contact between the rotating coil and the external circuit through the brushes, so that current can flow continuously without the connecting wires becoming twisted.

(c) With a.c. the voltage can be stepped up and down by transformers, allowing transmission at very high voltage and hence low current, which greatly reduces the power lost as heat in the cables.

(d) The dotted graph is the inverse of the original one, starting at $-E_0$ instead of $+E_0$, and it completes **two** full cycles within the time T. Its peak value is doubled to $2E_0$, because doubling the rotation speed doubles the rate of change of flux linkage.

Question 9

B Pitch of A is higher than B.

The two traces complete the same number of cycles in the same time, so they have the same period and therefore the same frequency. Pitch depends on frequency, so the two notes have the same pitch and statement B is the wrong one.

The other statements are correct: B has the smaller amplitude so it is softer; both notes travel through the same air at the same speed of sound; and since $v = f\lambda$ with equal v and equal f, the wavelengths are equal, so B does not have a longer wavelength than A.

Question 10

(a) Field lines leave each North pole and enter each South pole, with arrowheads showing the direction from N to S outside the magnets. The pattern is symmetrical above and below both magnets, and the lines emerging from the two facing North poles curve away from each other rather than joining. No field lines lie along the vertical line midway between the two North poles.

(b) The soft iron remains stationary.

This is because it is located at a null or neutral point, where the fields of the two identical magnets are equal in magnitude and opposite in direction, so there is no net magnetic field at that point and no resultant force on the iron.

Question 11

(a) Microwaves. Another application: microwave ovens (or mobile phone / satellite communication).

(b)(i) $T = \frac{1}{f} = \frac{1}{12 \times 10^9} = 8.33 \times 10^{-11}$ s.

(b)(ii) $v = f\lambda$: $3.0 \times 10^8 = (12 \times 10^9)\lambda$, so $\lambda = 0.025$ m.

(c)(i) Laser light is an electromagnetic (transverse) wave that can travel through a vacuum, whereas ultrasound is a longitudinal (mechanical) wave that cannot (and travels far slower, about 340 m/s versus 3×10^8 m/s).

(c)(ii) Ultrasound cannot travel through the vacuum of space, as there are no particles to transmit it, so the signal could not reach the satellite.

Question 12

Answer: C. During evaporation the fastest, most energetic molecules escape from the surface, lowering the average kinetic energy of the molecules left behind and so lowering the temperature.

Question 13

B

Moment = force × perpendicular distance, so its unit is newton × metre = N m.

Question 14

B

Energy required per day = $mgh = 500 \times 10 \times 6 = 30000$ J.

Time for one day = $24 \times 3600 = 86400$ s.

$P = \frac{30000}{86400} = 0.35$ W.

Question 15

(a) The critical angle is the angle of incidence, in the optically denser medium, for which the angle of refraction in the less dense medium is exactly 90°.

(b) $\sin c = \frac{1}{n} = \frac{1}{2.4} = 0.4167$, so $c = 24.6°$.

(c)(i) $\frac{\sin i}{\sin r} = n$, so $\sin r = \frac{\sin 30°}{2.4} = \frac{0.5}{2.4} = 0.2083$ and $r = 12.0°$.

(ii) Draw the normal at O and the refracted ray inside the diamond bent towards that normal, making an angle of 12.0° with it, so the ray travels into the body of the diamond.

(iii) Continue that ray until it strikes one of the sloping lower facets. Because the facets are steeply inclined, the angle of incidence there is greater than the critical angle of 24.6°, so no light is refracted out: the ray is totally internally reflected. Draw the reflected ray on the other side of the normal at that facet, with the angle of reflection equal to the angle of incidence.

(iv) At O the intensity falls slightly, because part of the incident light is reflected at the surface instead of entering. Where total internal reflection occurs no light escapes at all, so the intensity stays essentially unchanged there. When the ray finally meets a surface at an angle of incidence smaller than the critical angle it refracts out, and the intensity of the emerging ray drops again because part of the light is reflected back inside.

(v) Diamond has a slightly different refractive index for each colour, so the colours in white light are refracted through slightly different angles and are dispersed as they pass through the stone. Different colours therefore leave by different facets, and a facet can appear coloured.

Question 16

C — A circuit-breaker core must be a strong electromagnet when current flows but lose its magnetism immediately when the current stops (a soft magnetic material). Rod C picks up many clips (6) yet holds none when switched off, so it is the best choice.

Question 17

D

Light, shiny, pale surfaces are the best reflectors and dark, dull surfaces the worst. So the white washed surface reflects the most (P, 70%), red brick is intermediate (Q, 55%) and black tar reflects the least (R, 10%).

Question 18

(a) During rubbing, electrons are transferred from the glass rod to the silk cloth.

The glass rod therefore loses electrons and is left with a net positive charge, which is why it repels the positively charged gold foil.

(b)(i) When petrol is pumped into a tank, the flow of fuel over the nozzle and pipe transfers electrons, so charge builds up on the tank and nozzle. If the charge builds up sufficiently, a spark (static discharge) can jump across and ignite the petrol vapour, causing a fire or explosion. (A similar hazard occurs in coal mines, where a static discharge can ignite coal dust suspended in the air.)

(b)(ii) Earth the petrol tank and the nozzle with a grounding wire during pumping, so that the excess charge flows safely to earth instead of building up and sparking.

Question 19

(a) Gas molecules are far apart with large spaces and negligible forces between them, so the gas is highly compressible and the piston moves in; the stopper stays because the same molecules simply occupy a smaller volume.

(b) The molecules are in constant motion and collide with the walls, exerting a force on them; this force per unit area on the walls is the gas pressure.

(c) The molecules are in continuous random motion with no preferred direction, so at any instant equal numbers strike each part of the wall, giving the same pressure everywhere.

(d) The pressure doubles. Halving the volume doubles the number of molecules per unit volume, so the rate of collisions with the walls doubles and the force per unit area doubles.

(e) The mass/number of gas molecules (and the temperature) stays constant.

(f) Heating increases the kinetic energy of the molecules, so they move faster.

Question 20

(a) The $6.0\ \Omega$ resistor carries the whole battery current:

$$V = IR = 2.0 \times 6.0 = 12\text{ V}$$

(b) The p.d. across the parallel combination is

$$V_p = 18 - 12 = 6.0\text{ V}$$

and the same 2.0 A passes through it, so

$$R_p = \frac{6.0}{2.0} = 3.0\ \Omega$$

(c) For two resistors in parallel,

$$\frac{1}{R_p} = \frac{1}{12} + \frac{1}{R}$$

$$\frac{1}{R} = \frac{1}{3.0} - \frac{1}{12} = \frac{3}{12}$$

$$R = 4.0\ \Omega$$

(d) The current would decrease. A larger R raises the effective resistance of the parallel combination, so the total resistance of the circuit increases and, for the same e.m.f., $I = \frac{V}{R_{\text{total}}}$ is smaller.

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