Diploma Programme
Programme du diplôme
Programa del Diploma

Physics
Higher level
Paper 2

Tuesday 8 November 2016 (morning)

2 hours 15 minutes

Candidate session number

Instructions to candidates

- Write your session number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Answer all questions.
- Write your answers in the boxes provided.
- A calculator is required for this paper.
- A clean copy of the **physics data booklet** is required for this paper.
- The maximum mark for this examination paper is **[95 marks]**.

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Answers written on this page
will not be marked.

Answer **all** questions. Write your answers in the boxes provided.

1. A tennis ball is hit with a racket from a point 1.5 m above the floor. The ceiling is 8.0 m above the floor. The initial velocity of the ball is 15 m s^{-1} at 50° above the horizontal. Assume that air resistance is negligible.
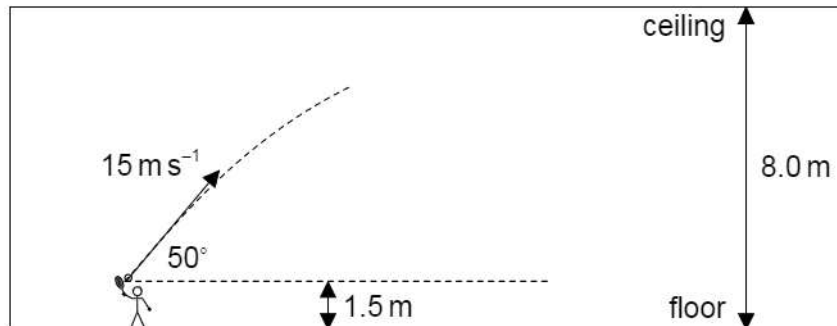
(a) Determine whether the ball will hit the ceiling. [3]

(b) The tennis ball was stationary before being hit. It has a mass of 5.8×10^{-2} kg and was in contact with the racket for 23 ms.

(i) Calculate the mean force exerted by the racket on the ball. [1]

(ii) Explain how Newton's third law applies when the racket hits the tennis ball. [2]
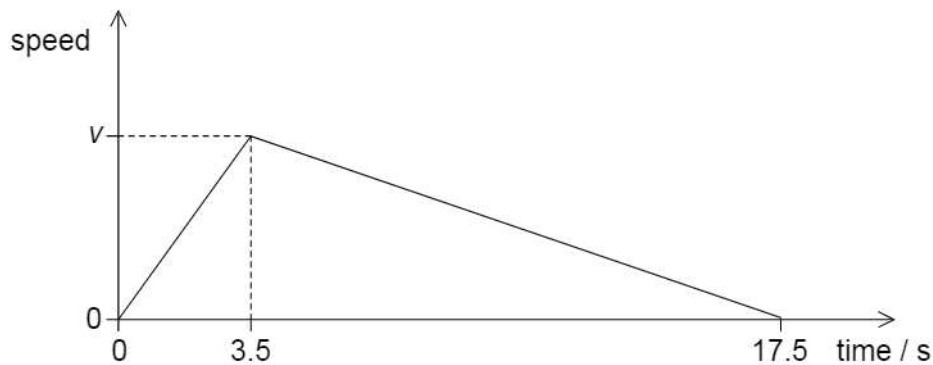
2.   Curling is a game played on a horizontal ice surface. A player pushes a large smooth stone across the ice for several seconds and then releases it. The stone moves until friction brings it to rest. The graph shows the variation of speed of the stone with time.

The total distance travelled by the stone in 17.5 s is 29.8 m.

(a)   Determine the maximum speed v of the stone.   [2]

(b)   Determine the coefficient of dynamic friction between the stone and the ice during the last 14.0 s of the stone's motion.   [3]
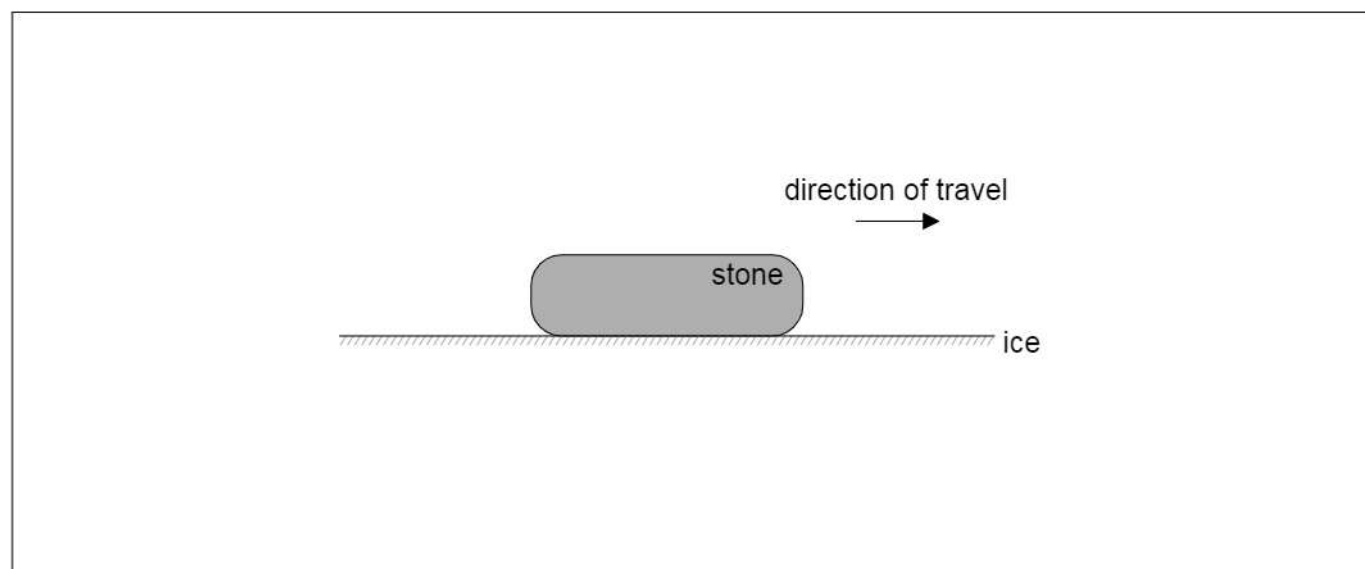
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(Question 2 continued)

(c)   The diagram shows the stone during its motion **after** release.

direction of travel

stone

ice

Label the diagram to show the forces acting on the stone. Your answer should include the name, the direction **and** point of application of each force.   [3]

3. (a) Define *internal energy*. [2]

(b) 0.46 mole of an ideal monatomic gas is trapped in a cylinder. The gas has a volume of $21\,m^3$ and a pressure of 1.4 Pa.

(i) State how the internal energy of an ideal gas differs from that of a real gas. [1]

(ii) Determine, in kelvin, the temperature of the gas in the cylinder. [2]

(iii) The kinetic theory of ideal gases is one example of a scientific model.
Identify **two** reasons why scientists find such models useful. [2]

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2. ....

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4.   (a)   A particular K meson has a quark structure $\bar{u}s$. State the charge, strangeness and baryon number for this meson.   [2]
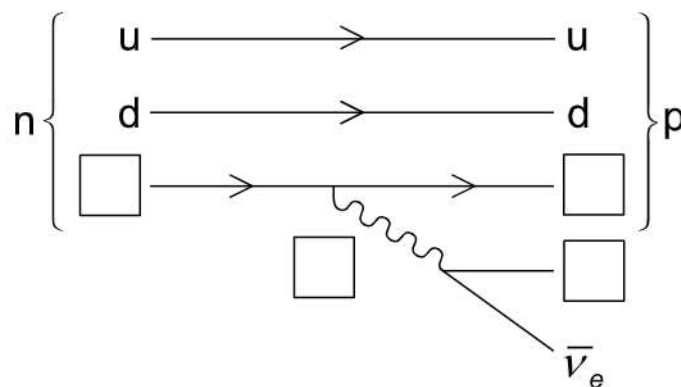
Charge: . . . .

Strangeness: . . . .

Baryon number: . . . .

(b)   The Feynman diagram shows the changes that occur during beta minus (β^-) decay.

Label the diagram by inserting the **four** missing particle symbols **and** the direction of the arrows for the decay particles.   [3]

(c)   Carbon-14 (C-14) is a radioactive isotope which undergoes beta minus (β^-) decay to the stable isotope nitrogen-14 (N-14). Energy is released during this decay. Explain why the mass of a C-14 nucleus and the mass of a N-14 nucleus are slightly different even though they have the same nucleon number.   [2]

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Turn over

(Question 4 continued)

(d)   The C-14 decay in (c) is used to estimate the age of an old dead tree. The activity of C-14 in the dead tree is determined to have **fallen to** 21 % of its original value. C-14 has a half-life of 5700 years.

(i)   Explain why the activity of C-14 in the dead tree decreases with time.   [1]

(ii)   Calculate, in years, the age of the dead tree. Give your answer to an appropriate number of significant figures.   [3]

5.   (a)   Two microwave transmitters, X and Y, are placed 12 cm apart and are connected to the same source. A single receiver is placed 54 cm away and moves along a line AB that is parallel to the line joining X and Y.
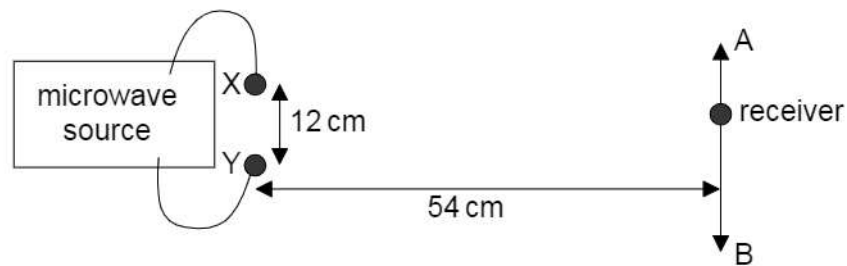
Maxima and minima of intensity are detected at several points along AB.

(i)   Explain the formation of the intensity **minima**.   [2]

(ii)   The distance between the central maximum and the first minimum is 7.2 cm. Calculate the wavelength of the microwaves.   [2]

(This question continues on the following page)

(Question 5 continued)

(b) Radio waves are emitted by a straight conducting rod antenna (aerial). The plane of polarization of these waves is parallel to the transmitting antenna.

polarized radio waves →

56 km

transmitting antenna   receiving antenna
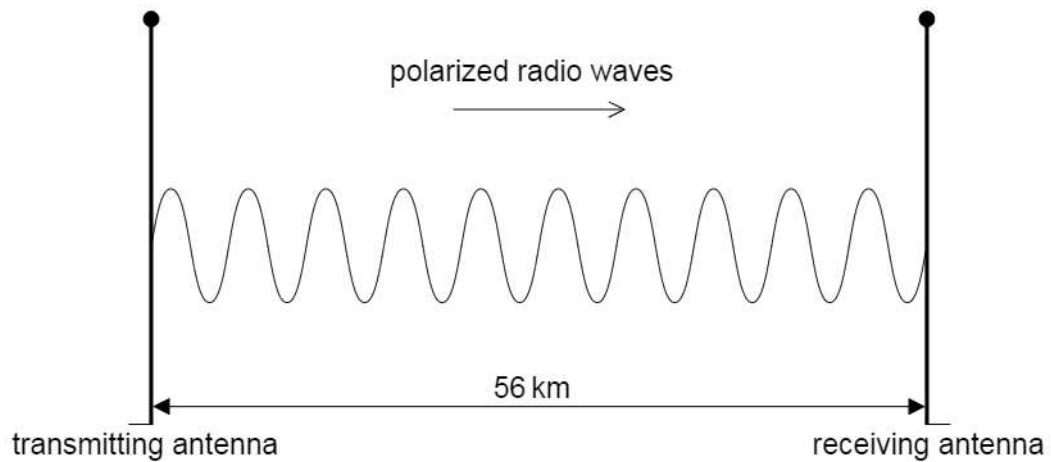
An identical antenna is used for reception. Suggest why the receiving antenna needs to be be parallel to the transmitting antenna.   [2]

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(Question 5 continued)

(c)   The receiving antenna becomes misaligned by 30° to its original position.
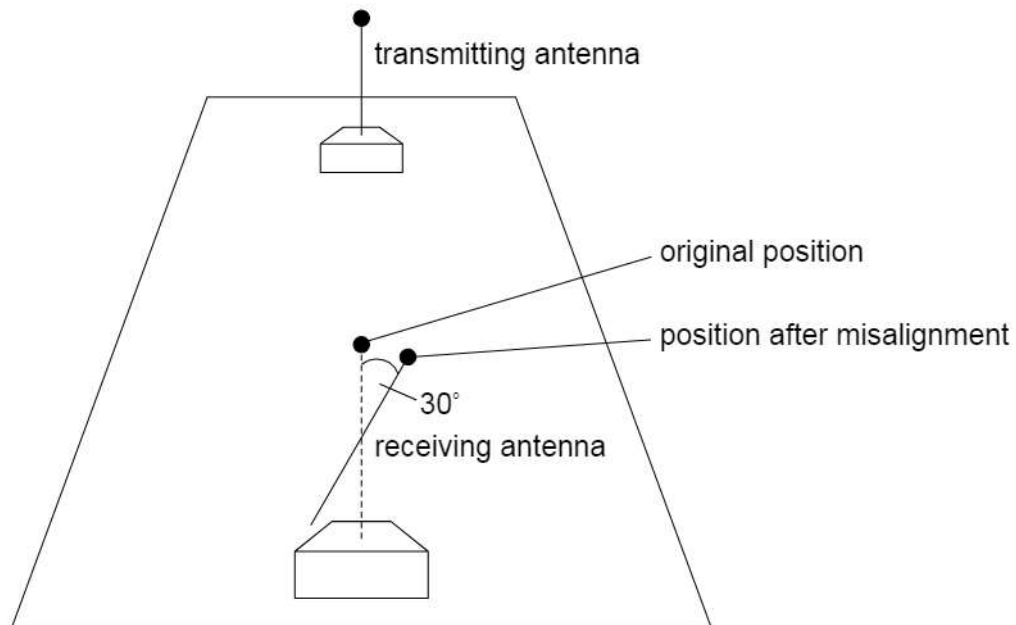
The power of the received signal in this new position is $12\,\mu W$.

(i)   Calculate the power that was received in the original position.   [2]

(ii)   Calculate the minimum time between the wave leaving the transmitting antenna and its reception.   [1]

6.   (a)   Police use radar to detect speeding cars. A police officer stands at the side of the road and points a radar device at an approaching car. The device emits microwaves which reflect off the car and return to the device. A change in frequency between the emitted and received microwaves is measured at the radar device.

The frequency change Δf is given by

$$\Delta f = \frac{2fv}{c}$$

where f is the transmitter frequency, v is the speed of the car and c is the wave speed.

The following data are available.

$$\text{Transmitter frequency } f \quad = 40\,\text{GHz}$$
$$\Delta f \qquad\qquad\qquad\qquad = 9.5\,\text{kHz}$$
$$\text{Maximum speed allowed} \ = 28\,\text{m s}^{-1}$$

(i)   Explain the reason for the frequency change.   [3]

(ii)   Suggest why there is a factor of 2 in the frequency-change equation.   [1]

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(Question 6 continued)

    (iii)   Determine whether the speed of the car is below the maximum speed allowed.   [2]

    (b)   Airports use radar to track the position of aircraft. The waves are reflected from the aircraft and detected by a large circular receiver. The receiver must be able to resolve the radar images of two aircraft flying close to each other.

        The following data are available.

Diameter of circular radar receiver	$= 9.3\,\text{m}$
Wavelength of radar	$= 2.5\,\text{cm}$
Distance of two aircraft from the airport	$= 31\,\text{km}$

        Calculate the minimum distance between the two aircraft when their images can just be resolved.   [2]

7.   (a)   Explain what is meant by the gravitational potential at the surface of a planet.   [2]

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(b)   An unpowered projectile is fired vertically upwards into deep space from the surface of planet Venus. Assume that the gravitational effects of the Sun and the other planets are negligible.

The following data are available.

Mass of Venus	$= 4.87 \times 10^{24}$ kg
Radius of Venus	$= 6.05 \times 10^{6}$ m
Mass of projectile	$= 3.50 \times 10^{3}$ kg
Initial speed of projectile	$= 1.10 \times$ escape speed

(i)   Determine the initial kinetic energy of the projectile.   [2]

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(ii)   Describe the subsequent motion of the projectile until it is effectively beyond the gravitational field of Venus.   [3]

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(Question 7 continued)

(c)   A planet orbits the Sun in a circular orbit with orbital period T and orbital radius R.
The mass of the Sun is M.

(i)   Show that $T = \sqrt{\dfrac{4\pi^2 R^3}{GM}}$.   [2]

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(ii)   The Earth's orbit around the Sun is almost circular with radius 1.5×10^{11} m.
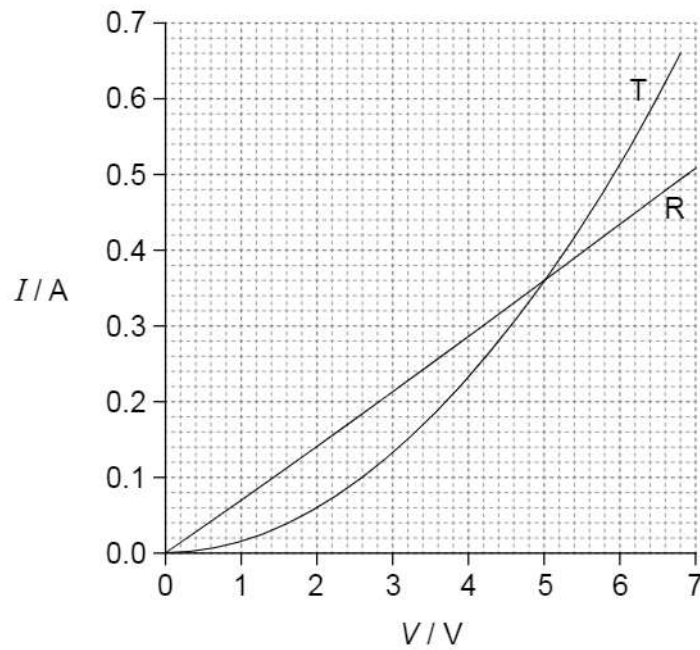Estimate the mass of the Sun.   [2]

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Turn over

8. The graph shows how current I varies with potential difference V for a resistor R and a non-ohmic component T.

(a) (i) State how the resistance of T varies with the current going through T. [1]

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(ii) Deduce, without a numerical calculation, whether R **or** T has the greater resistance at $I = 0.40\,\text{A}$. [2]

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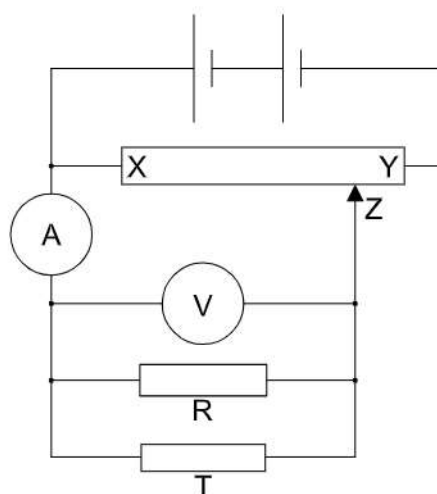
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(Question 8 continued)

(b)   Components R and T are placed in a circuit. Both meters are ideal.

Slider Z of the potentiometer is moved from Y to X.

(i)   State what happens to the magnitude of the current in the ammeter.   [1]

(ii)   Estimate, with an explanation, the voltmeter reading when the ammeter
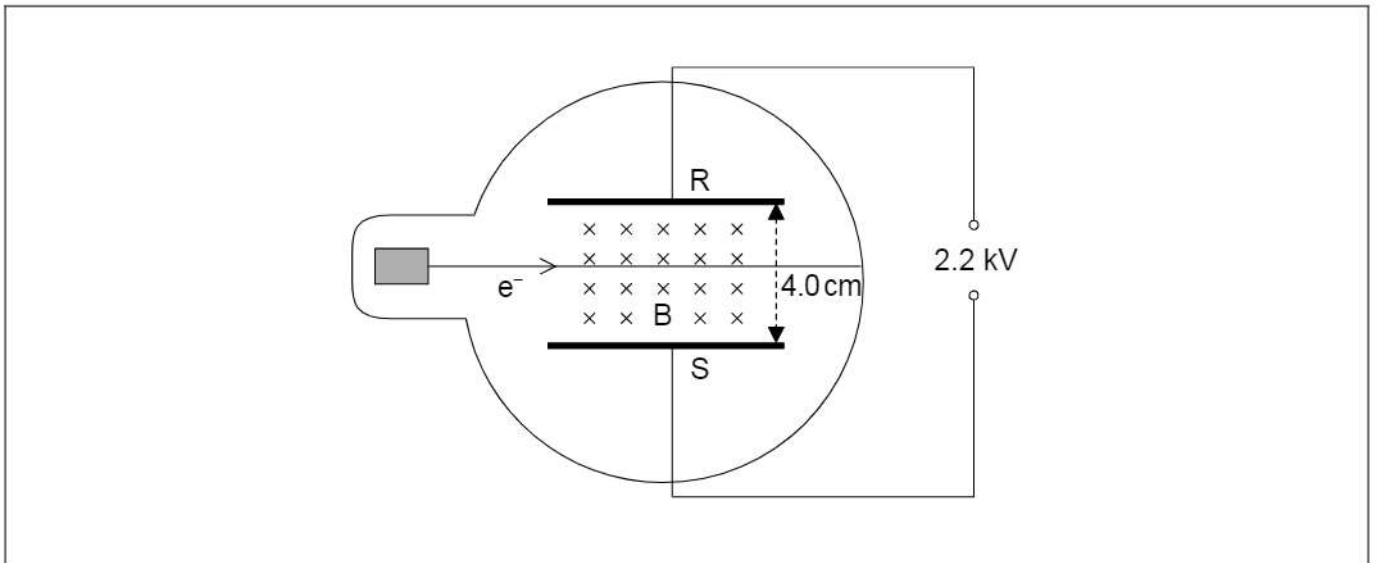reads 0.20 A.   [2]

Turn over

9. A beam of electrons e⁻ enters a uniform electric field between parallel conducting plates RS. RS are connected to a direct current (dc) power supply. A uniform magnetic field B is directed into the plane of the page and is perpendicular to the direction of motion of the electrons.

The magnetic field is adjusted until the electron beam is **undeflected** as shown.

(a)   Identify, on the diagram, the direction of the electric field between the plates.   [1]

(b)   The following data are available.

Separation of the plates RS $= 4.0 \, cm$
Potential difference between the plates $= 2.2 \, kV$
Velocity of the electrons $= 5.0 \times 10^5 \, m \, s^{-1}$

Determine the strength of the magnetic field B.   [2]

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(Question 9 continued)

(c) The velocity of the electrons is now increased. Explain the effect that this will have on the path of the electron beam. [2]

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10. The following data are available for a natural gas power station that has a high efficiency.

Rate of consumption of natural gas $= 14.6\,\text{kg s}^{-1}$
Specific energy of natural gas $= 55.5\,\text{MJ kg}^{-1}$
Efficiency of electrical power generation $= 59.0\,\%$
Mass of CO_2 generated per kg of natural gas $= 2.75\,\text{kg}$
One year $= 3.16 \times 10^7\,\text{s}$

(a) (i) Calculate, with a suitable unit, the electrical power output of the power station. [1]

(ii) Calculate the mass of CO_2 generated in a year assuming the power station operates continuously. [1]

(iii) Explain, using your answer to (a)(ii), why countries are being asked to decrease their dependence on fossil fuels. [2]

(iv) Describe, in terms of energy transfers, how thermal energy of the burning gas becomes electrical energy. [2]

(This question continues on the following page)

(Question 10 continued)

(b)   The electrical power output is produced by several alternating current (ac) generators which use transformers to deliver energy to the national electricity grid.

The following data are available. Root mean square (rms) values are given.

ac generator output voltage to a transformer	= 25 kV
ac generator output current to a transformer	= 3.9 kA
Transformer output voltage to the grid	= 330 kV
Transformer efficiency	= 96 %

(i)   Calculate the current output by the transformer to the grid. Give your answer to an appropriate number of significant figures.   [2]

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(ii)   Electrical energy is often delivered across large distances at 330 kV. Identify the main advantage of using this very high potential difference.   [2]
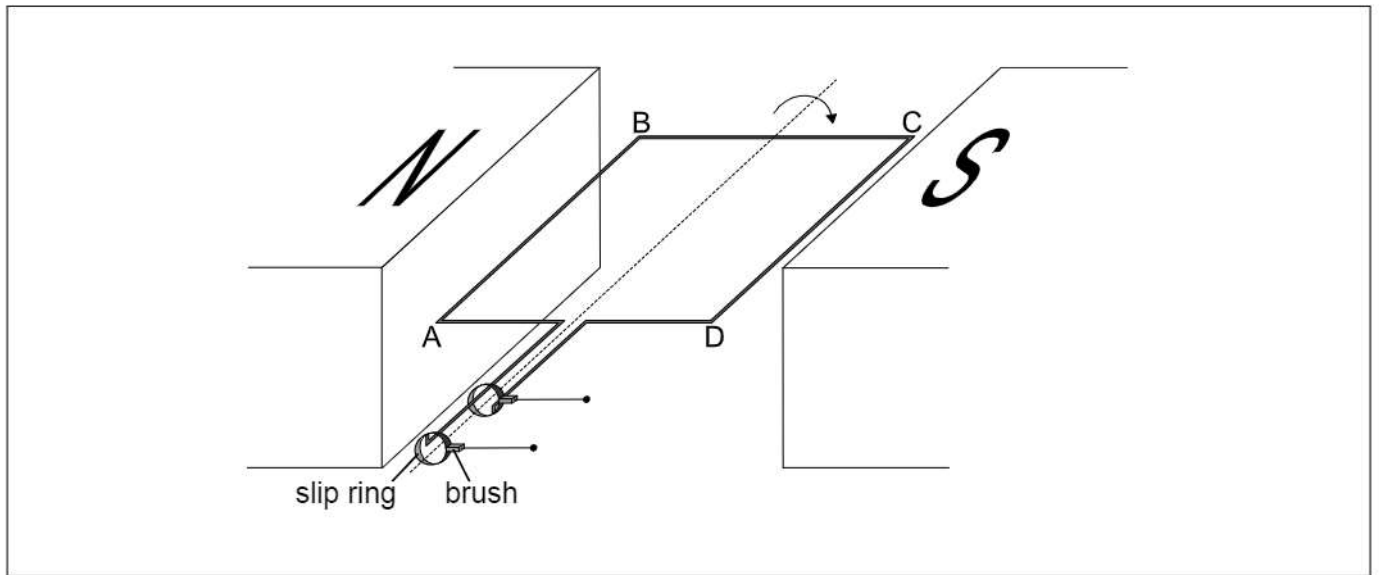
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(Question 10 continued)

(c)   In an alternating current (ac) generator, a square coil ABCD rotates in a magnetic field.

The ends of the coil are connected to slip rings and brushes. The plane of the coil is shown at the instant when it is parallel to the magnetic field. Only one coil is shown for clarity.

The following data are available.

Dimensions of the coil	$= 8.5\,cm \times 8.5\,cm$
Number of turns on the coil	$= 80$
Speed of edge AB	$= 2.0\,ms^{-1}$
Uniform magnetic field strength	$= 0.34\,T$

(i)   Explain, with reference to the diagram, how the rotation of the generator produces an electromotive force (emf) between the brushes.   [3]

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(Question 10 continued)

(ii) Calculate, for the position in the diagram, the magnitude of the instantaneous emf generated by a **single** wire between A and B of the coil. [1]

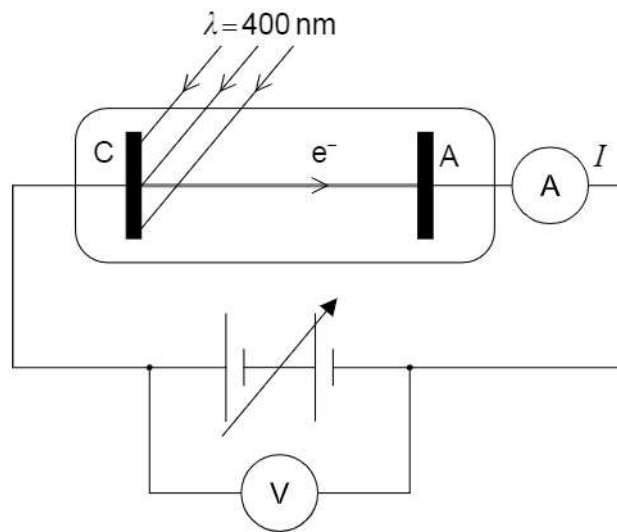(iii) Hence, calculate the total instantaneous peak emf between the brushes. [1]

Turn over

11. An apparatus is used to investigate the photoelectric effect. A caesium cathode C is illuminated by a variable light source. A variable power supply is connected between C and the collecting anode A. The photoelectric current I is measured using an ammeter.

(a) A current is observed on the ammeter when violet light illuminates C. With V held constant the current becomes zero when the violet light is replaced by red light of the same intensity. Explain this observation. [3]
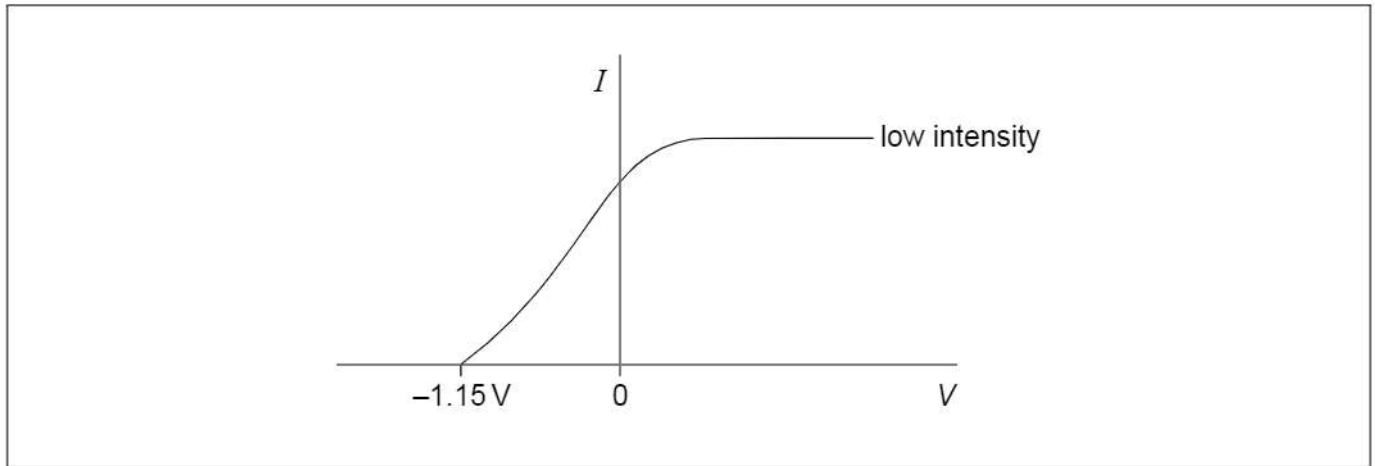
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(Question 11 continued)

(b)   The graph shows the variation of photoelectric current I with potential difference V between C and A when violet light of a particular intensity is used.

The intensity of the light source is increased without changing its wavelength.

(i)   Draw, on the axes, a graph to show the variation of I with V for the increased intensity.   [2]

(ii)   The wavelength of the violet light is 400 nm. Determine, in eV, the work function of caesium.   [2]

(iii) V is adjusted to $+2.50\,V$. Calculate the maximum kinetic energy of the photoelectrons just before they reach A.   [2]

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