Cambridge International Examinations
Cambridge Pre-U Certificate

CANDIDATE NAME	

CENTRE NUMBER						CANDIDATE NUMBER						

4835253219

PHYSICS (PRINCIPAL) **9792/03**

Paper 3 Written Paper **May/June 2018**

3 hours

Candidates answer on the Question Paper.

No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your Centre number, candidate number and name on all the work you hand in.
Write in dark blue or black pen.
You may use an HB pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.
DO **NOT** WRITE IN ANY BARCODES.

Section 1
Answer **all** questions.
You are advised to spend about 1 hour 30 minutes on this section.

Section 2
Answer any **three** questions. All six questions carry equal marks.
You are advised to spend about 1 hour 30 minutes on this section.

Electronic calculators may be used.

You may lose marks if you do not show your working or if you do not use appropriate units.

At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

For Examiner's Use	
1	
2	
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10	
11	
12	
Total	

This document consists of **37** printed pages and **3** blank pages.

DC (KN/FC) 149411/3

Data

gravitational field strength close to Earth's surface	$g = 9.81\,\mathrm{N\,kg^{-1}}$
elementary charge	$e = 1.60 \times 10^{-19}\,\mathrm{C}$
speed of light in vacuum	$c = 3.00 \times 10^{8}\,\mathrm{m\,s^{-1}}$
Planck constant	$h = 6.63 \times 10^{-34}\,\mathrm{J\,s}$
permittivity of free space	$\varepsilon_0 = 8.85 \times 10^{-12}\,\mathrm{F\,m^{-1}}$
gravitational constant	$G = 6.67 \times 10^{-11}\,\mathrm{N\,m^2\,kg^{-2}}$
electron mass	$m_e = 9.11 \times 10^{-31}\,\mathrm{kg}$
proton mass	$m_p = 1.67 \times 10^{-27}\,\mathrm{kg}$
unified atomic mass constant	$u = 1.66 \times 10^{-27}\,\mathrm{kg}$
molar gas constant	$R = 8.31\,\mathrm{J\,K^{-1}\,mol^{-1}}$
Avogadro constant	$N_A = 6.02 \times 10^{23}\,\mathrm{mol^{-1}}$
Boltzmann constant	$k = 1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$
Stefan-Boltzmann constant	$\sigma = 5.67 \times 10^{-8}\,\mathrm{W\,m^{-2}\,K^{-4}}$

Formulae

uniformly accelerated motion

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

$$v^2 = u^2 + 2as$$

$$s = \left(\frac{u+v}{2}\right)t$$

heating

$$\Delta E = mc\Delta\theta$$

change of state

$$\Delta E = mL$$

refraction

$$n = \frac{\sin\theta_1}{\sin\theta_2}$$

$$n = \frac{v_1}{v_2}$$

diffraction

single slit, minima $n\lambda = b\sin\theta$

grating, maxima $n\lambda = d\sin\theta$

double slit interference $\lambda = \frac{ax}{D}$

Rayleigh criterion $\theta \approx \frac{\lambda}{b}$

photon energy $E = hf$

de Broglie wavelength $\lambda = \frac{h}{p}$

simple harmonic motion $x = A\cos\omega t$

$v = -A\omega\sin\omega t$

$a = -A\omega^2\cos\omega t$

$F = -m\omega^2 x$

$E = \frac{1}{2}mA^2\omega^2$

energy stored in a capacitor $W = \frac{1}{2}QV$

capacitor discharge $Q = Q_0 e^{-\frac{t}{RC}}$

electric force $F = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r^2}$

electrostatic potential energy $W = \frac{Q_1 Q_2}{4\pi\varepsilon_0 r}$

gravitational force $F = -\frac{Gm_1 m_2}{r^2}$

gravitational potential energy $E = -\frac{Gm_1 m_2}{r}$

magnetic force $F = BIl\sin\theta$

$F = BQv\sin\theta$

electromagnetic induction $E = -\frac{d(N\Phi)}{dt}$

Hall effect $V = Bvd$

time dilation $t' = \frac{t}{\sqrt{1-\frac{v^2}{c^2}}}$

length contraction $l' = l\sqrt{1-\frac{v^2}{c^2}}$

kinetic theory $\frac{1}{2}m\langle c^2\rangle = \frac{3}{2}kT$

work done on/by a gas $W = p\Delta V$

radioactive decay $\frac{dN}{dt} = -\lambda N$

$N = N_0 e^{-\lambda t}$

$t_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$

attenuation losses $I = I_0 e^{-\mu x}$

mass-energy equivalence $\Delta E = c^2\Delta m$

hydrogen energy levels $E_n = \frac{-13.6\,\text{eV}}{n^2}$

Heisenberg uncertainty principle $\Delta p\Delta x \geqslant \frac{h}{2\pi}$

Wien's displacement law $\lambda_{max} \propto \frac{1}{T}$

Stefan's law $L = 4\pi\sigma r^2 T^4$

electromagnetic radiation from a moving source $\frac{\Delta\lambda}{\lambda} \approx \frac{\Delta f}{f} \approx \frac{v}{c}$

Section 1

Answer **all** questions in this section.
You are advised to spend about 1 hour 30 minutes on this section.

1 **(a)** State Kepler's three laws of planetary motion.

1. ....

....

2. ....

....

3. ....

....
[3]

(b) Use Newton's law of gravity to derive, for a circular orbit of a satellite around the Earth, the relationship between the radius r of the satellite's orbit and its period T.

[3]

(c) **(i)** A person of mass 80.0 kg is on the surface of the Earth.

The mass of the Earth is 5.99×10^{24} kg and its radius is 6.38×10^{6} m.

Calculate the gravitational potential energy of the person.

gravitational potential energy = ... J [2]

(ii) Explain why there is a minus sign in the equation for gravitational potential energy.

....

....

....

....[2]

(iii) Calculate the minimum initial speed that a projectile leaving the surface of the Earth must have if it is to escape to infinity from the Earth's gravitational field.

Ignore the effect of the atmosphere.

speed = ... $m\,s^{-1}$ [2]

[Total: 12]

2 **(a)** State the conditions for an object to vibrate with simple harmonic motion.

....

....[2]

(b) An object of mass 4.31 g is undergoing simple harmonic motion according to the equation

$$x = a \sin \omega t.$$

(i) Fig. 2.1 is the sketch graph of its motion.

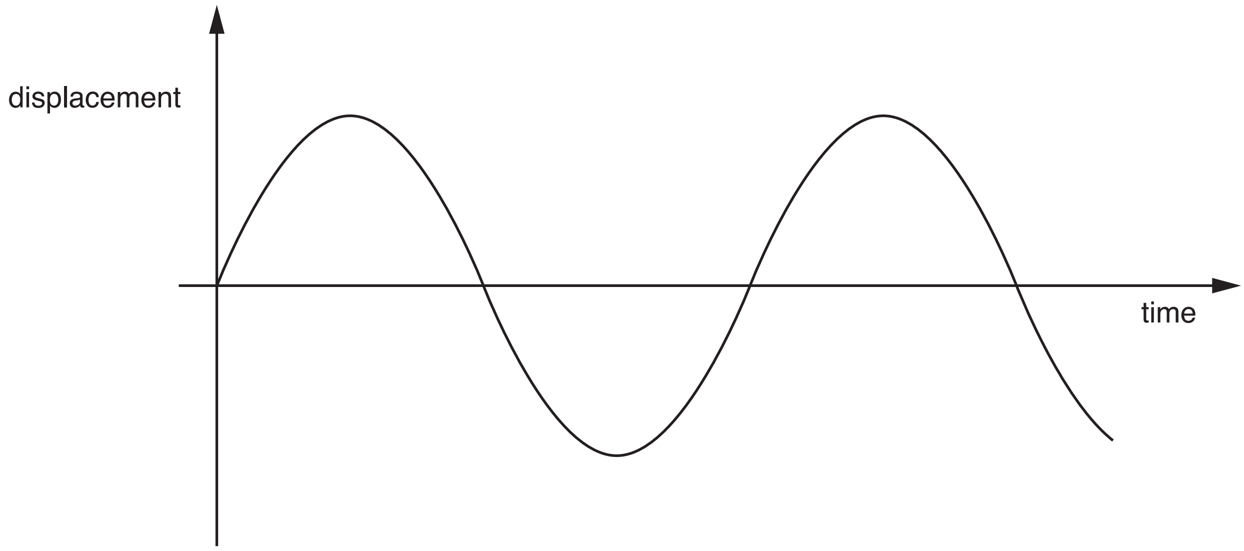


Fig. 2.1

On Fig. 2.1 draw and label graphs, all of different amplitudes, showing how

1. the velocity of the object changes with time, and label this *V*,

2. the acceleration of the object changes with time, and label this *A*.

[4]

(ii) The object oscillates with a frequency of 55.0 Hz with an amplitude of 2.00 mm.

Calculate,

1. the maximum velocity of the object,

velocity = ... $m\,s^{-1}$ [3]

2. the maximum acceleration of the object,

acceleration = ... $m\,s^{-2}$ [2]

3. the total energy of the oscillation.

total energy = ... J [2]

(c) A single note is played on a piano. A microphone, connected to an oscilloscope, is placed near the piano and the image on the oscilloscope is recorded over a short time. The pattern observed is shown in Fig. 2.2.

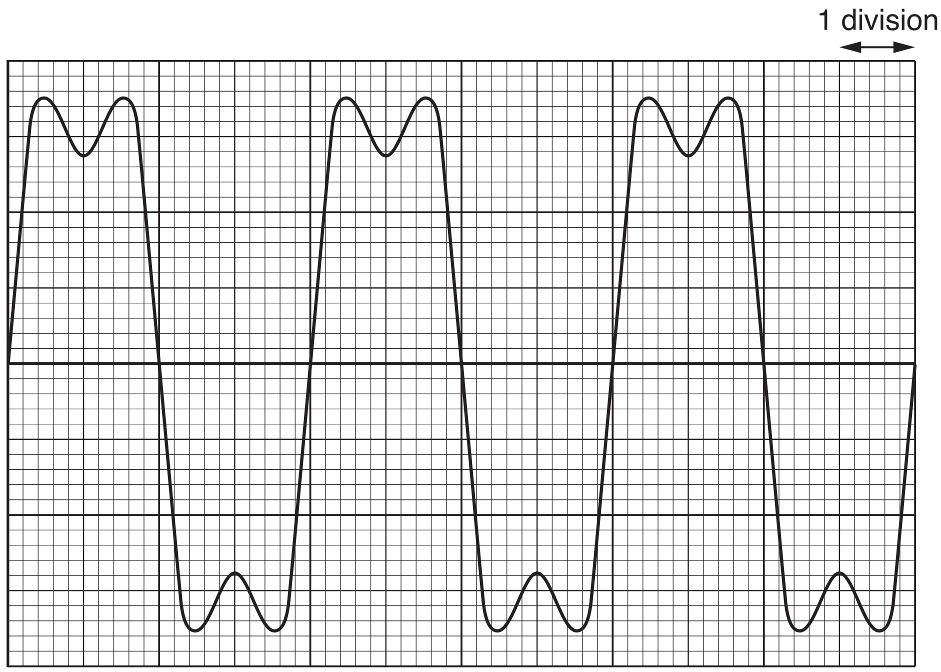


Fig. 2.2

The time base setting is 0.50 ms / division. The note produced by a piano is almost always a series of different frequencies that are a multiple of the lowest frequency.

Using Fig. 2.2 and giving your answer to an appropriate number of significant figures, deduce

(i) the lowest frequency,

lowest frequency = ... Hz [2]

(ii) one other frequency present.

other frequency = ... Hz [2]

[Total: 17]

3 **(a)** **(i)** Most of the electrical power supplied through the National Grid is produced by electromagnetic induction. The equation that is fundamental to this method of producing electrical power is

$$E = -\frac{d(N\Phi)}{dt}.$$

Explain how this equation is an expression of both Faraday's and Lenz's laws.

....

....

....

....

....

....[3]

(ii) An electric power generator has a coil with 800 turns. An emf of 7200 V is produced at certain instants.

Calculate the rate of change of magnetic flux at these instants.

rate of change of magnetic flux = ... $Wb\,s^{-1}$ [2]

(b) **(i)** An electron enters a region of uniform magnetic field, as shown in Fig. 3.1.

Fig. 3.1

Draw on the diagram a possible path that the electron will take in the magnetic field. [2]

(ii) A similar situation to that in **(b)(i)** is in the Hall effect, when electrons move in a slice of semiconductor material that is placed in a uniform magnetic field. This is shown in Fig. 3.2.

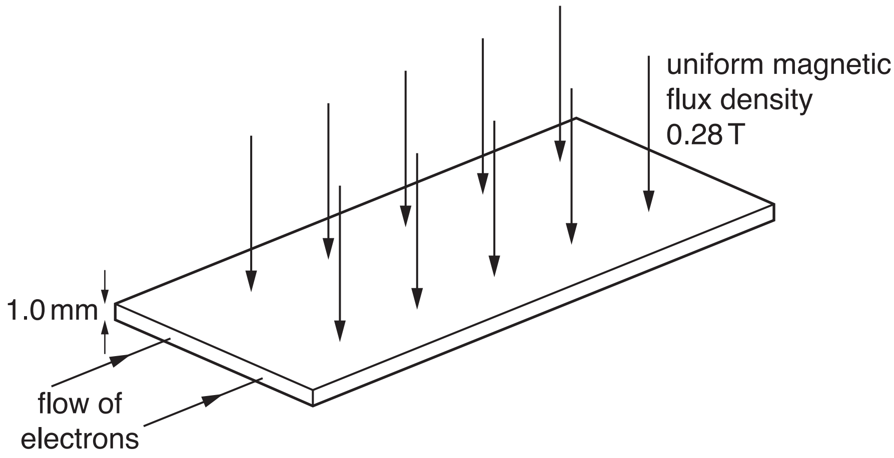


Fig. 3.2

The semiconductor slice has dimensions of length l = 20 mm, width w = 9.0 mm and depth d = 1.0 mm.

The magnetic flux density B is 0.28 T and the mean velocity u of the electrons is 56 m s^{-1}.

A Hall voltage V is established across the slice.

1. Derive an equation for this Hall voltage.

[3]

2. Calculate the Hall voltage.

Hall voltage = ... V [1]

3. On Fig. 3.2 label with a + the side of the slice which becomes positive because of the Hall effect. [1]

(iii) The semiconductor slice is replaced by a slice of copper with the same dimensions. The measured Hall voltage is now very small.

Suggest a reason for this difference.

....

....

....[2]

[Total: 14]

4 On a day when atmospheric pressure is 1.01×10^5 Pa the density of the atmosphere at sea level is $1.29\,kg\,m^{-3}$.

The composition of gases in the atmosphere is very complex and varies from day to day and from place to place. The average percentage of the four most common gases in dry air are, by mass

nitrogen	75%
oxygen	23%
argon	1.3%
carbon dioxide	0.04%.

(a) Calculate the mass of oxygen in a cubic metre of dry air.

mass = ... kg [2]

(b) As a result of a large number of collisions between molecules, the average kinetic energy of the molecules is the same for all gases. This results in the equation

$$\tfrac{1}{2}m\langle c^2\rangle = \tfrac{3}{2}kT,$$

where k is the Boltzmann constant = $1.38 \times 10^{-23}\,\mathrm{J\,K^{-1}}$.

Measurements for nitrogen, for oxygen and for water vapour were made at a temperature of 293 K.

Measurements for carbon dioxide were made at a different temperature.

Complete the table, of Fig. 4.1, showing the masses, temperatures and the root mean square speeds of four different molecules.

Show your working in the space below.

oxygen

water vapour

carbon dioxide

	average mass of a molecule / 10^{-26} kg	temperature / K	root mean square speed / m s^{-1}
nitrogen	4.65	293	511
oxygen	5.31	293	
water vapour		293	635
carbon dioxide	7.31		608

Fig. 4.1

[5]

(c) The root mean square speed of nitrogen molecules in a container is given in part **(b)** as $511\,\text{m}\,\text{s}^{-1}$ at a temperature of 293 K. Fig. 4.2 shows the distribution of speeds of molecules at that temperature.

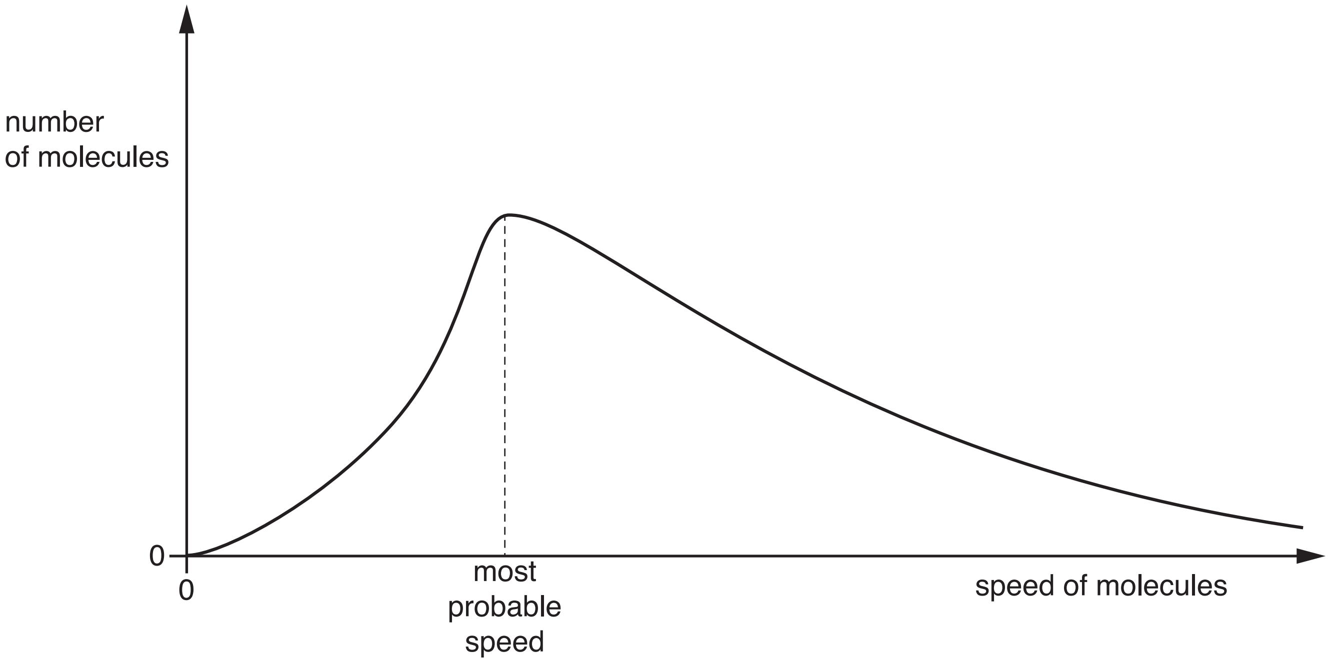


Fig. 4.2

(i) The mean speed differs from the most probable speed.

1. Mark on Fig. 4.2 a line to show a possible value of the mean speed of the molecules. [1]

2. Explain the reason for your answer to **(c)(i)1**.

....

....[1]

(ii) The peak of the graph corresponds to the most probable molecular speed v and occurs when

$$v = \sqrt{\frac{2kT}{m}}.$$

Calculate the most probable speed.

most probable speed = ...$\text{m}\,\text{s}^{-1}$ [2]

(iii) Draw on Fig. 4.2 the shape of two graphs, one when the molecules in the container are at a much higher temperature, labelled H, and the other when the molecules are at a much lower temperature, labelled L. [4]

[Total: 15]

5 (a) (i) Calculate the distance, in metres, of a light year. The speed of light is $3.00 \times 10^8\,\text{m}\,\text{s}^{-1}$.

1 light year = ...m [2]

(ii) As the Earth moves around the Sun, a nearby star seems to move relative to much more distant stars.

Over a period of six months, a star at a distance *d* from the Sun seems to move through an angle θ, as shown in Fig. 5.1.

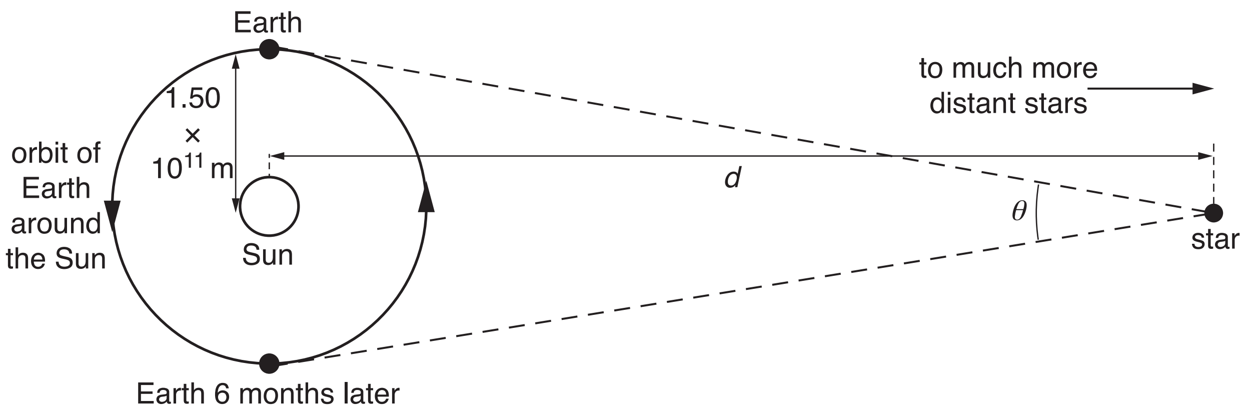


Fig. 5.1

The distance from the Earth to the Sun is 1.50×10^{11} m.

The maximum value of *d* that can be measured using a particular telescope is 1.72×10^{17} m.

Calculate the minimum value of θ that can be measured using this telescope. Give your answer in degrees.

θ = ... ° [2]

(iii) Measurements of the distance to nearby stars called Cepheid variables, which have a fixed pattern of intensity variation, enable distances to other Cepheid variables to be obtained.

Suggest why these measurements are important in measuring far greater distances.

....

....

....

....

....[2]

(b) Fig. 5.2 shows the intensity against wavelength graph for the electromagnetic radiation emitted by a star.

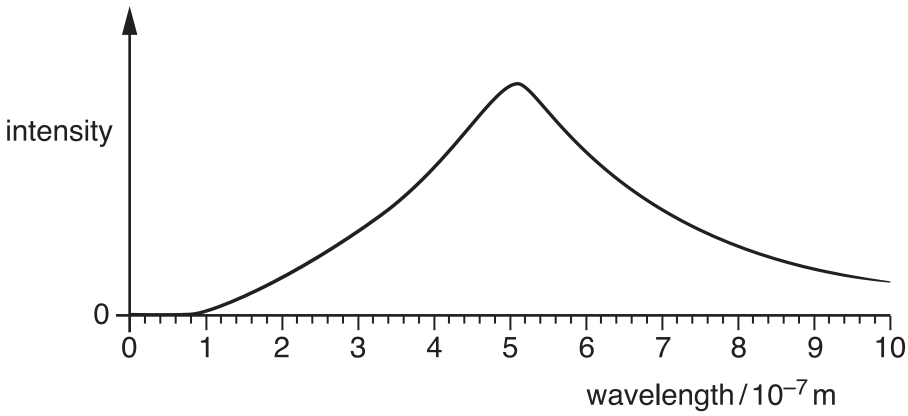


Fig. 5.2

(i) Use Wien's law, $T\lambda_{max} = 2.90 \times 10^{-3}$ m K, to determine the approximate surface temperature of the star emitting a spectrum of light as shown in Fig. 5.2.

approximate temperature = ... K [2]

(ii) The star is a distance of 1.88×10^{17} m from the Earth. At the Earth's surface, the intensity of radiation I received from this star is 3.7×10^{-8} W m^{-2}.

Use Stefan's law to estimate the radius of the star.

The Stefan-Boltzmann constant has a value $\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4}.

radius = ...m [4]

[Total: 12]

6 **(a)** Describe and explain the experimental evidence for the existence of energy levels in the hydrogen atom.

....

....

....

....

....

....[3]

(b) **(i)** Use the equation for energy levels in a hydrogen atom $E_n = \frac{-13.6\,\text{eV}}{n^2}$ to complete the table for values of n from 1 to 5 and infinity.

n	E / eV
1	
2	
3	
4	
5	
infinity	

[2]

(ii) An electron with a kinetic energy of 11.0 eV collides with an isolated hydrogen atom in its ground state.

Suggest and explain possible values of the kinetic energies of the scattered electron after the collision.

....

....

....

....

....

....

....

....

....

....[5]

[Total: 10]

Section 2

Answer any **three** questions in this section.
You are advised to spend about 1 hour 30 minutes on this section.

7 **(a)** An object rotates in a vertical circle with constant speed, as shown in Fig. 7.1. The arrows in Fig. 7.1 represent the weight of the object in three different positions.

(i) Draw on Fig. 7.1, for each of the three positions, an arrow labelled F which represents the resultant force that acts on the object. [2]

(ii) The resultant force at each point is the vector sum of the weight of the object and a second force which changes in magnitude and direction as the object moves in a circle.

Draw an arrow at each of the positions of the object to represent this second force in magnitude and direction. [4]

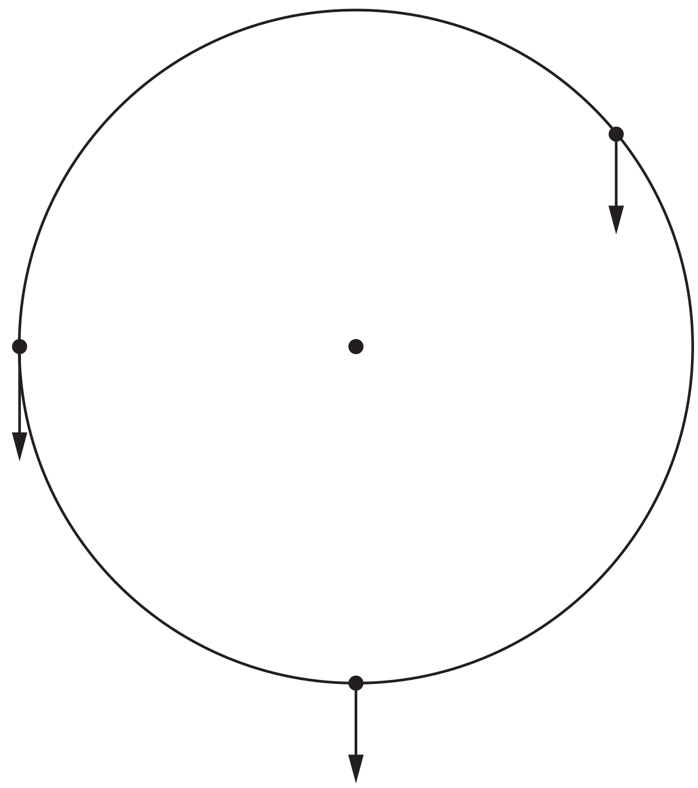


Fig. 7.1

(b) **(i)** State the formula for the moment of inertia I of a point mass *m* rotating in a circle of radius *R*.

I = ...[1]

(ii) Derive an expression, using integration, for the moment of inertia I of a uniform disc of mass M and radius R rotating about its centre.

[4]

(c) The rotating part of a motor used to start a car is called its armature. The armature in one starter motor has a moment of inertia of 0.0050 kg m^2. When used to start a car the resultant torque Γ applied to the armature is as shown in Fig. 7.2.

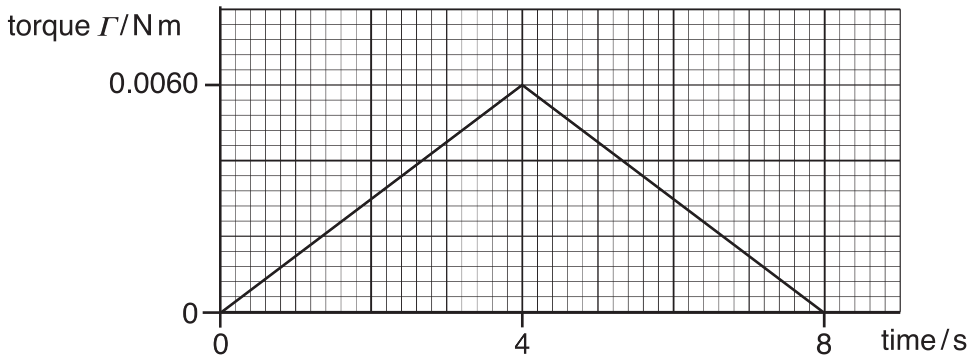


Fig. 7.2

The armature is initially at rest.

(i) Sketch on the graph of Fig. 7.3 the variation with time of the angular velocity of the armature over 8.0 seconds. No scale is required on the vertical axis.

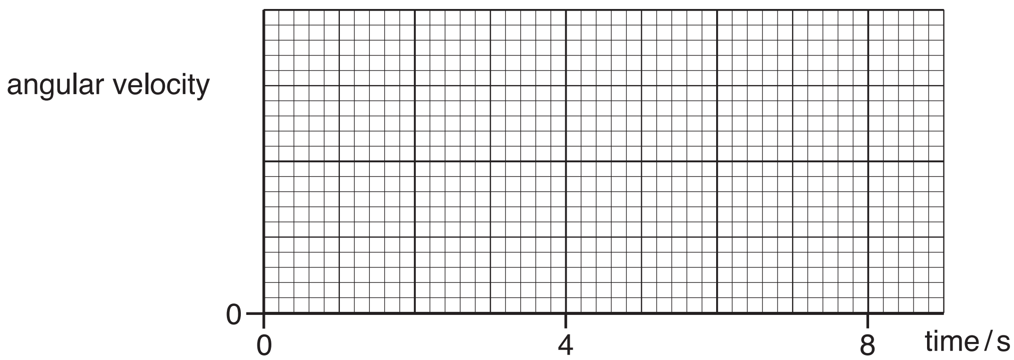


Fig. 7.3

[3]

(ii) Using the average value of Γ, or otherwise, calculate the angular velocity of the armature after 8.0 s. Give the unit for angular velocity.

angular velocity = ... unit .... [4]

(iii) Calculate the kinetic energy of the armature after 8.0 s.

kinetic energy = ... J [2]

[Total: 20]

8 **(a)** **(i)** Show that the random nature of radioactive decay leads to the differential equation

$$\frac{dN}{dt} = -\lambda N$$

where N is the number of radioactive nuclei, λ is a constant and $\frac{dN}{dt}$ is the rate of change of N with time.

[2]

(ii) Show that $N = N_0 e^{-\lambda t}$ is a solution of the equation in **(a)(i)**.

[1]

(b) A radioactive source was monitored over the years for its activity. The readings are shown in the table in Fig. 8.1.

time from start / years	count rate / s^{-1}	ln (count rate / s^{-1})
0	8.67	
5	8.33	2.12
10	7.03	1.95
15		1.72
20	4.62	1.53
25	4.06	1.40
30		1.15
36	2.89	1.06
40	2.53	

Fig. 8.1

(i) complete the table by filling in the missing values. [4]

(ii) On Fig. 8.2 plot a suitable graph and use it to determine the half-life of the source.

Fig. 8.2

half-life = ... years [5]

(c) **(i)** Explain what is meant by the term *nuclear binding energy*.

....

....

....[2]

(ii) A nucleus of strontium-90 has a mass of 89.907 u. It contains 38 protons. The mass of a neutron is 1.00867 u and the mass of a proton is 1.00783 u.

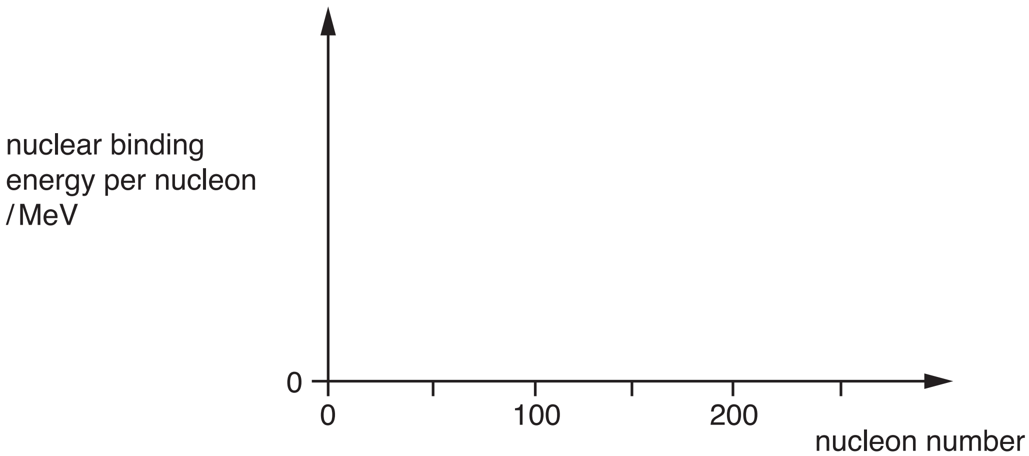
Calculate the nuclear binding energy per nucleon of strontium-90.
Give your answer in units of MeV.

(931 MeV is the energy equivalent of 1u)

binding energy per nucleon = ... MeV [3]

(iii) The nuclear binding energy per nucleon varies across the whole range of elements.

On the axes of Fig. 8.3 draw a sketch graph to show this variation. Put some approximate numerical values on the vertical axis of the graph.



[3]

Fig. 8.3

[Total: 20]

9 **(a)** **(i)** The charge on a parallel plate capacitor is said to be 4.0 μC.

Describe how the charge is distributed within the capacitor.

....

....

....[2]

(ii) A capacitor of capacitance 8.6 μF is fully charged from a battery of emf 2.8 V.

1. Calculate the charge on the capacitor.

charge = ... C [1]

2. Explain why it is not necessary to know the internal resistance of the battery when calculating the charge in **(a)(ii)1.**.

....

....

....[2]

3. Calculate the energy stored in the fully charged capacitor.

energy = ... J [2]

(b) A capacitor has a capacitance of 3.8 μF and discharges through a resistor of resistance 47 kΩ.

Calculate the time taken for the charge on this capacitor to decrease from 68 μC to 18 μC.

time = ... s [3]

(c) An alternating voltage supply of maximum emf E and frequency f is connected across a capacitor of capacitance C. The variation of the alternating voltage with time is shown in Fig. 9.1a.

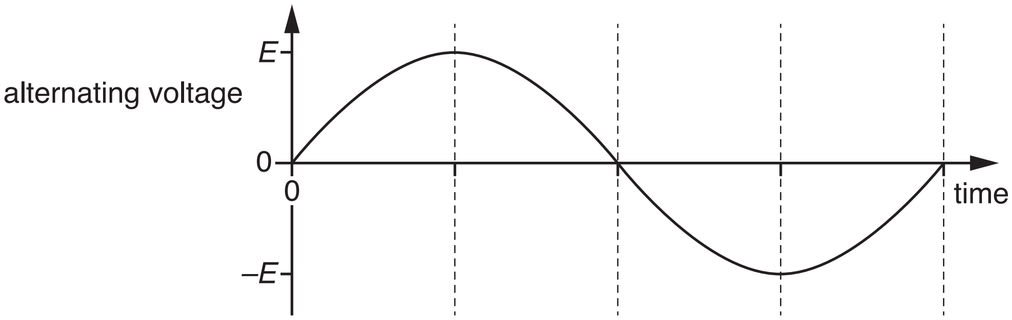


Fig. 9.1a

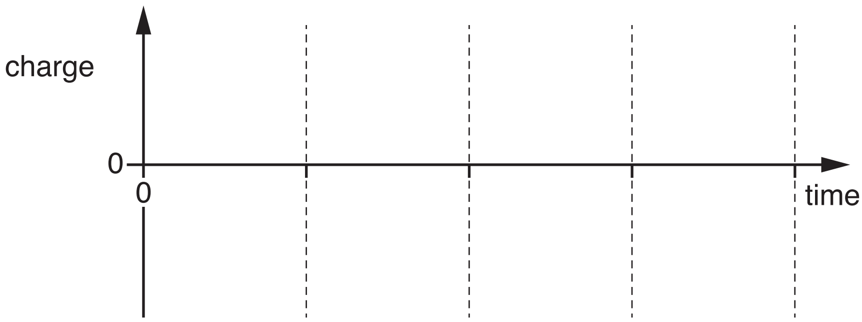


Fig. 9.1b

Fig. 9.1c

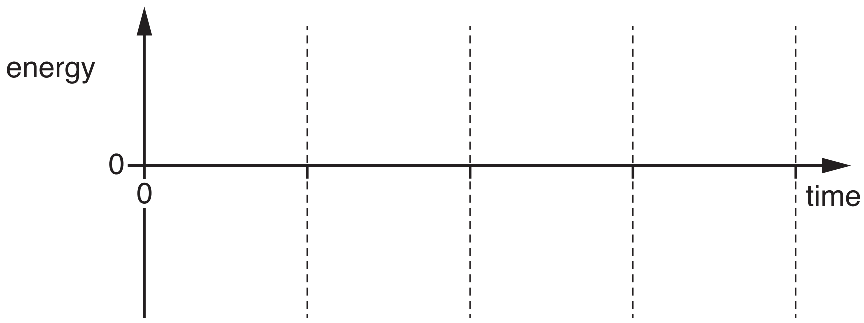


Fig. 9.1d

The resistance of the supply can be considered to be zero.

Figs. 9.1b, 9.1c and 9.1d use the same time scale as Fig. 9.1a.

(i) Sketch a graph on Fig. 9.1b to show how the charge on the capacitor varies with time.

Mark on the vertical axis an expression, in terms of *C*, *E* and *f* for the peak value of the charge. [2]

(ii) **1.** Sketch a graph on Fig. 9.1c to show how the current in the circuit varies with time. [2]

2. Deduce an expression, in terms of *C*, *E* and *f*, for the peak current and mark this on the vertical axis.

[2]

(iii) **1.** Sketch a graph on Fig. 9.1d to show how the energy stored in the capacitor varies with time.

Mark on the vertical axis an expression, in terms of *C* and *E*, for the peak value of energy. [2]

2. There are times when the energy stored is decreasing.

Describe what is happening to this energy.

....

....

....[2]

[Total: 20]

10 (a) Explain what is meant by absolute time.

....

....

....

....[2]

(b) A pair of identical atomic clocks, X and Y, are used in a series of three experiments to test relativistic time dilation. In each experiment, the clocks are initially zeroed and placed side by side before being moved apart in different ways. At the end of each experiment the clocks are again placed side by side at rest in the original position and the times shown on each clock are compared.

Assume that the periods of acceleration and deceleration are negligible compared to the total time in each experiment and that all motions take place along the same line. Ignore the effects of gravitational fields.

Experiment 1

Clock X remains at rest and clock Y is taken on a round-trip journey at constant speed v relative to clock X and then placed at rest beside X as shown in Fig. 10.1.

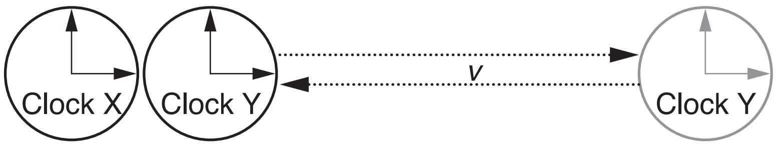


Fig. 10.1

Experiment 2

Both clocks are moved in opposite directions away from their original position at speed v and then returned at speed v and placed at rest beside one another as shown in Fig. 10.2.

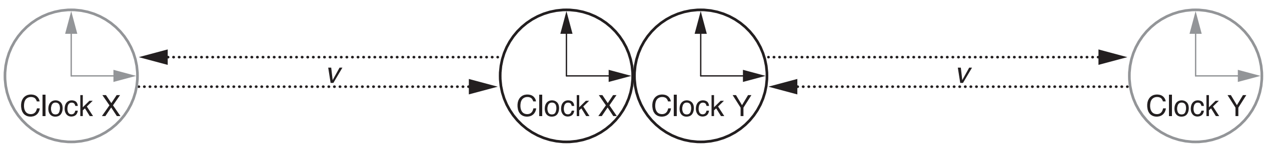


Fig. 10.2

Experiment 3

Clock Y remains at rest and clock X is taken on a round-trip journey at constant speed v relative to clock Y and then placed at rest beside Y as shown in Fig. 10.3.

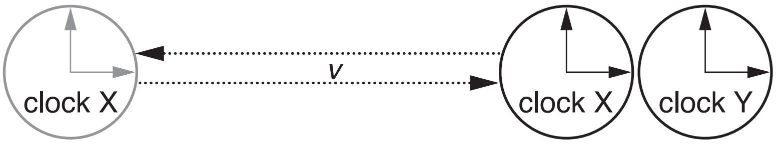


Fig. 10.3

(i) Complete the table of Fig. 10.4 to show the expected results according to Einstein's special theory of relativity.

	time recorded by X during experiment	State whether the time recorded by Y is **equal to / less than / more than** the time recorded by X	Write an expression for the time recorded by Y in terms of v and c and the time recorded by X
experiment 1	T_1		
experiment 2	T_2		
experiment 3	T_3		

Fig. 10.4

[5]

(ii) Explain how these results conflict with Newton's hypothesis of absolute time in the Universe.

....

....

....

....[2]

(c) The nearest star (apart from the Sun) to the Earth is Proxima Centauri which is 4.2 light years away. The fastest man-made object is the NASA Helios 2 space probe which reached about $6.0 \times 10^4\,m\,s^{-1}$ as it travelled towards the Sun.

There are approximately $3.2 \times 10^7\,s$ in one year.

(i) Show that it would take a spacecraft travelling at a constant speed of $6.0 \times 10^4\,m\,s^{-1}$ about 20 000 years to travel from Earth to Proxima Centauri as measured by an observer on the Earth.

[1]

(ii) Time dilation would mean that less than 20 000 years passed for astronauts inside the spacecraft. Show that this is still a very small effect at a speed of $6.0 \times 10^4\,m\,s^{-1}$ and that it would be impossible for humans to reach Proxima Centauri during one lifetime.

....

....

....

....[2]

(iii) In the future, it might be possible to build spacecraft that can travel at speeds that are a significant fraction of the speed of light.

Calculate the velocity required, in terms of the speed of light, so that astronauts on board the spacecraft will live through just 5 years during a round trip from Earth to Proxima Centauri.

[3]

(iv) Explain why an astronaut travelling from Earth to Proxima Centauri inside a high-speed spacecraft will find that the distance travelled is less than 4.2 light years.

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....[2]

(d) Another consequence of special relativity is the relativity of simultaneity.

(i) Explain what is meant by the relativity of simultaneity.

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(ii) Discuss how the relativity of simultaneity undermines the idea of an absolute time.

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....[2]

[Total: 20]

11 **(a)** A neutron inside a nucleus is effectively trapped in a small region of space so that the uncertainty in its position is roughly equal to the radius of the nucleus.

(i) Use Heisenberg's uncertainty principle to calculate the minimum uncertainty in the momentum of a neutron inside a gold nucleus of radius 7.30×10^{-15} m.

uncertainty in momentum = ... kg m s^{-1} [2]

(ii) Derive an equation that links the kinetic energy E_K to the momentum p of a particle of mass m.

[2]

(iii) Use your answers to **(i)** and **(ii)** to calculate the minimum uncertainty in the kinetic energy of the neutron in this nucleus. The mass of a neutron is 1.67×10^{-27} kg.

uncertainty in kinetic energy = ... J [1]

(iv) Show that this uncertainty in energy is small enough to ignore relativistic effects when considering the motion of the neutron.

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(v) The binding energy per nucleon in this nucleus is about 8.0 MeV.

Deduce how the uncertainty in the neutron's kinetic energy affects the stability of the nucleus.

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(b) Electrons are negatively charged and nuclei are positively charged so it is tempting to think that electrons can become trapped inside a nucleus.

(i) Calculate the electric potential energy of an electron at a distance of 7.30×10^{-15} m from the centre of a gold nucleus of charge +79e.

potential energy = ... J [3]

(ii) Use an energy argument based on the uncertainty principle to explain why electrons cannot become trapped inside a gold nucleus.

Support your answer by carrying out a suitable calculation.

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(c) Discuss how the uncertainty principle places limits on our ability to predict the future.

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[Total: 20]

12 **(a)** Explain, by referring to relevant laws and principles of physics, why each of the following is impossible.

(i) To construct a torch that emits a perfectly parallel beam of light.

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(ii) To predict where a particular single photon will arrive on a screen in a double slit experiment.

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(iii) To construct a refrigerator that works without an external source of energy.

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....[3]

(b) A glass of water is left outside on a cold night and the water freezes.

(i) Describe the energy transfer that takes place as the water freezes.

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....[2]

(ii) Explain how and why the entropy of the water and the surroundings change when the water freezes.

1. the water

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2. the surroundings.

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[4]

(iii) Suggest in terms of entropy why water does not freeze when the surrounding temperature is 10 °C.

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....[2]

(c) One of the consequences of special relativity is that the mass of a moving object increases according to the formula

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}.$$

m_0 is the rest mass of the particle (the mass it has when it is at rest in a laboratory).

m is the mass it has when it is moving at velocity *v* relative to the laboratory in which its mass is measured.

Use this equation to explain why it would be impossible to accelerate a particle such as an electron to the speed of light.

You might find it helpful to include a sketch graph.

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....[4]

[Total: 20]

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