JC2 Preliminary Examinations
Higher 2

H2 Physics 9646/01

Paper 1 Multiple Choice

22 September 2016

1 hour 15 minutes

Additional Materials: Multiple Choice Answer Sheet

Candidate Name: ______________________	Class	Reg No

READ THESE INSTRUCTIONS FIRST

Write in soft pencil.
Do not use staples, paper clips, glue or correction fluid.
Write your name, class and index number on the Answer Sheet in the spaces provided.

In the Index Number section, shade your index number using the first two spaces (e.g. index number 5 should be entered as "05"). Ignore the remaining numbers and letters.

There are **forty** questions in this section. Answer **all** questions.
For each question there are four possible answers **A**, **B**, **C** and **D**.
Choose the **one** you consider correct and record your choice in **soft pencil** on the Answer Sheet.

Each correct answer will score one mark. A mark will not be deducted for a wrong answer.

Any rough working should be done in this booklet.

The use of an approved scientific calculator is expected, where appropriate.

Data

speed of light in free space	c	=	$3.00 \times 10^{8}\ \text{m s}^{-1}$
permeability of free space	μ_0	=	$4\pi \times 10^{-7}\ \text{H m}^{-1}$
permittivity of free space	ε_0	=	$8.85 \times 10^{-12}\ \text{F m}^{-1}$
		=	$(1/(36\pi)) \times 10^{-9}\ \text{F m}^{-1}$
elementary charge	e	=	$1.60 \times 10^{-19}\ \text{C}$
the Planck constant	h	=	$6.63 \times 10^{-34}\ \text{J s}$
unified atomic mass constant	u	=	$1.66 \times 10^{-27}\ \text{kg}$
rest mass of electron	m_e	=	$9.11 \times 10^{-31}\ \text{kg}$
rest mass of proton	m_p	=	$1.67 \times 10^{-27}\ \text{kg}$
molar gas constant	R	=	$8.31\ \text{J K}^{-1}\ \text{mol}^{-1}$
the Avogadro constant	N_A	=	$6.02 \times 10^{23}\ \text{mol}^{-1}$
the Boltzmann constant	k	=	$1.38 \times 10^{-23}\ \text{J K}^{-1}$
gravitational constant	G	=	$6.67 \times 10^{-11}\ \text{N m}^{2}\ \text{kg}^{-2}$
acceleration of free fall	g	=	$9.81\ \text{m s}^{-2}$

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-\frac{GM}{r}$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
	v	=	$\pm \omega \sqrt{x_o^2 - x^2}$
mean kinetic energy of a molecule of an ideal gas	E	=	$\frac{3}{2}kT$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	x	=	$x_o \sin \omega t$
transmission coefficient	T	$\propto$	$\exp(-2kd)$
	where k	=	$\sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay	x	=	$x_o \exp(-\lambda t)$
decay constant	λ	=	$\frac{0.693}{t_{\frac{1}{2}}}$

1 The SI unit for magnetic flux density is the tesla (T). How should the tesla be expressed in terms of SI base units?

A kg s^{-1} A^{-2} **B** kg s^{-2} A^{-1} **C** kg s^{-1} C^{-1} **D** kg s^{-2} C^{2}

2 Which pair includes a vector and scalar quantity?

A	displacement	acceleration
B	magnetic flux density	kinetic energy
C	power	electromotive force
D	electric current	potential energy

3 A stone falls freely from rest to the ground. The effect of air resistance on the stone is negligible. The stone travels $\frac{3}{4}$ of the total distance to the ground in the last two seconds of its fall. What is the total time of its fall?

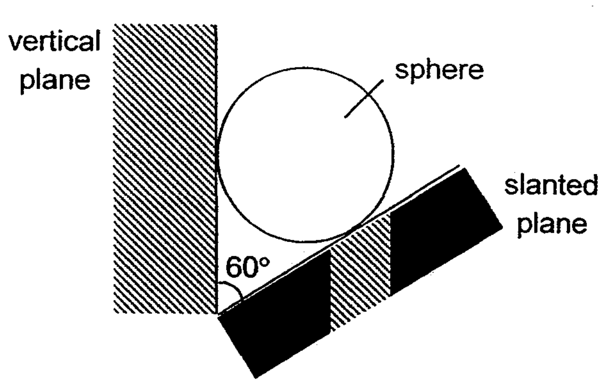
A 1.3 s **B** 2.7 s **C** 4.0 s **D** 14.9 s

4 A man throws a stone upwards off the edge of a cliff with an initial velocity u. The stone reaches the highest point at 2.0 s and then reaches the bottom of the cliff at 7.0 s. Air resistance is negligible.

Which of the following shows the correct signs for displacement s, velocity v and acceleration a of the stone at the respective times t?

	t / s	s	v	a
A	1.0	+	+	+
B	3.0	+	+	−
C	3.5	−	−	−
D	6.5	−	−	−

5 A uniform sphere of weight 15 N is placed in between two smooth planes as shown.



What is the magnitude of the force exerted by the vertical plane on the sphere?

A zero **B** 7.5 N **C** 8.7 N **D** 13.0 N

6 A mass is suspended using a spring balance from the ceiling of a lift.

When the lift is moving up at a constant speed, the reading on the spring balance is F. Under which of the following situations is the reading on the spring balance more than F?

A The lift is moving down at increasing speed

B The lift is moving down at decreasing speed

C The lift is moving down at constant speed

D The lift is stationary

7 A particle X moving with kinetic energy E and momentum p makes a head-on inelastic collision with an identical particle Y which is initially at rest.

Which of the following options shows possible values for the kinetic energy of the particle X and the system as a whole, and the magnitude of the momentum of X and the system as a whole, after this collision?

	kinetic energy of		momentum of	
	X	system	X	system
A	0	E	0	p
B	$\frac{E}{2}$	E	$\frac{p}{2}$	p
C	$\frac{E}{4}$	$\frac{E}{2}$	$\frac{p}{4}$	$\frac{p}{2}$
D	$\frac{E}{4}$	$\frac{E}{2}$	$\frac{p}{2}$	p

8 Two ice boats, of masses m and $2m$, are made to compete in a race on a frictionless frozen lake. The boats have identical sails so that the wind pushes them forward with the same force. The two boats start from rest and travel the same distance.

Which of the following statements is correct?

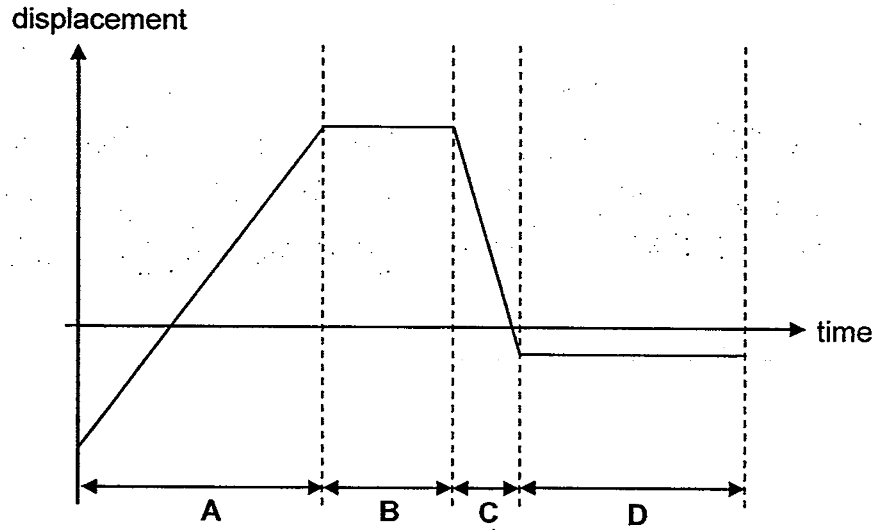
A The boat of mass m will win the race but the two boats will have the same final speed.

B The boat of mass m will win the race but it will have a lower final kinetic energy.

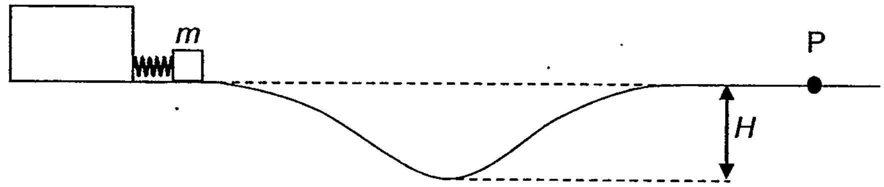
C The boat of mass m will win the race and it will have a higher final kinetic energy.

D The boat of mass m will win the race but the two boats will have the same final kinetic energy.

9 The following shows a displacement-time graph of a mass being moved on a table. It experiences a constant force of friction. Which time interval has the greatest work done per unit time against friction?



10 A small mass m is launched by a spring and travels along a rough track to a point P. The spring constant is k and the initial compression of the spring was x. As it travels to P it goes through a dip of depth H. The mass experiences a constant force of friction f for the entire distance of d.



What is the kinetic energy of the mass at point P?

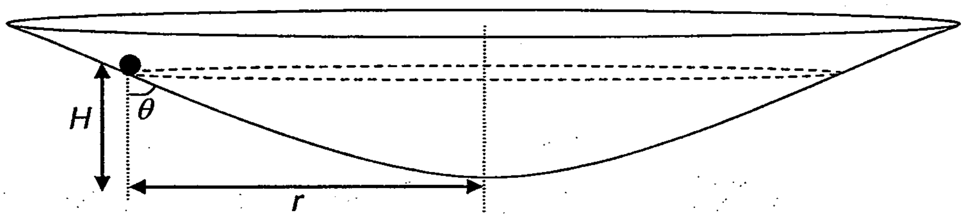
A $\frac{1}{2}kx^2 - fd$ **B** $\frac{1}{2}kx^2 + fd + mgH$

C $\frac{1}{2}kx^2 + fd$ **D** $\frac{1}{2}kx^2 - fd - mgH$

11 An object of mass m moves in a complete circle with constant speed v. What is the average momentum of the object?

A zero **B** $\frac{1}{2}mv$ **C** mv **D** $2mv$

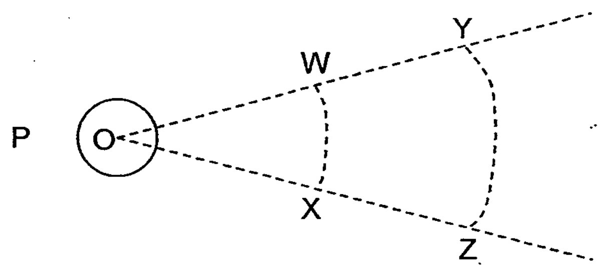
12 A sphere of mass m moves along a smooth horizontal circular path of radius r in a bowl with a constant linear speed v.



Which of the following gives the expression for angle θ?

A $\tan^{-1}\left(\dfrac{v^2}{rg}\right)$ **B** $\tan^{-1}\left(\dfrac{rg}{v^2}\right)$ **C** $\tan^{-1}\left(\dfrac{r}{H}\right)$ **D** $\tan^{-1}\left(\dfrac{H}{r}\right)$

13 P is a planet with centre O. WX and YZ are equipotential lines. Which one of the following is false?



A $\dfrac{\text{Gravitational potential at W}}{\text{Gravitational potential at Y}} = \dfrac{\text{Distance OY}}{\text{Distance OW}}$

B $\dfrac{\text{Kinetic energy of satellite orbiting at radius OW}}{\text{Kinetic energy of the same satellite orbiting at radius OY}} = \dfrac{\text{Distance OY}}{\text{Distance OW}}$

C Positive work has to be done by an external agent to move a mass from Y to W.

D The work needed to move a mass from W to Z is equal to the work needed to move a mass from W to Y.

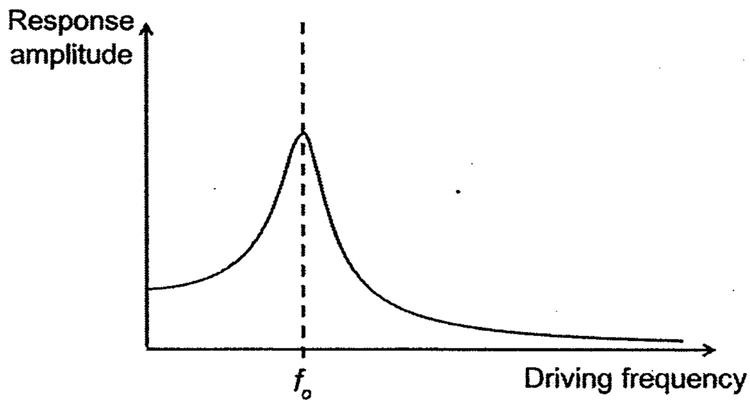
14 A satellite is in a circular orbit about Earth. Its orbital radius is about 30 times the diameter of the Earth. Taking the gravitational field strength on the Earth's surface to be 10 N kg^{-1}, what is the value of the Earth's gravitational field strength experienced by the satellite?

A 2.8 mN kg^{-1} **B** 11 mN kg^{-1} **C** 40 mN kg^{-1} **D** 100 mN kg^{-1}

15 An object is moving in simple harmonic motion. The amplitude of its motion is 0.050 m and its frequency is 2.0 Hz. It starts from the amplitude at $t = 0$ s. What is the magnitude of the acceleration of the object at 1.7 s?

A 0.25 m s^{-2} **B** 0.51 m s^{-2} **C** 1.60 m s^{-2} **D** 6.40 m s^{-2}

16 The figure shows how the response amplitude of a lightly-damped oscillating system varies with the frequency at which it is driven. The resonance peak occurs at a driving frequency of f_0.



When damping is increased, which of the following is false?

A The resonant frequency decreases.

B The amplitude of the oscillation decreases.

C The sharpness of the resonance peak decreases.

D The period of the oscillation at resonance decreases.

17 At a pressure of about 610 Pa, water, water vapour and ice can co-exist in equilibrium at a temperature of 0.01 °C. This is known as the triple point of water. Which statement about the properties of the molecules at this temperature is true?

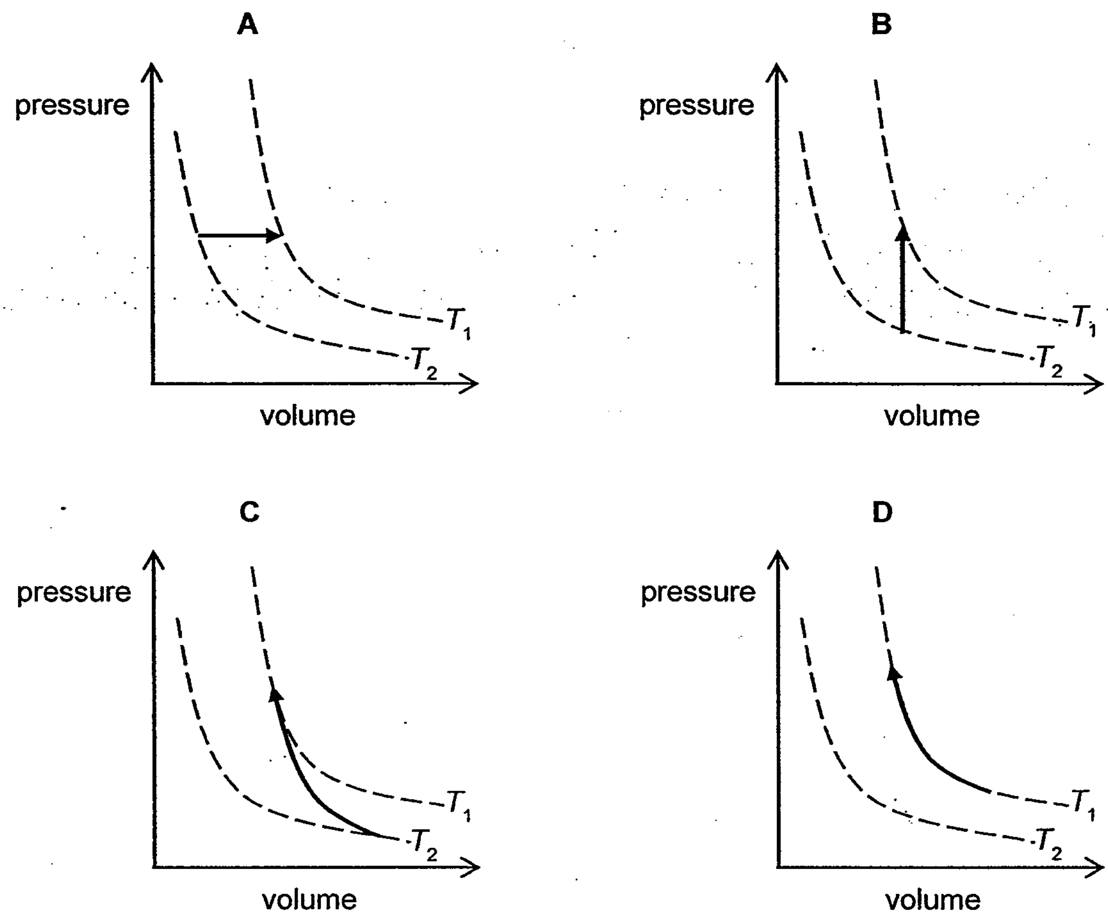
A Molecules in ice are closer to one another than molecules in liquid water.

B Molecules in water vapour have a larger mean kinetic energy than molecules in liquid water.

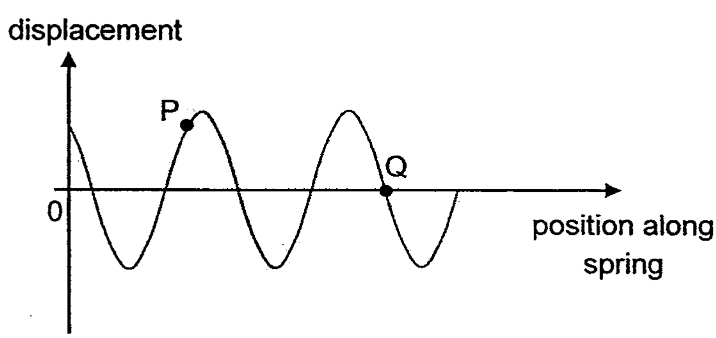
C Molecules in water vapour are less massive than molecules in liquid water.

D Molecules in water vapour have the same r.m.s. speed as molecules in liquid water.

18 A closed system of an ideal gas can undergo different thermodynamic processes. Which of the following arrows shows a process that can occur without any heat exchange between the system and its environment?



19 A longitudinal wave travels to the right along a long horizontal spring. The graph below shows the displacement of different points of the spring at a given instant of time.



Which of the following statements is true?

A P is moving vertically downwards.

B P and Q are moving in opposite directions.

C Q is stationary.

D P has higher speed than Q.

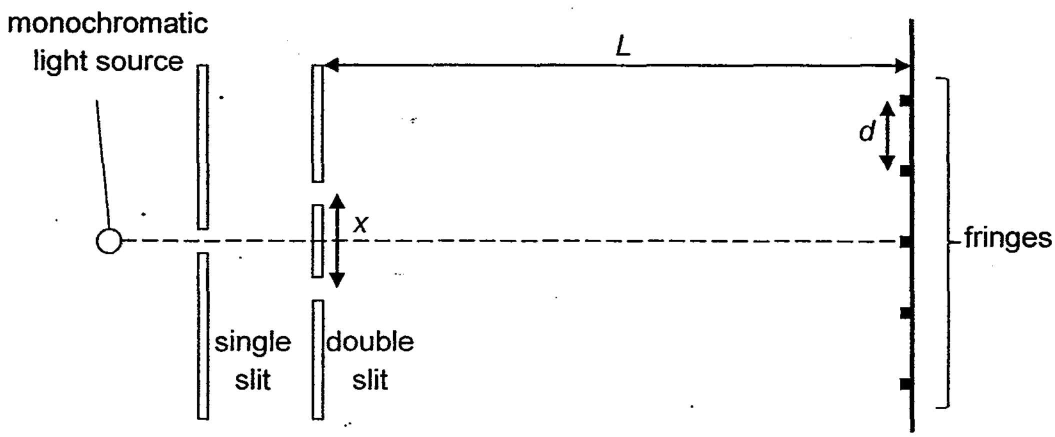
20 Two speakers S_1 and S_2 emit coherent sound waves. The sound waves reach a point P by two paths which differ in length by 0.70 m. When the frequency of the sound is gradually increased, the resultant intensity at P goes through a series of maxima and minima.

A maximum occurs when the frequency is 2400 Hz and the next maximum occurs at 2800 Hz.

What is the speed of the sound waves?

A 200 m s^{-1} **B** 280 m s^{-1} **C** 340 m s^{-1} **D** 400 m s^{-1}

21 A double slit experiment is shown below. The light source has wavelength λ, the slit separation is x, the fringe separation is d and the distance between the slits and screen is L.



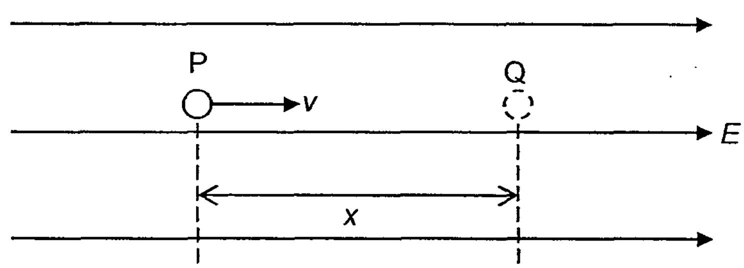
The wavelength is increased to 2λ, the slit separation is increased to $4x$ and the distance between the slits and the screen is decreased to ½L. What is the resulting fringe separation?

A 0.25 d **B** 0.50 d **C** 2.0 d **D** 4.0 d

22 A diffraction grating has 500 lines per millimeter and is illuminated normally by monochromatic light of wavelength 600 nm. What is the total number of bright fringes seen on the screen?

A 3 **B** 4 **C** 6 **D** 7

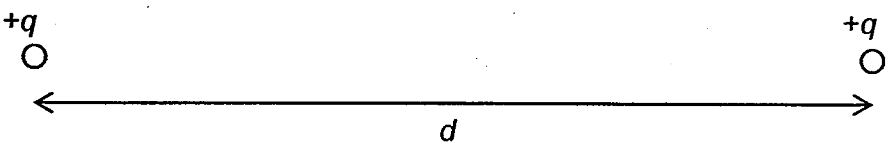
23 An electron with charge e and mass m travels from point P to point Q within a uniform electric field of strength E. At point P, the electron has a velocity of v. It comes to a stop at point Q.



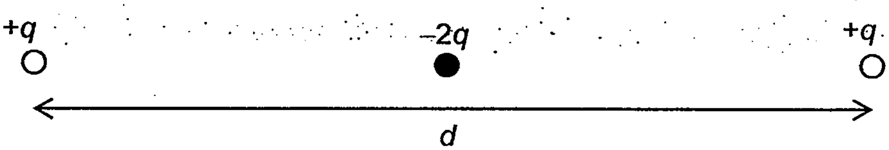
The distance between point P and Q is x. Which expression gives the value of x?

A $\frac{mv}{E}$ **B** $\frac{mv}{Ee}$ **C** $\frac{mv^2}{2E}$ **D** $\frac{mv^2}{2Ee}$

24 A system of two fixed point charges of $+q$ are at a distance d apart. The electric potential energy of the system is U.



Another point charge of $-2q$ is brought from infinity to the mid-point between the positive point charges as shown below.



What is the electric potential energy of the new system?

A zero **B** $-3\,U$ **C** $-7\,U$ **D** $-8\,U$

25 A cell of e.m.f. E and internal resistance r is connected to a variable resistor R as shown in Fig. (a).

Fig. (b) shows the variation with ammeter reading I of the voltmeter reading V as R is varied.

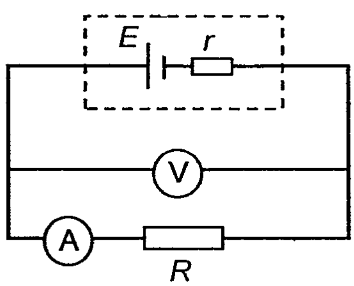


Fig. (a)

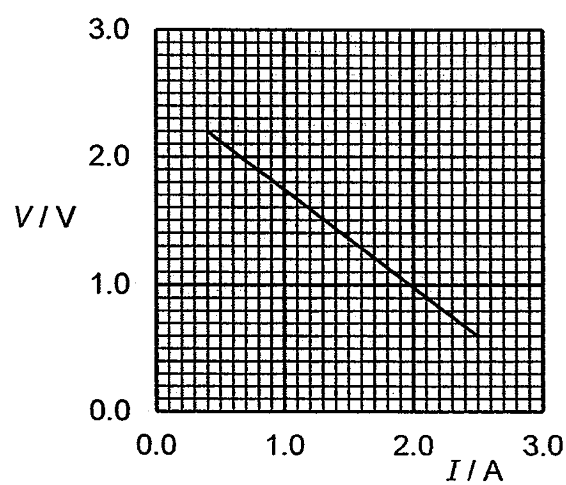
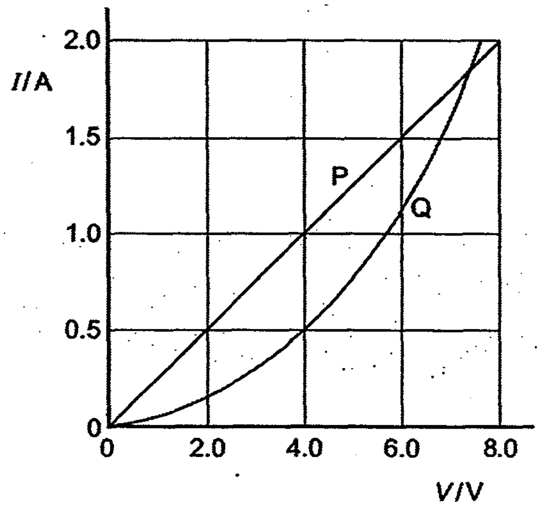


Fig. (b)

What is the e.m.f. and internal resistance of the battery?

	E / V	r / Ω
A	2.2	1.3
B	2.5	1.3
C	2.2	0.76
D	2.5	0.76

26 The I-V characteristics of two electrical components P and Q are shown below.



Which of the following statements is false?

A Q could be a thermistor.

B The resistance of Q decreases as current increases.

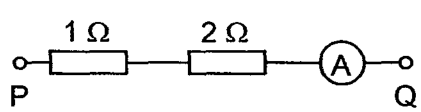
C When the current is 1.9 A, the resistance of Q is approximately half that of P.

D When the current is 0.5 A, the power dissipated in Q is double that in P.

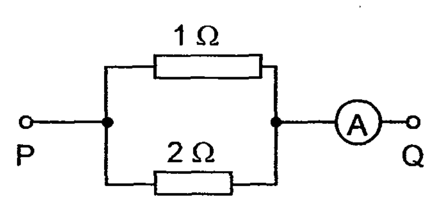
27 An ammeter with a resistance of 2 Ω is placed in different resistor configurations.

The same potential difference is applied across P and Q. In which configuration does the ammeter give the smallest reading?

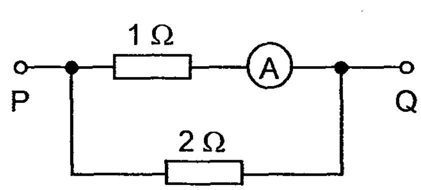
A



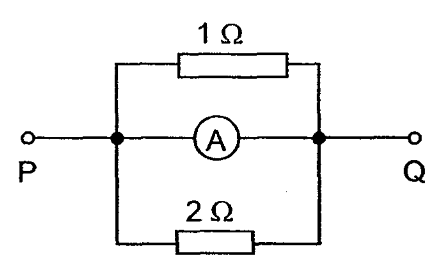
B



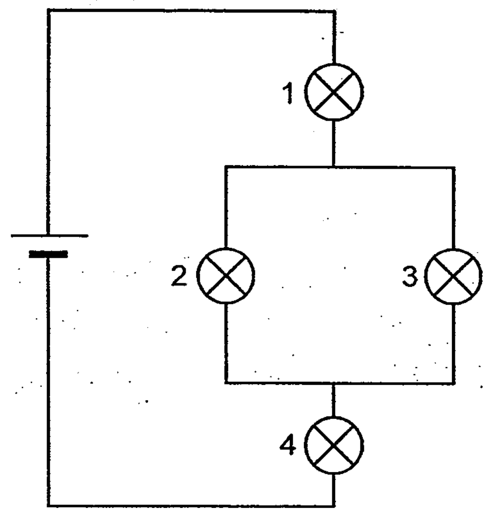
C



D



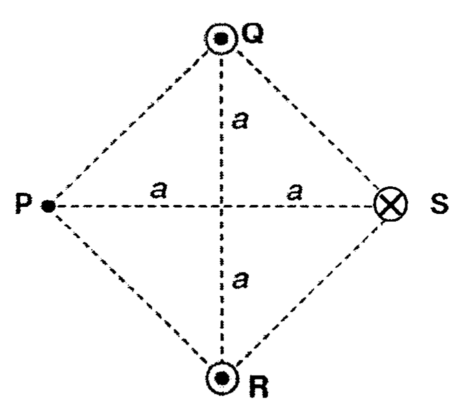
28 An ideal cell and four identical bulbs are connected as shown.



Bulb 3 is removed. Which of the following describes the changes in the brightness of bulbs 1, 2 and 4?

	Bulb 1	Bulb 2	Bulb 4
A	dimmer	brighter	brighter
B	dimmer	brighter	dimmer
C	brighter	dimmer	brighter
D	brighter	dimmer	dimmer

29 Three long, parallel conductors, Q, R and S carry currents of equal magnitude. The figure below shows the plan view of the conductors, whereby the current in S is opposite in direction to those in Q and R. The distance between P and S is $2a$.



Which of the following shows the direction of the magnetic field at point P?

A zero field **B** $\downarrow$ **C** $\uparrow$ **D** $\rightarrow$

30 Fig. (a) shows a square coil CDEF of sides 0.25 m, lying in a vertical plane and carrying a current I of 2.0 A. The magnetic flux density B of 0.010 T is parallel to DE.

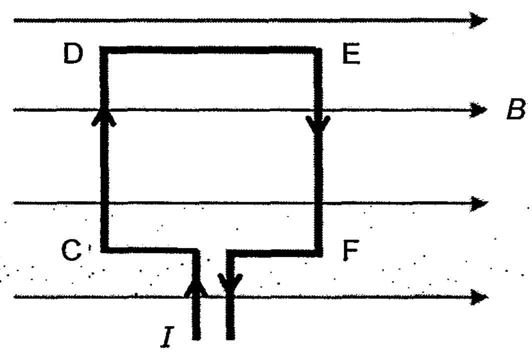


Fig. (a) side view

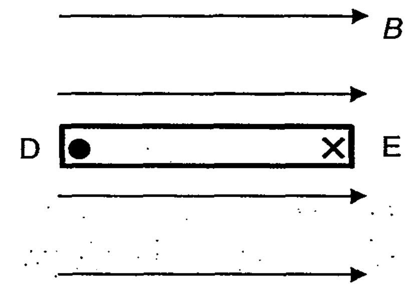


Fig. (b) top view

What is the magnitude of the torque and its direction when viewed from the top, as shown in Fig. (b)?

A 1.3×10^{-3} Nm, clockwise

B 1.3×10^{-3} Nm, anticlockwise

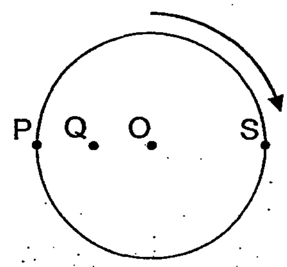
C 2.5×10^{-3} Nm, clockwise

D 2.5×10^{-3} Nm, anticlockwise

31 A magnetic field passes through a coil perpendicularly. The magnetic flux density changes from 0.60 T to 0.80 T at a constant rate over a duration of 0.50 s. The magnitude of the induced e.m.f. in the coil is 13 V. What could possibly be the number of turns of the coil and the area of the coil?

	number of turns of coil	area of coil / m^2
A	50	0.65
B	20	0.54
C	10	0.81
D	5	1.0

32 An uniform aluminium disc is rotated about its centre O at a constant angular speed. It is placed in a magnetic field perpendicular to its surface. P and S are on the circumference, and Q is midway between O and P. The magnitude of the e.m.f. between any two points "X" and "Y" is denoted as E_{XY}.



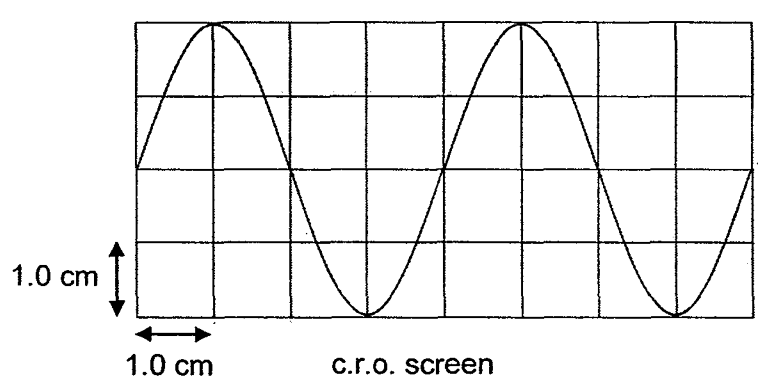
Which of the following options is correct?

A	$E_{PQ} < E_{QS}$	$E_{PQ} = E_{QO}$
B	$E_{PQ} < E_{QS}$	$E_{PQ} > E_{QO}$
C	$E_{PQ} = E_{QS}$	$E_{PQ} = E_{QO}$
D	$E_{PQ} = E_{QS}$	$E_{PQ} > E_{QO}$

33 The primary coil of an ideal transformer has a sinusoidal alternating current. The phase difference between the alternating currents of the primary coil and secondary coil is

A zero **B** $\frac{\pi}{4}$ rad **C** $\frac{\pi}{2}$ rad **D** π rad

34 A cathode-ray oscilloscope (c.r.o) screen with a grid of 1 cm squares displays an alternating voltage waveform. The settings of the oscilloscope are: gain = 5.00 V cm^{-1}, time base = 2.0 s cm^{-1}.



Which expression gives the e.m.f. of this waveform?

A 2.0 sin 4.0 t

B 5.0 sin 2.0 t

C 10 sin 0.785 t

D 10 sin 3.1 t

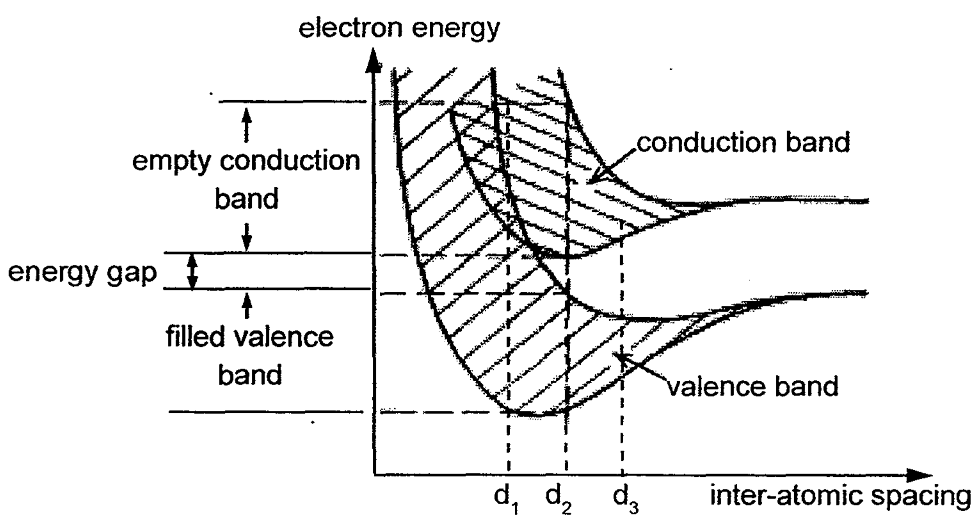
35 The equation $hf = \phi + \frac{1}{2}mv_{max}^2$ is used when studying the photoelectric effect. What is the meaning of each term in this equation?

	hf	ϕ	$\frac{1}{2}mv_{max}^2$
A	the energy of an incoming photon	the least energy required to release an electron	the maximum kinetic energy of a photoelectron
B	the energy of an incoming photoelectron	the work done by the incoming photoelectron	the maximum kinetic energy of the outgoing photoelectron
C	the energy of an incoming photoelectron	the least energy required to release an photon	the maximum kinetic energy of a photon
D	the energy of an incoming photon	the work done by the incoming photon	the maximum kinetic energy of the outgoing photon

36 What is a reasonable estimate, to one significant figure, of the energy of a photon of red light?

A 2 eV **B** 3 eV **C** 4 eV **D** 5 eV

37 The figure below shows how the energy of electrons in the conduction and valence bands varies with inter-atomic spacing. d_1, d_2 and d_3 are the equilibrium inter-atomic separations for different solids of varying electrical properties.



Which correctly lists the type of materials with their corresponding inter-atomic spacing?

	d_1	d_2	d_3
A	conductor	insulator	semiconductor
B	conductor	semiconductor	insulator
C	insulator	semiconductor	conductor
D	semiconductor	conductor	insulator

38 Which of the following statements about lasers is false?

A Population inversion is needed for continued lasing to occur.

B Laser beams are highly coherent and always monochromatic.

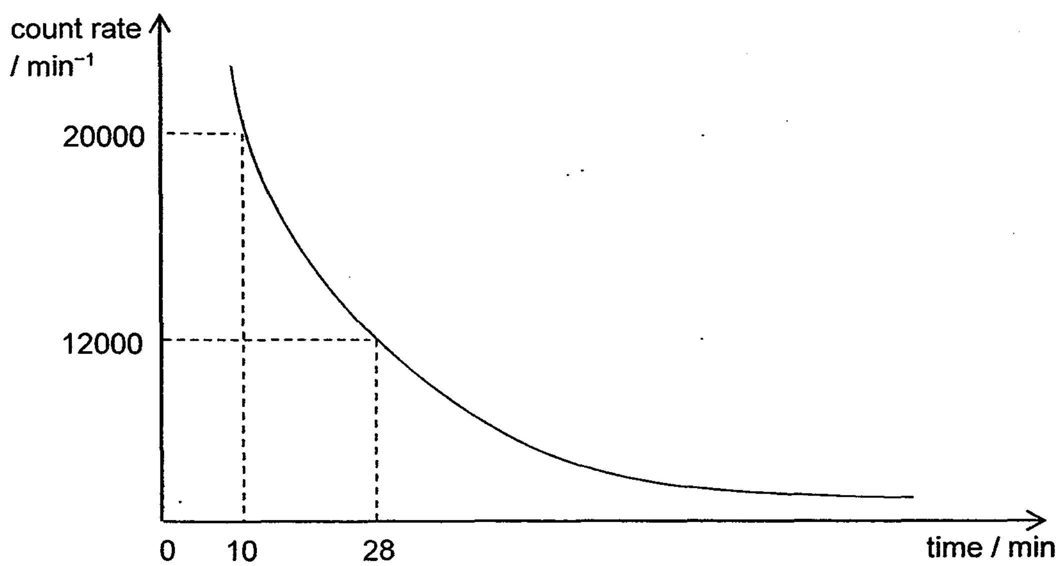
C It is possible to produce laser beams that are perfectly collimated (do not spread).

D The atoms in a laser system must have a meta-stable state for lasing to occur.

39 The mass defect of $^{P}_{Q}X$ is Δm. What is the binding energy per nucleon of X?

A $\dfrac{\Delta m}{Q}$ **B** $\dfrac{\Delta m}{P}$ **C** $\dfrac{c^2\Delta m}{Q}$ **D** $\dfrac{c^2\Delta m}{P}$

40 The figure shows the variation with time of the count rate for a sample of a radioactive isotope.



What is the half-life of the isotope?

A 18 min **B** 20 min **C** 24 min **D** 32 min

JC2 Preliminary Examinations 2016

Proposed solutions for H2 Physics Prelim P1

1	**B**	**21**	**A**
2	**B**	**22**	**D**
3	**C**	**23**	**D**
4	**D**	**24**	**C**
5	**C**	**25**	**D**
6	**B**	**26**	**C**
7	**D**	**27**	**A**
8	**D**	**28**	**B**
9	**C**	**29**	**B**
10	**A**	**30**	**A**
11	**A**	**31**	**A**
12	**B**	**32**	**D**
13	**C**	**33**	**C**
14	**A**	**34**	**C**
15	**D**	**35**	**A**
16	**D**	**36**	**A**
17	**D**	**37**	**B**
18	**C**	**38**	**C**
19	**B**	**39**	**D**
20	**B**	**40**	**C**

Q1: B

$F = BIL$

$B = \dfrac{F}{IL} = \dfrac{ma}{IL}$

$$\text{Base unit of } B = \frac{\text{kg m s}^{-2}}{\text{A m}}$$
$$= \text{kg s}^{-2}\ \text{A}^{-1}$$

Q2: B

A Both vectors
B Magnetic flux density: vector, kinetic energy: scalar
C Both scalars
D Both scalars

Q3: C
Let the total distance be S and the total time t.
Since the stone falls 0.75S in the last two seconds of its fall, it travels 0.25S in the first (t-2) seconds.

$$\frac{1}{2}g(t-2)^2 = 0.25S$$

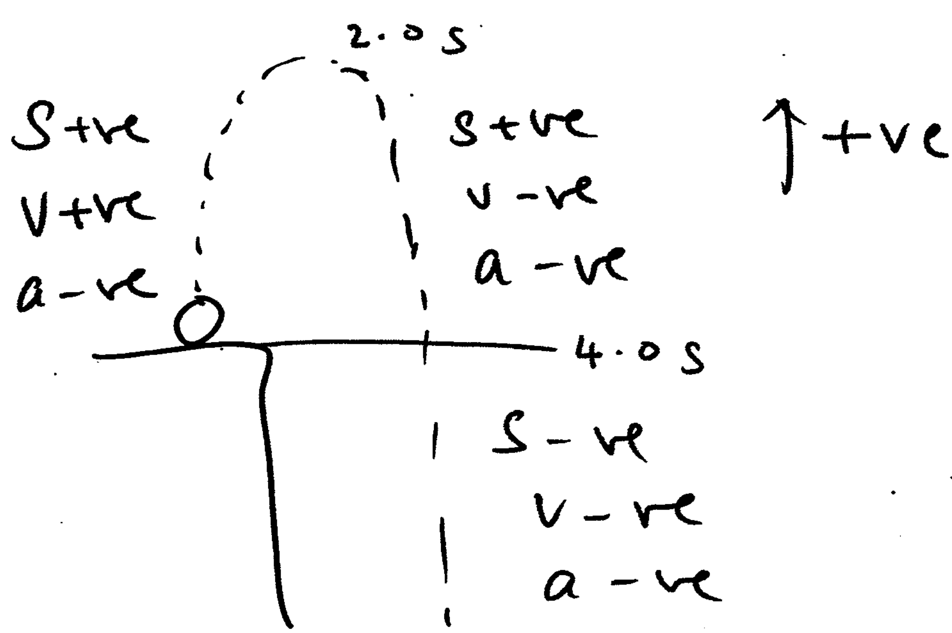
$$\frac{1}{2}g(t-2)^2 = 0.25(\frac{1}{2}gt^2)$$

$$(t-2)^2 = 0.25t^2$$

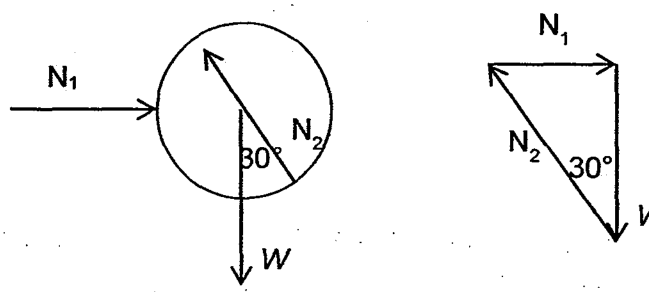
$$t-2 = 0.5t$$

$$t = 4.0\,\text{sec}$$

Q4: D
Since the stone takes 2.0 s to reach its highest point, at 4.0 s it will have reached the point of S = 0.
Taking upwards as positive,
Option A incorrect – Stone is on its upwards motion. The displacement and velocity is positive and the acceleration is negative.
For option B and C, the stone is on its downwards motion but has not reach the point of S = 0. Hence displacement is positive, velocity and acceleration are negative.
Option D correct – the stone is on its downward motion (having passed the point of S = 0) with negative displacement. Velocity and acceleration are negative.



Q5: C



Using force diagram and resolving horizontally and vertically,

$N_2 \sin 30 = N_1$ (1)

$N_2 \cos 30 = W$ (2)

$\frac{(1)}{(2)}$: $\tan 30 = \frac{N_1}{W}$

(Alternative: Using vector triangle)

$N_1 = W \tan 30 = 15 \tan 30 = 8.66 = 8.7$ (2s.f.)

Q6: B

When reading is more than F, means that upward force by spring balance on mass is greater than weight of mass. Net force upwards – acceleration directed upwards.

Q7: D

Since particle Y is stationary (no KE nor momentum),
Initial KE of system is *E*, initial momentum of system is *p*.
Collision is inelastic – final kinetic energy of system should be less than *E* (Option C or D)
Momentum of any collision must be conserved, final momentum of system should be still *p*.

Full working:
Conservation of momentum, $mu + 0 = 2mv \rightarrow v = ½ u$
System: Total $p = 2mv = 2m (½ u) = mu = p$
Total KE = $½ (2m)(v^2)$
$= ½ (2m) (½u)^2 = ½ (½ mu^2) = ½ E$
X: $p = mv = m (½ u) = ½ p$
KE = $½ mv^2$
$= ½ (m) (½u)^2 = ¼ (½ m u^2) = ¼ E$

Q8: D

Both boats travel the same distance s and experience the same force F. Hence the total work done by the force F between the starting line and the finish line is the same for each boat – they will have the same final kinetic energy.

Boat with mass m will experience a larger acceleration, and will thus reach the finish line first.

Note: Boat with mass m will also have a higher speed, since the two boats have the same final kinetic energy.

Q9: C

Section C has the steepest gradient, indicating the highest velocity. Since $P=Fv$, this section has the greatest work done per unit time against friction.

Q10: A

By conservation of energy, elastic potential energy is converted to kinetic energy and work done against friction. As height is the same at initial and final positions, gravitational potential energy is unchanged.

$$EPE_{loss} = KE_{gain} + WD_{friction}$$

$$\frac{1}{2}kx^2 = \left(KE_{final} - KE_{initial}\right) + fd$$

$$KE_{final} = \frac{1}{2}kx^2 - fd \qquad \left(KE_{initial} = 0\right)$$

Q11: A

Displacement is zero, thus average velocity is zero since average velocity is total displacement over time taken.

Therefore, average momentum is zero. ($p = mv$)

Q12: B

$$N\sin\theta = mg$$

$$N\cos\theta = \frac{mv^2}{r}$$

$$\Rightarrow \tan\theta = \frac{rg}{v^2}$$

$$\theta = \tan^{-1}\left(\frac{rg}{v^2}\right)$$

Q13: C

A: $\phi = \frac{GM}{r} \Rightarrow \phi \propto \frac{1}{r}$

B: $KE = \frac{1}{2}\frac{GMm}{r} \Rightarrow KE \propto \frac{1}{r}$

C: Negative work done by external force as external force points rightwards and the displacement is leftwards. However, positive work is done by the gravitational force.

D: $W = \Delta U = m\Delta\phi$

Q14: A

Gravitational field strength on the surface of the Earth is $g_0 = \frac{GM}{R^2} = \frac{4GM}{d^2}$ .....(1)

At the position of the satellite, Earth's gravitational field strength is $g = \frac{GM}{r^2} = \frac{GM}{(30d)^2}$ ......(2)

$$\frac{g}{g_0} = \frac{1}{(30^2)4}$$
$$g = \frac{10}{(30^2)4}$$
$$= 2.8 \times 10^{-3} \text{ N kg}^{-1}$$

Q15: D

$$x = x_o \cos(\omega t)$$
$$= 0.050\cos(2\pi \times 2.0 \times 1.7)$$
$$= -0.0405 \text{ cm}$$
$$|a| = |\omega^2 x| = (2\pi \times 2)^2 (0.0405) = 6.40 \text{ m s}^{-2}$$

Q16: D

The period of the forced oscillation at resonance increases when the system is damped. (The resonance frequency decreases.)

Q17: D

A Incorrect: Ice is less dense than water at around 0 °C, so ice molecules are further apart.
B Incorrect: Mean kinetic energy of the water molecules is a measure of temperature. Since all 3 phases co-exist at triple point, they have the same temperature and hence same mean kinetic energy
C Incorrect: Mass of each molecule in solid, liquid and gaseous phase are the same. Only volume and therefore density differs.
D Correct: as temperature is proportional to mean kinetic energy of the molecules, at the same temperature (triple point) and same mass per molecule, the r.m.s. speed is the same.

Q18: C
T_1 is higher temperature than T_2.
From $\Delta U = Q + W$

	T	ΔU	W_{on}	Q	
A	Increase	Positive	Expand → Negative	Need to be positive	Wrong
B	Increase	Positive	Zero	Need to be positive	Wrong
C	Increase	Positive	Contract → Positive	can be positive, zero or not < $-\lvert W_{on}\rvert$	Correct
D	No change	Zero	Contract → Positive	Need to be negative	Wrong

Q19: B
P and Q will move in opposite direction regardless of direction of wave propagation. If the wave moves rightwards, P will be displaced less positive (moving leftwards) while Q will be displaced positive (moving rightwards).

Q20: B

$$\lambda_1 = \frac{v}{2400}$$

$$\lambda_2 = \frac{v}{2800}$$

At 2800 Hz the path difference has 1 more λ than at 2400 Hz

Number of wavelengths occupying 0.70 m $= \dfrac{0.7}{\lambda_2} = \dfrac{0.7}{\lambda_1} + 1$

$$\frac{0.70 \times 2800}{v} = \frac{0.70 \times 2400}{v} + 1$$

$v = 280 \text{ m s}^{-1}$

Q21: A

$d = \dfrac{\lambda L}{x}$

$d_{new} = \dfrac{(2\lambda)(0.5L)}{4x} = 0.25\dfrac{\lambda L}{x} = 0.25d$

Q22: D

$d\sin\theta = n\lambda$

$\dfrac{1\times10^{-3}}{500}(1) = n_{max}\left(600\times10^{-9}\right)$

$n_{max} = 3.33$

Total number of fringes = 3 + 1 + 3 = 7

Q23: D

By conservation of energy

gain in electric potential energy = loss in kinetic energy

$$(qE)x = \frac{1}{2}mv^2$$

$$(eE)x = \frac{1}{2}mv^2$$

$$x = \frac{mv^2}{2Ee}$$

Q24: C

The electric potential energy of the original system is

$U = \dfrac{(q)(q)}{4\pi\varepsilon_o(d)} = \dfrac{q^2}{4\pi\varepsilon_o d}$

In bringing the negative point charge into the system, the change in the electric potential energy,

$\Delta U = \dfrac{(q)(-2q)}{4\pi\varepsilon_o\left(\frac{d}{2}\right)} + \dfrac{(q)(-2q)}{4\pi\varepsilon_o\left(\frac{d}{2}\right)} = \dfrac{(-8)q^2}{4\pi\varepsilon_o d} = -8U$

Therefore the electric potential energy of the new system is

$U_{new} = U + (-8U) = -7U$

Q25: D

When $I = 0$, $E = 2.5\ V$

$V = E - Ir$

Substituting point from graph,

$1.2 = 2.5 - 1.7r$

$r = 0.76\ \Omega$

Q26: C

Option A is a true statement. The metallic conductor obeys Ohms Law and the IV characteristics is a straight line P passing through origin while Q represents a thermistor's IV characteristics as the resistance of semiconductor diode decreases with increasing forward biased voltage.
Option B is a true statement. As graph Q illustrates that as current increases, its resistance decreases.
Option C is a false statement. As At 1.9 A, both P and Q have the same p.d. Hence they have the same resistance. The resistance is not given by the reciprocal of the gradient at current 1.9 A
Option D is a true statement. The power can be determined as product IV. At 0.5 A, pd across Q is twice of that of P, hence power dissipated is twice.

Q27: A

A: $$I_{ammeter} = \frac{V_{PQ}}{R_{total}} = \frac{V_{PQ}}{1+2+2} = 0.2V_{PQ}$$

B: $$I_{ammeter} = \frac{V_{PQ}}{R_{total}} = \frac{V_{PQ}}{\left(\frac{1}{1}+\frac{1}{2}\right)^{-1}+2} = \frac{V_{PQ}}{8/3} = 0.375V_{PQ}$$

C: $$I_{ammeter} = \frac{V_{PQ}}{R_{total}} = \frac{V_{PQ}}{1+2} = \frac{V_{PQ}}{3} = 0.333V_{PQ}$$

D: $$I_{ammeter} = \frac{V_{PQ}}{R_{ammeter}} = \frac{V_{PQ}}{2} = 0.5V_{PQ}$$

Q28: B

With bulb 3 in parallel to bulb 2, the potential difference across bulb 2 is a smaller fraction of the cell's e.m.f as compared to that of bulbs 1 and 4.
With bulb 3 removed, the potential difference across bulb 2 increases while those of bulb 1 and bulb 4 decrease correspondingly. With fixed resistance, power dissipated increases as potential increases, hence bulbs 1 and 4 became dimmer and bulb 2 became brighter.

Alternatively,
Before bulb 3 was removed,

$$R_{total} = R + \left(\frac{1}{R}+\frac{1}{R}\right) + R = 2.5R$$

$$I_{total} = \frac{V}{2.5R} = 0.4\frac{V}{R} = I_{bulb1} = I_{bulb4}$$

$$I_{bulb2} = I_{bulb3} = 0.2\frac{V}{R}$$

After bulb 3 was removed,

$R_{total} = R + R + R = 3R$

$I_{total} = \frac{V}{3R} = 0.33\frac{V}{R} = I_{bulb1} = I_{bulb2} = I_{bulb4}$

$\therefore I_{bulb1}$ and I_{bulb4} decreased, I_{bulb2} increased

since brightness $\propto$ power dissipated $= I^2R$

bulbs 1 and 4 became dimmer, bulb 2 became brighter

Q29: B

At point P,

(1) Magnetic field due to S is upwards (small magnitude due to larger distance)
(2) Magnetic field due to Q (towards R)
(3) Magnetic field due to R (away from Q) – magnitude same as 2)

The horizontal components of (2) and (3) point in exact opposite direction. Net horizontal component is zero.

Therefore, resultant of (2) and (3) point downwards (with a larger magnitude than that of "S")

Q30: A

Direction: By Fleming's left hand rule, a magnetic force acts into the paper along CD and out of the paper along EF. Hence, viewing from the top, the rotation is clockwise.

Magnitude:

$$\begin{aligned} F &= BIL \\ &= 0.010 \times 2.0 \times 0.25 \\ &= 0.0050 \text{ N} \end{aligned}$$

Torque $= Fd = 0.0050 \times 0.25 = 1.3 \times 10^{-3}$ Nm

Q31: A

Using Faraday's law,

$$\begin{aligned} |\varepsilon| &= \frac{dN\phi}{dt} \\ &= NA\frac{\Delta B}{\Delta t} \end{aligned}$$

$$\begin{aligned} NA &= |\varepsilon|\frac{\Delta t}{\Delta B} = 13\left(\frac{0.5}{0.2}\right) \\ &= 32.5 \text{ m}^2 \\ &= 50 \times 0.65 \end{aligned}$$

Q32: D

Electrons either accumulate in the centre or at the rim. In either case, 2 points equidistant from O will have the same potential, and the difference in potential between O and a point gets larger with distance. Therefore, $E_{PQ} = E_{QS}$.

Since points further from O travel faster, the length PQ cuts flux faster than QO. Therefore, $E_{PQ} > E_{QO}$

Q33: C

Since current is directly proportional to the magnetic field strength it generates, an alternating current is in phase with the magnetic flux linkage it generates. However, as e.m.f. induced in the secondary coil is proportional to the rate of change of magnetic flux linkage with respect to time, the alternating current in the secondary coil will be $\frac{\pi}{2}$ out of phase with the primary circuit. A more formal proof follows.

$$\begin{aligned} I_{secondary} &= \frac{\varepsilon}{R} \\ &= \frac{1}{R}\frac{dN\phi}{dt} && \left(\varepsilon = \frac{dN\phi}{dt}\right) \\ &= \frac{NA}{R}\frac{dB}{dt} && (\phi = BA) \\ &= \frac{NA\mu n}{R}\ \frac{d}{dt}I_{primary} && (B = \mu n I)\ \text{solenoid} \end{aligned}$$

E.g. if the primary AC followed a sine curve, the secondary AC will follow a cosine curve.

Q34: C

The gain on the y- axis indicates and e.m.f. amplitude of 10 V, while the period of 8.0 s provides a value of 0.785 rad s^{-1} for the angular frequency. These are hence substituted into $\varepsilon = V_o \sin \omega t$

Q35: A

In the photoelectric experiment, photons are shone on the metal surface.

Hence by COE, the energy of the incoming photon = the least energy required to release a photoelectron + the maximum kinetic energy of the photoelectron.

Q36: A

The visible spectrum ranges from 400 nm (violet) to 700 nm (red).

$$=\frac{hc}{\lambda}$$

Energy of a red light photon = $=\dfrac{6.63\times10^{-34}(3.00\times10^{8})}{7.0\times10^{-7}}$

$$=2.84\times10^{-19}\,\mathrm{J}$$

$$=1.77\ \mathrm{eV}$$

Q37: B

For d_1 (conductor) the valence band and the conduction band overlap and electrons may freely move among the empty energy levels, thus able to move through the material.

For d_2 (semiconductor) there is a small energy gap between the valence band and the conduction band. When heated, valence electrons gain sufficient energy to jump across the gap and become conduction electrons.

For d_3 (insulator) the energy gap between the conduction band and valence band are too large for electrons to jump across, hence conduction cannot take place.

Q38: C

laser will still diffract slightly – not possible to be perfectly collimated.

Q39: D

$$BE\text{ per nucleons} = \frac{BE}{\text{number of nucleons}} = \frac{c^2\Delta m}{P}$$

Q40: C

$12000 = 20000\, e^{-\lambda(18)}$

$\lambda = 0.02837920132\ \mathrm{min}^{-1}$

$t_{1/2} =$ 24.4 min

JC2 Preliminary Examinations
Higher 2

H2 Physics 9646/02

Paper 2 Structured Questions

16 September 2016

1 hour 45 minutes

Candidates answer on the Question Paper.
No Additional Materials are required.

Class	Reg No

Candidate Name: ______________________

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a 2B pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Answer **all** questions.

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	/ 10
2	/ 10
3	/ 8
4	/ 12
5	/ 11
6	/ 9
7	/ 12
Deductions	
Total	/ 72

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
		=	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} J K^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-\frac{GM}{r}$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
	v	=	$\pm \omega\sqrt{x_o^2 - x^2}$
mean kinetic energy of a molecule of an ideal gas	E	=	$\frac{3}{2}kT$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential	V	=	$\frac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	x	=	$x_o \sin \omega t$
transmission coefficient	T	$\propto$	$\exp(-2kd)$
	where k	=	$\sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay	x	=	$x_o \exp(-\lambda t)$
decay constant	λ	=	$\frac{0.693}{t_{\frac{1}{2}}}$

1 **(a)** An object S of weight 10.0 N is supported by two ropes A and B, as shown in Fig. 1.1.

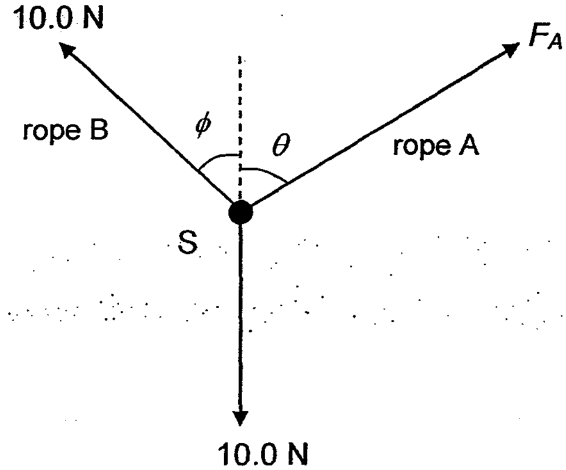


Fig. 1.1

Rope A is at an angle θ to the vertical and exerts force F_A on S. Rope B is at an angle ϕ to the vertical and exerts a force of 10.0 N on S.

The angle ϕ of rope B is varied from 0° to 90°. The force F_A is varied in magnitude and direction to keep S in equilibrium.

(i) Determine the magnitude and direction of force F_A when the angle ϕ is 30°.

magnitude of F_A = ... N

angle θ = ... ° [3]

(ii) Explain, without detailed calculation, why the magnitude of F_A increases as the angle ϕ is increased from 0° to 90°.

....

....

....

....

....

.... [3]

(b) Cart A, moving rightward at a speed of 10 m s^{-1}, collided head-on with an identical cart B, which was initially stationary. During the collision, 20% of the kinetic energy was dissipated. Determine the magnitude and direction of the velocity of cart A after the collision.

magnitude of velocity of cart A = ...m s^{-1}

direction of velocity of cart A = ... [4]

2 **(a)** A pendulum bob undergoes simple harmonic motion.

(i) Explain what is meant by the term simple harmonic motion.

....

....[1]

(ii) Fig. 2.1 shows the variation with time of the displacement of the bob.

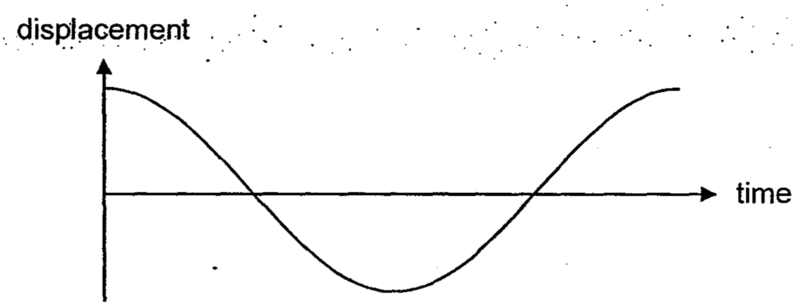


Fig. 2.1

On Fig. 2.1,

1. Label with 'A' the point(s) at which the magnitude of acceleration of the pendulum bob is a maximum. [1]

2. Label with 'S' the point(s) at which the speed of the pendulum bob is a maximum. [1]

(b) Fig. 2.2 shows a pendulum bob of mass 60 g. It is displaced until its centre is 3.5 cm above its rest position and then released from rest. The length of the pendulum is 160 cm.

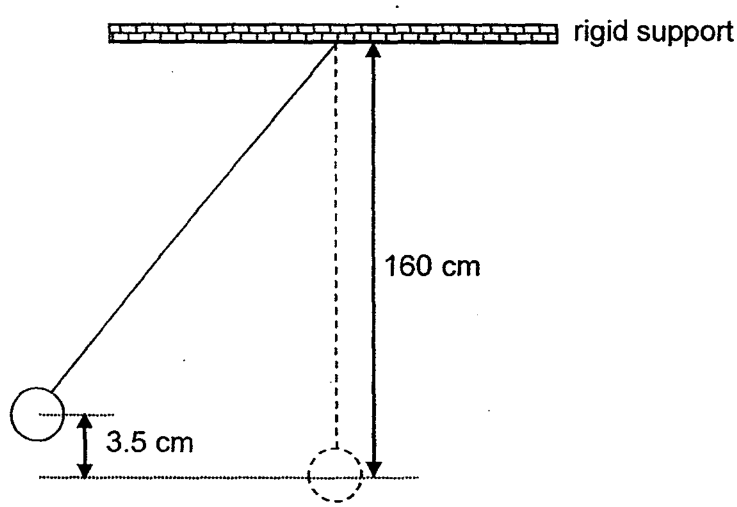


Fig. 2.2

(i) Calculate the speed of the pendulum bob at the midpoint of the oscillation.

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

(ii) Calculate the magnitude of the tension in the string when the pendulum bob is at the midpoint of the oscillation.

tension = ... N [2]

(c) An obstacle of length 60 cm is now placed directly beneath the point of suspension, so that only the lower section (100 cm) of the string can follow the pendulum bob when it swings to the right, as shown in Fig. 2.3.

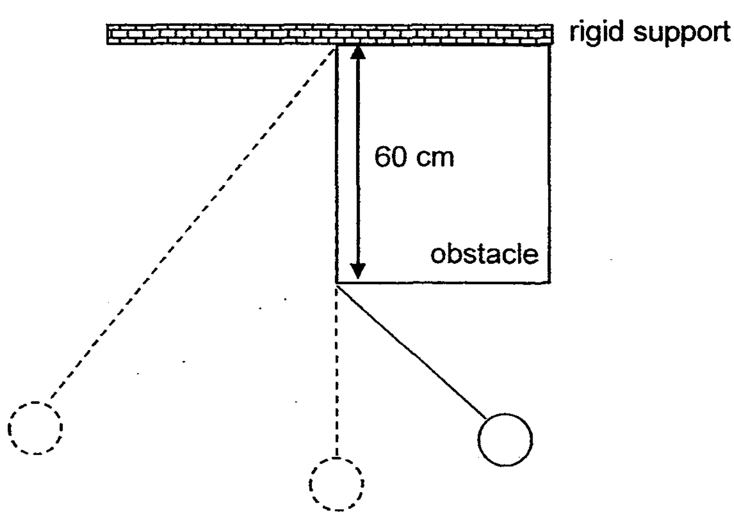


Fig. 2.3

The period of the pendulum is given by the expression

$$T = 2\pi\sqrt{\frac{L}{g}},$$

where L is the length of the pendulum and g the acceleration of free fall.

Calculate the period for the setup in Fig. 2.3.

period = ... s [3]

3 **(a)** Define electric field strength at a point.

....

....[1]

(b) Two point charges A and B are fixed at a distance of 6.0 cm apart, as shown in Fig. 3.1.

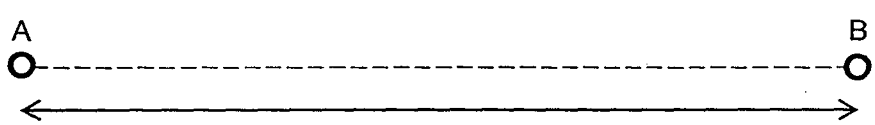


Fig. 3.1

The variation with distance d from A of the net electric field strength E along the line AB is shown in Fig. 3.2.

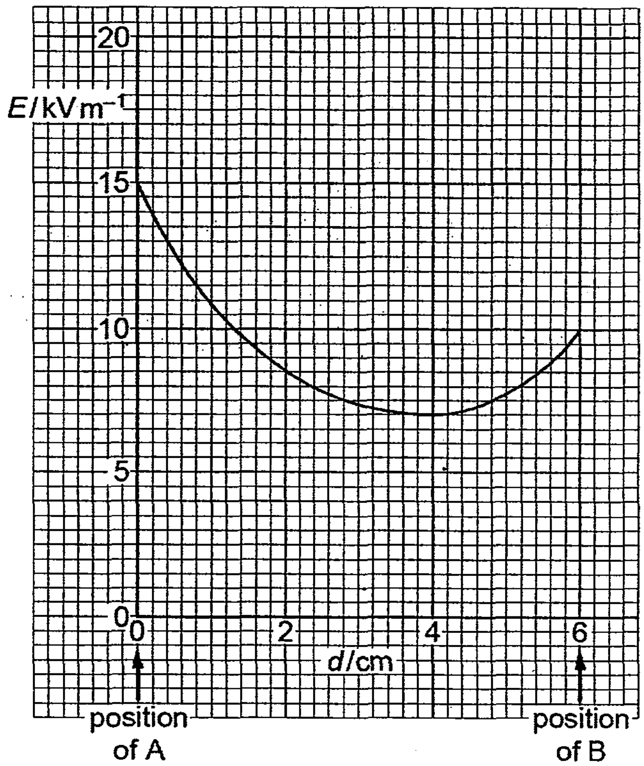


Fig. 3.2

(i) State and explain which feature of Fig. 3.2 shows that the point charge A and B are charges of opposite signs.

....

....

....

.... [2]

(ii) Estimate the potential difference between A and B.

potential difference = ... V [3]

(iii) An electron is released from rest at B and travels towards A. Use your answer in **(b)(ii)** to calculate the speed of the electron just before it reaches point A.

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

4 At high pressures, a real gas does not behave as an ideal gas. For a certain range of pressures, it is suggested that the relation between the pressure p and volume V of one mole of the gas at constant temperature is given by the equation

$$pV = A + Bp$$

where A and B are constants.

In an experiment to measure the deviation of nitrogen gas from ideal gas behaviour, the volume V of the gas was measured for different values of the pressure p. Fig. 4.1 shows the readings obtained.

p / 10^6 Pa	V / 10^{-4} m^3	pV / N m
2.0	6.200	1240
6.0	2.000	1200
10.0	1.160	1160
14.0	0.800	
18.0	0.600	1080
22.0	0.473	1040

Fig. 4.1

(a) Complete Fig. 4.1 for $p = 14.0 \times 10^6$ Pa. [1]

(b) A graph of some of the data showing the variation of pV with p is shown in Fig. 4.2.

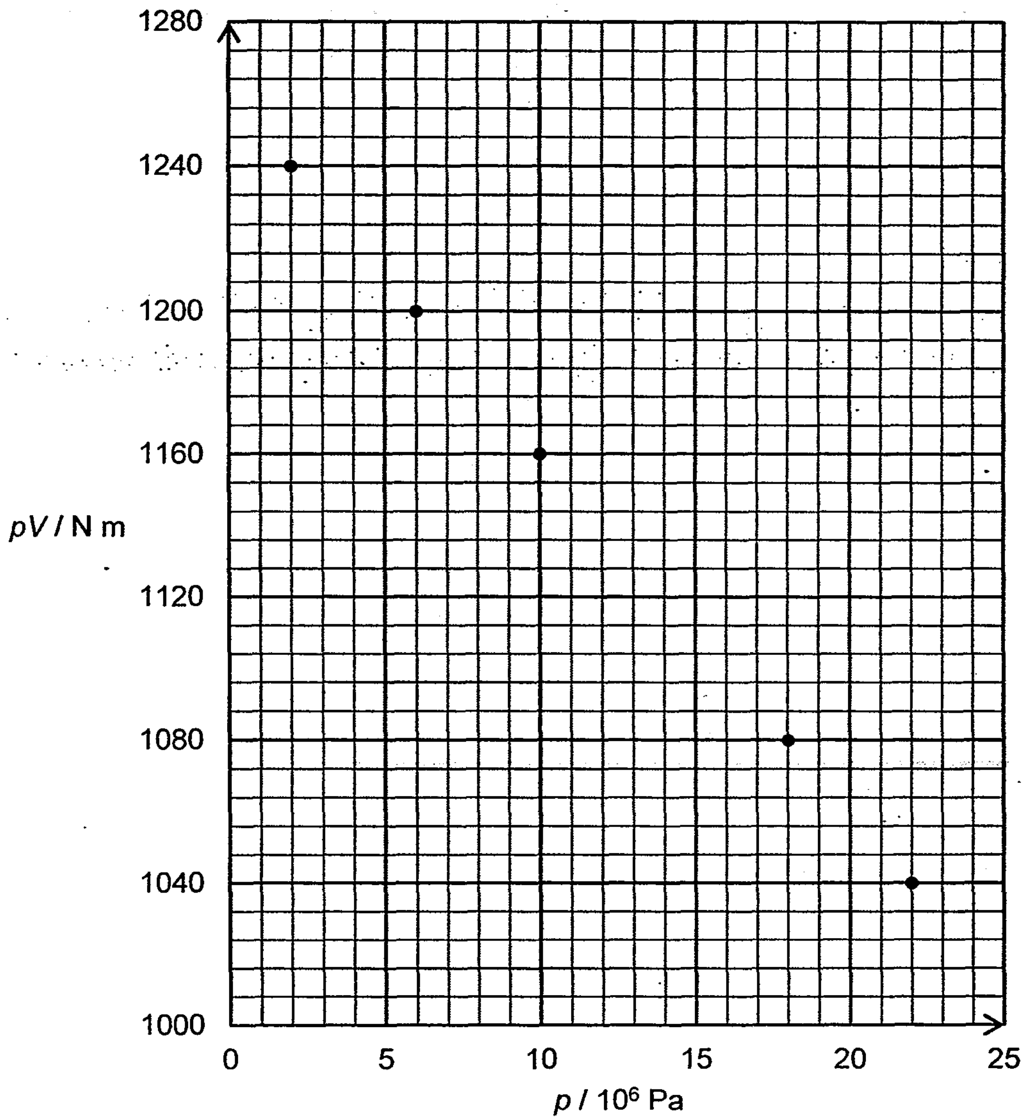


Fig. 4.2

(i) On Fig. 4.2, plot the point corresponding to $p = 14.0 \times 10^6$ Pa. [1]

(ii) Draw the line of best fit for all the points. [1]

(iii) Use the graph to determine the values of constants A and B.

A = ... N m [2]

B = ... m^3 [2]

(iv) Suggest why the value of B is negative.

....

.... [1]

(v) For $p = 10.0 \times 10^6$ Pa, the measurements of p and V have percentage uncertainties of 5% and 3% respectively. Calculate the absolute uncertainty of the corresponding pV value.

$\Delta(pV)$ = ... N m [2]

(vi) Fig. 4.2 was based on an experiment conducted with 1 mole of real gas at a constant temperature of 150 K. State and explain the shape of the graph of pV against p if the experiment is conducted again with 1 mole of an ideal gas at the same temperature.

....

....

....

.... [2]

5 **(a)** A pulse of an X-ray wave lasts for 1.0×10^{-10} s. A photon of the X-ray may be considered to be at a point anywhere within this pulse, although the location of the point is not known.

(i) Calculate the length of the pulse.

length of pulse = ... m [1]

(ii) State the uncertainty in the position of the photon.

uncertainty in position = ... m [1]

(iii) Calculate the uncertainty in the momentum of the photon.

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

(b) Fig. 5.1 shows the wave function of a particle incident on a potential barrier.

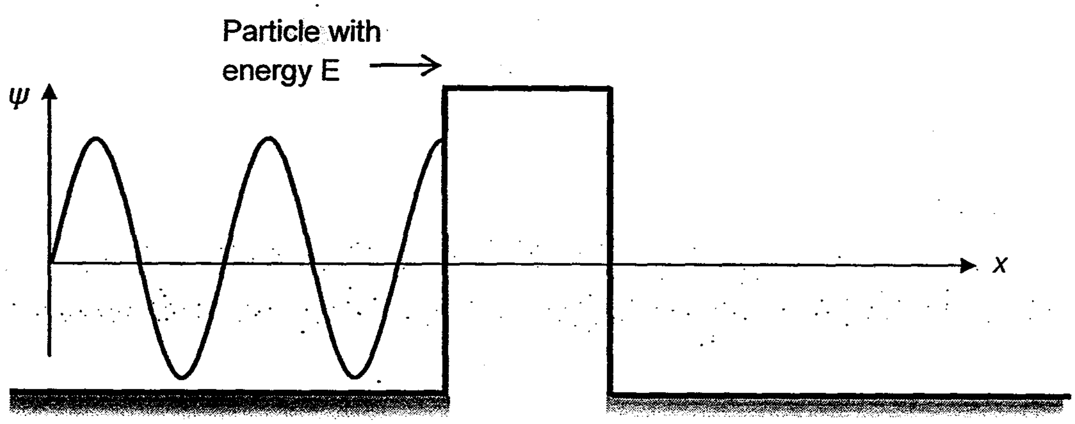


Fig. 5.1

(i) Explain what is meant by a potential barrier.

....

.... [1]

(ii) By completing the wave function in Fig. 5.1, discuss how the wave nature of particles allows particles to tunnel through such a barrier.

....

....

....

....

.... [4]

(c) The tip of a STM probe is positioned at a distance d from a sample surface. The potential barrier has a height of 7.0 eV. Calculate the value of d at which the electrons of energy 1.0 eV have a transmission coefficient T of 0.0001.

d = ... m [2]

6 **(a)** Fig. 6.1 shows some of the energy levels of helium and neon.

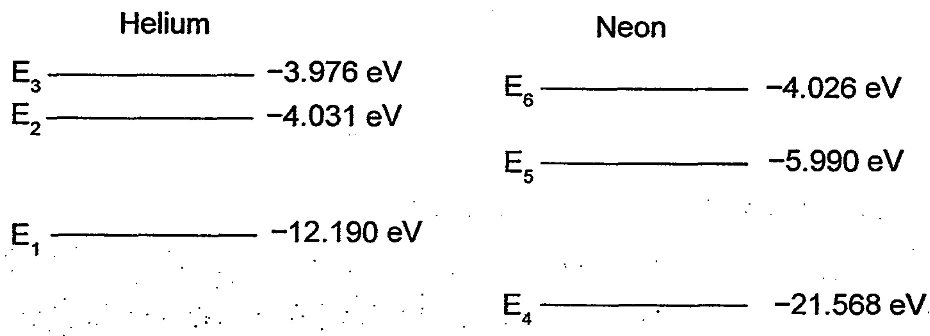


Fig. 6.1

(i) Energy level E_3 of helium is a metastable state. Explain what is meant by a metastable state.

....

.... [1]

(ii) The transition between E_6 and E_5 gives rise to the emission of laser light. Determine the wavelength of the laser light produced.

wavelength = ... m [2]

(iii) Hence, state the colour of the laser light produced in **(a)(ii)**.

.... [1]

(b) Fig. 6.2 shows a p-type semiconductor placed in contact with an n-type semiconductor.

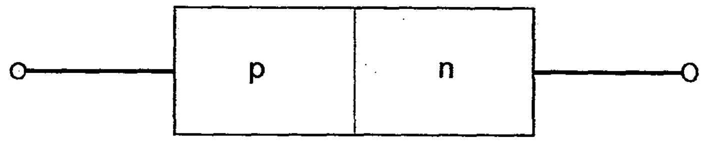


Fig. 6.2

(i) Explain how a depletion layer is formed between the p-type and n-type semiconductors.

....

....

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....

....

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....

....

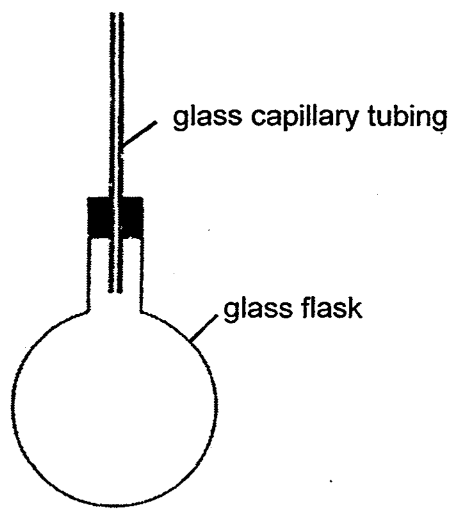
....[4]

(ii) On Fig. 6.2, draw an e.m.f. source connected to the p-n junction in a manner so as to widen the depletion region. [1]

7 It is predicted that the average temperature of the Earth will increase by a few degrees over the next few hundred years. One consequence of this is that sea levels will rise due to the melting of the Antarctic ice cap, and the expansion of water in the oceans. In order for scientists to make any kind of estimate of how much the levels will rise, it is necessary to know how much expansion will occur for a given rise in temperature. It is known that the increase in volume of water per degree temperature rise is very small.

Design a laboratory experiment to determine how the total volume of a given amount of water changes with temperature.

The following equipment is available: a glass flask with a glass capillary tubing, and any other equipment normally available in a school laboratory. The inner diameter d of the glass capillary tubing is known.



You should draw a labelled diagram to show the arrangement of your apparatus. In your account, you should pay particular attention to:

(a) the identification and control of variables,

(b) the equipment you would use,

(c) the procedure to be followed,

(d) how the initial volume of water would be accurately measured (you may assume that the density of water at the starting temperature is known),

(e) any precautions that would be taken to improve the accuracy and safety of the experiment.

[12]

Name: ______________________________

CG: **15S**_________

12

Diagram

....

....

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....

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....

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....

....

JC2 Preliminary Examinations 2016

Proposed solutions to JC2 H2 Physics Prelim Paper 2

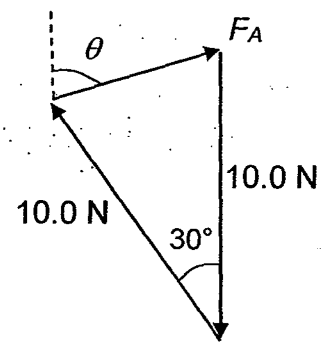
1 (a) (i)

$10 \sin 30° - F_A \sin\theta = 0$ or $10 \sin 30° = F_A \sin\theta$

$10 \cos 30° + F_A \cos\theta - 10 = 0$ or $10 \cos 30° + F_A \cos\theta = 10$

[M1 for horizontal forces & vertical forces]

Alternatively, solve using sine rule / cosine rule for a closed vector triangle



[M1 for correct application]

Solving, $\theta = 75°$ [A1 for angle]

$F_A = 5.18$ N or 5.2 N [A1 for magnitude]

(ii)

As the angle ϕ is increased,

1) The horizontal [leftward] component of F_B increases in magnitude. Thus the horizontal [rightward] component of F_A has to increase in magnitude to ensure equilibrium.

2) The vertical [upward] component of F_B reduces in magnitude, while the [downward] force due to the weight remains constant. Thus the vertical [upward] component of F_A has to increase in magnitude to maintain equilibrium.

[M2 for **both** horizontal and vertical components]

Since **both** horizontal and vertical components of F_A increase, the magnitude of F_A has to increase. [A1]

(b)

Conservation of momentum:

$m(10) + m(0) = mv_A + mv_B$ [C1]

Simplify: $10 = v_A + v_B$

20% of initial total KE was lost

$0.8 [\frac{1}{2} m(10)^2 + \frac{1}{2} m(0)^2] = \frac{1}{2} m(v_A)^2 + \frac{1}{2} m(v_B)^2$ [C1]

Simplify: $80 = v_A^2 + v_B^2$

Solve: $80 = v_A^2 + (10 - v_A)^2$

$v_A = 1.13$ or 8.87

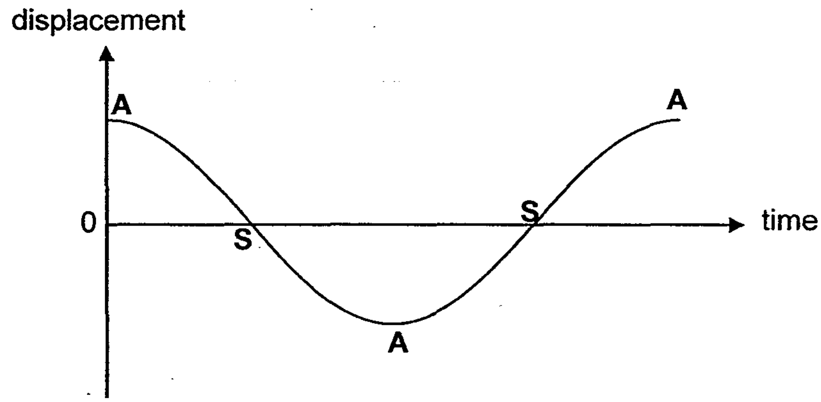
$v_B = 8.87$ or 1.13 [C1 for <u>both</u> solutions if final answer was not identified correctly]

(both velocities are positive, i.e. A and B are both moving to the right, so v_B must be larger than v_A, i.e. B moves faster than A to the right)
Magnitude = 1.13 m s^{-1}, direction: rightwards [A1]

2 (a) (i)

Simple harmonic motion (S.H.M.) is the oscillatory motion of a particle whose acceleration is always proportional to and opposite in direction from a displacement from an equilibrium point.

(ii)



(b) (i)

loss in GPE = gain in KE

$$mgh = \frac{1}{2}mv^2$$

$$v = \sqrt{2gh}$$

$$= \sqrt{2 \times 9.81 \times \left(3.5 \times 10^{-2}\right)} \quad \text{[M1]}$$

$$= 0.83 \text{ m s}^{-1} \quad \text{[A1]}$$

(ii)

$$T - mg = \frac{mv^2}{r}$$

$$T = \frac{mv^2}{r} + mg$$

$$= \frac{0.060(0.83^2)}{1.6} + 0.060(9.81) \quad \text{[M1]}$$

$$= 0.62 \text{ N} \quad \text{[A1]}$$

(c)

$$T = 2\pi\sqrt{\frac{L}{g}} = 2\pi\sqrt{\frac{1.6}{9.81}} = 2.54\text{ s}$$ [M1]

After striking the obstacle,

$$T_{new} = 2\pi\sqrt{\frac{1.0}{9.81}} = 2.01\text{ s}$$ [M1]

Hence,

$$T_{total} = \frac{1}{2}T + \frac{1}{2}T_{new} = \frac{1}{2}(2.54) + \frac{1}{2}(2.01) = 2.28\text{ s}$$ [A1]

3 (a)

The electric field strength E at a point is the (electric) force per unit charge acting on a small stationary positive charge placed at that point. [B1]

(b) (i)

The value of the net electric field strength along AB is always non-zero. [A1]
If the point charges are of opposite signs, the electric field due to the both charges will always be pointing in the same direction. [M1]
OR
If the point charges are of the same sign, there will be a point along AB where the net E (or net electric force) is zero
as the individual field (or force) experienced by any charge due to the two charges will be opposite in direction. [M1]

(ii)

By counting squares → 530 small squares [M1]
Each small square → (5000/10) × (0.02/10) = 1.0 V [C1]
Therefore the potential difference between A and B is 530 V [A1]
(allow range 500 V – 550 V)

(iii)

Given by question, assume initial KE ≈ 0
By conservation of energy,
gain in kinetic energy = loss in electric potential energy

$$\frac{1}{2}mv^2 - 0 = q\Delta V$$

$$\frac{1}{2}\left(9.11\times10^{-31}\right)v^2 = 1.6\times10^{-19}(530)$$ [M1]

$$v = 1.37\times10^7\text{ m s}^{-1}$$ [A1]

4 (a) 1120

4 (b) (i) & (ii) Marks given for correct plotted points and best fit line.

(iii)

Using (2×10^6, 1240) and (22×10^6, 1040),

$$B = \text{ gradient } = \frac{1240 - 1040}{(2-22)\times 10^6} \quad [M1]$$

$$= -0.000010 \text{ m}^3 \quad [A1]$$

$$A = \text{ vertical intercept } = 1240 - (-0.000010)(2\times 10^6) \quad [M1]$$

$$= 1260 \text{ N m} \quad [A1]$$

(iv)

As pressure increases at constant temperature, volume occupied by a real gas decreases more than proportionally, hence the product pV decreases with increasing pressure.

(v)

$$\frac{\Delta(pV)}{pV} = \frac{\Delta p}{p} + \frac{\Delta V}{V} = 0.05 + 0.03 = 0.08 \quad [M1]$$

$$\Delta(pV) = 0.08 \times 1160 = 92.8$$

$$\approx 90 \text{ N m} \quad [A1]$$

(vi)

Horizontal straight line [A1]
At constant temperature T and number of mole = 1, from ideal gas equation, $pV = nRT$ = constant. [M1]

5 (a) (i)

Length of pulse = speed x time = $3.0 \times 10^8 \times 1.0 \times 10^{-10} = 3.0 \times 10^{-2}$ m

(ii)

$\Delta x = 3.0 \times 10^{-2}$ m

(iii)

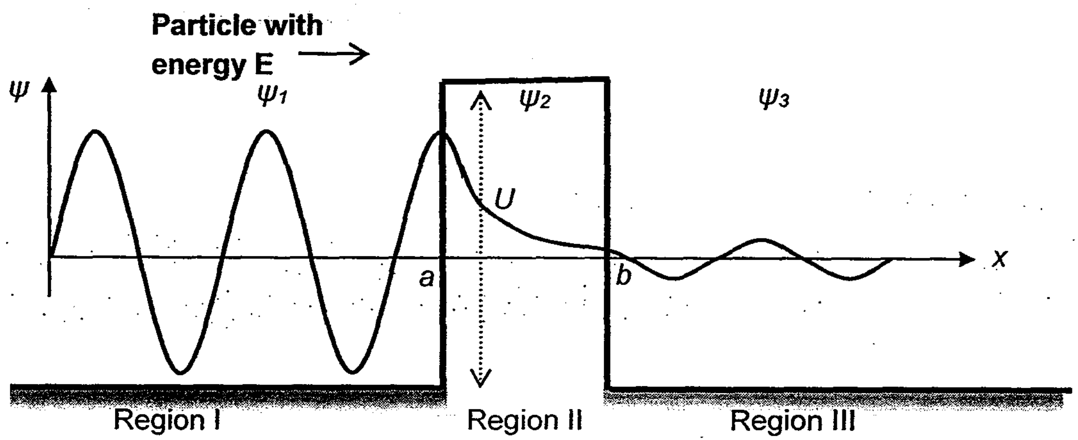
$\Delta x \Delta p \geq h/4\pi$

$$\Delta p = (h/4\pi\, \Delta x) = \frac{6.63 \times 10^{-34}}{4\pi(3.0 \times 10^{-2})} = 1.76\times 10^{-33} \text{ kgms}^{-1} \text{ [M1][A1]}$$

(b) (i)

A potential barrier is a region in space where there exists a maximum potential U, higher than that of the energy E of the particle, hence classically preventing the particle to pass through. [B1]

(ii)



Region II: <u>exponentially (decreasing)</u>, Ψ at b is positive and has non-zero amplitude
Region III: sinusoidal wave function, smaller amplitude compared to Region I, same wavelength as in Region I
[B1 – for correct wave function drawing in region II
B1 – for correct wave function drawing in region III
Minus 1 mark if wave function is not smooth and continuous at a and b]

The <u>square of the amplitude of this function $|\psi|^2$</u> indicates the probability of finding a particle at a particular position and time. [B1]

The wave function has non zero amplitude on both sides of the barrier. Hence the $|\psi|^2$ is not zero at the region on the right side of the potential barrier. There is a probability that the particle can be found on the other side of the barrier. [B1]

(c)

$T = \exp(-2kd)$

where $k = \sqrt{\dfrac{8\pi^2 m(U-E)}{h^2}}$

$= \sqrt{\dfrac{8\pi^2(9.11\times10^{-31})(6.0\times1.6\times10^{-19})}{(6.63\times10^{-34})^2}}$

$= 1.25336\times10^{10}\ \text{m}^{-1}$ [M1]

$T = e^{[-2(1.25336\times10^{10})(d)]}$

$0.0001 = 9.0549\times10^{-6}$

$d = 3.67\times10^{-10}\text{m}$ [A1]

6 (a) (i)

A metastable state is an excited state whose lifetime (time interval until spontaneous emission) is appreciably longer than the typical 10^{-8} second. (10^{-3} s)

(ii)

$$E_6 - E_5 = \frac{hc}{\lambda}$$

$$[-4.026 - (-5.990)] \times 1.60 \times 10^{-19} = \frac{(6.63\times10^{-34})(3.00\times10^{8})}{\lambda} \qquad \text{[M1]}$$

$$\lambda = 6.33 \times 10^{-7} \text{ m} \qquad \text{[A1]}$$

(iii)

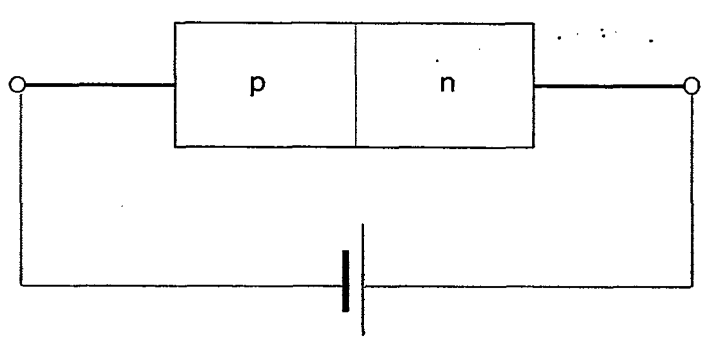
RED

(b) (i)

A p-n junction is formed when a p-type semiconductor is joined to an n-type conduction. At the boundary of the p-n junction, electrons from n-type diffuse into the p-type, while the holes from the p-type diffuse into the n type. [B1]
For the n-type which was originally neutral, a **localised** positive charge is generated due to the loss of electrons. Similarly, the p-type which was originally neutral now gains a localised negative charge as it has lost its holes. [B1]
This results in an electric field being set up at the junction, which opposes and limits further diffusion and recombination of the holes and electrons. [B1]

The region within the electric field that is **depleted** of charge carriers is called the depletion zone. [B1]

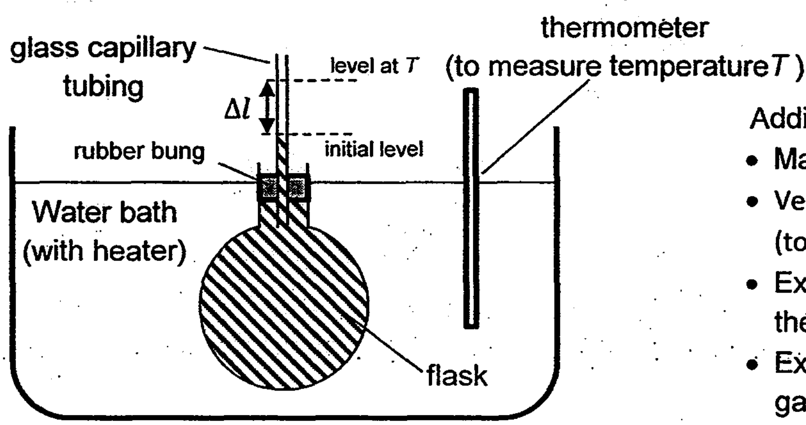
(ii)



7

Basic Procedure	B1 Workable diagram where temperature of water can change (e.g. water bath) and change in volume can be measured. B2 Vary temperature to obtain <u>at least 6 sets of data.</u>	2
Control	C1 Keep mass of water constant by cooling back to initial temperature and ensuring initial capillary level is unchanged, top up if needed. (counter evaporation) C2 Keep external pressure the same (check using pressure gauge.) C3 Monitor the ambient moisture in the air (humidity meter/ hygrometer). C4 Keep external temperature the same (air con room/use thermometer).	1
Methods of measurement	M1 Method to measure initial volume of water $V_i = \frac{mass}{density}$, with using mass balance to measure mass of water in the glass flask / Using a burette / pipette. Measuring flask is not accepted (accuracy). M2 $\Delta\ell$ measured using metre rule, vernier caliper or microscopic scale. M3 Method of measuring temperature, T using thermocouple or thermometer.	3
Analysis	A1 $V_T = \Delta V + V_i$ where $\Delta V = \Delta\ell \times \left(\pi \frac{d^2}{4}\right)$ A2 Plot relevant graph to determine relationship.(V_T vs T)	2
Safety Procedures	S1 Wear gloves when handling hot apparatus. S2 Mention relative safety of the experiment.	1
Reliability of experiment/ Other details	R1 Experiment repeated and results averaged under same conditions (to ensure repeatability). R2 Check zero order for apparatus (e.g mass balance, vernier caliper, thermometer, microscope with scale) – Sensitivity of instrument is important for this experiment! R3 Mark that capillary tube's initial level and final level (first and highest level) to be read with instrument. R4 Ensure container (with initial water) is wiped dry (to exclude extra mass) before weighing. R5 Check that the seal of the glass flask (cover) is tight to prevent evaporation of water. R6 Selected a good range of temperature, e.g. intervals of 10 °C R7 Using a water bath for even heating of flask. R8 Attaching vernier calipers/micrometer to a retort stand to prevent shaking during measurement of Δl. R9 Any other suitable reliability.	3

suggested diagram:



Additional apparatus:

- Mass scale
- Vernier calipers (to measure Δl)
- External thermometer
- External pressure gauge
- External hygrometer

JC2 Preliminary Examinations
Higher 2

H2 Physics 9646/03

Paper 3 Longer Structured Questions

20 September 2016

2 hours

Candidates answer on the Question Paper.
No Additional Materials are required.

Candidate Name: ______________________________

Class	Reg No

READ THESE INSTRUCTIONS FIRST

Write your name and class on all the work you hand in.
Write in dark blue or black pen on both sides of the paper.
You may use a 2B pencil for any diagrams or graphs.
Do not use staples, paper clips, glue or correction fluid.

The use of an approved scientific calculator is expected, where appropriate.

Section A
Answer **all** questions.

Section B
Answer any **two** questions.

You are advised to spend about one hour on each section.

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	
Section A	
1	**/ 6**
2	**/ 12**
3	**/ 10**
4	**/ 12**
Section B	
5	**/ 20**
6	**/ 20**
7	**/ 20**
Deductions	
Total	**/ 80**

Data

speed of light in free space	c	=	3.00×10^{8} m s^{-1}
permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
		=	$(1/(36\pi)) \times 10^{-9}$ F m^{-1}
elementary charge	e	=	1.60×10^{-19} C
the Planck constant	h	=	6.63×10^{-34} J s
unified atomic mass constant	u	=	1.66×10^{-27} kg
rest mass of electron	m_e	=	9.11×10^{-31} kg
rest mass of proton	m_p	=	1.67×10^{-27} kg
molar gas constant	R	=	8.31 J K^{-1} mol^{-1}
the Avogadro constant	N_A	=	6.02×10^{23} mol^{-1}
the Boltzmann constant	k	=	1.38×10^{-23} J K^{-1}
gravitational constant	G	=	6.67×10^{-11} N m^2 kg^{-2}
acceleration of free fall	g	=	9.81 m s^{-2}

Formulae

uniformly accelerated motion	s	=	$ut + \frac{1}{2}at^2$
	v^2	=	$u^2 + 2as$
work done on/by a gas	W	=	$p\Delta V$
hydrostatic pressure	p	=	ρgh
gravitational potential	ϕ	=	$-\dfrac{GM}{r}$
displacement of particle in s.h.m.	x	=	$x_o \sin \omega t$
velocity of particle in s.h.m.	v	=	$v_o \cos \omega t$
	v	=	$\pm\, \omega\sqrt{x_o^2 - x^2}$
mean kinetic energy of a molecule of an ideal gas	E	=	$\frac{3}{2}kT$
resistors in series	R	=	$R_1 + R_2 + \ldots$
resistors in parallel	$1/R$	=	$1/R_1 + 1/R_2 + \ldots$
electric potential	V	=	$\dfrac{Q}{4\pi\varepsilon_0 r}$
alternating current/voltage	x	=	$x_o \sin \omega t$
transmission coefficient	T	$\propto$	$\exp(-2kd)$
	where k	=	$\sqrt{\dfrac{8\pi^2 m(U-E)}{h^2}}$
radioactive decay	x	=	$x_o \exp(-\lambda t)$
decay constant	λ	=	$\dfrac{0.693}{t_{\frac{1}{2}}}$

Section A

Answer **all** the questions in the spaces provided.

1 Fig. 1.1 shows a light gate, which is an electronic sensor used to measure the speed of an object. The light gate consists of an infrared beam which travels between its two arms. The light gate is triggered when the beam is blocked by the object, and the time duration of the obstruction is recorded using a data logger (not shown).

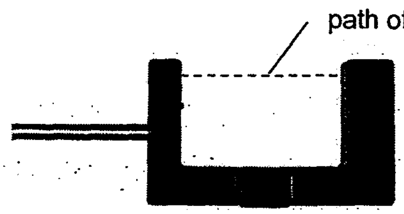


Fig. 1.1

A weighted card is released and falls vertically through the light gate, as shown in Fig. 1.2.

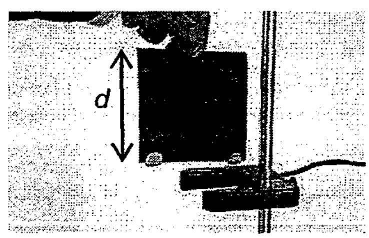


Fig. 1.2

The card has a length d = (0.200 ± 0.002) m, and the time taken for the card to travel through the light gate was t = (0.06428 ± 0.00001) s.

(a) Calculate the average speed of the card. Express it with its associated uncertainty.

speed = (.................... ± ....) m s^{-1} [3]

(b) Suggest two reasons why, with a single light gate, we can only measure the average speed of the falling card, but not its instantaneous velocity.

Reason 1: ....

....

Reason 2: ....

....[2]

(c) Suggest a source of random error that limits how precisely the speed can be measured.

....[1]

2 **(a)** **(i)** State how a polarised transverse wave differs from an unpolarised transverse wave.

....

....

.... [2]

(ii) Suggest how it can be verified that a laser light is plane-polarised.

....

.... [1]

(b) Fig. 2.1 shows the variation with distance of the displacement of the points along a string when a transverse wave propagates along the string.

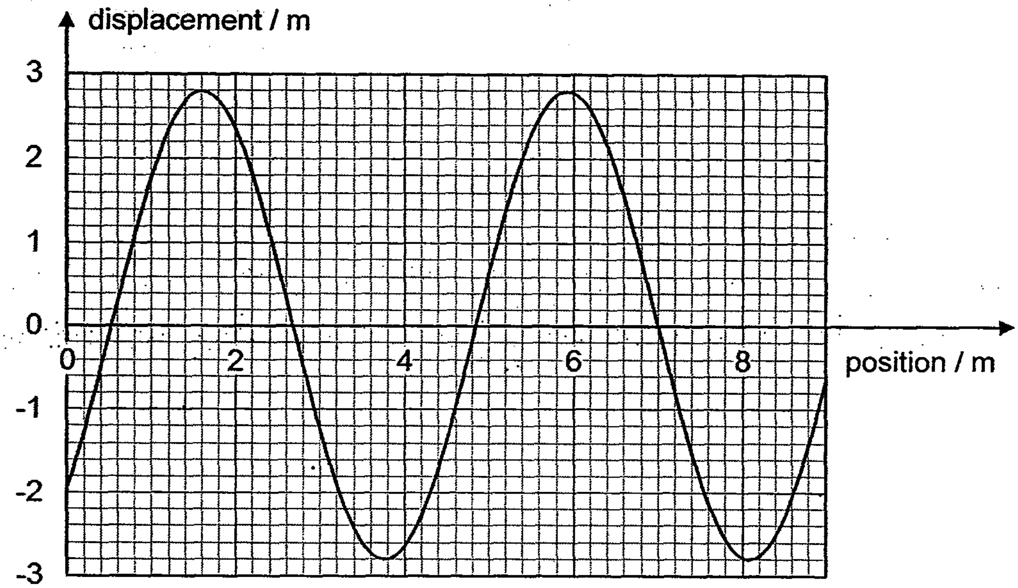


Fig. 2.1

State and explain why the speed of the wave cannot be determined from Fig. 2.1.

....

.... [2]

(c) Fig. 2.2 shows a double slit arrangement to demonstrate observable interference of light on the screen.

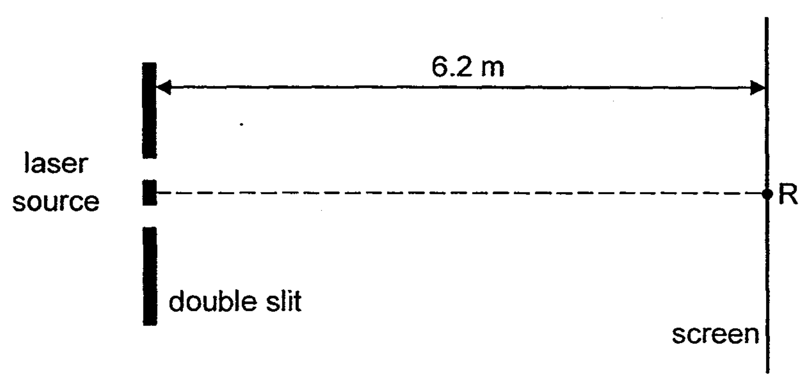


Fig. 2.2

(i) Suggest why a laser source is used.

....

.... [1]

(ii) The separation between the two slits is 0.80 mm. The fringe separation observed on the screen is 5.0 mm. Determine the wavelength of the laser light used.

wavelength = ... m [2]

(iii) The screen is now moved further from the slits. Explain what happens to the intensity of light reaching point R on the screen.

....

....

....[2]

(d) A standing sound wave is set up within a pipe with both ends open. Two nodes are observed within the pipe. The pipe is 1.5 m long. The speed of sound is 330 m s^{-1}.

Sketch the profile of the standing wave formed in the pipe on Fig. 2.3 and calculate the frequency of the sound.

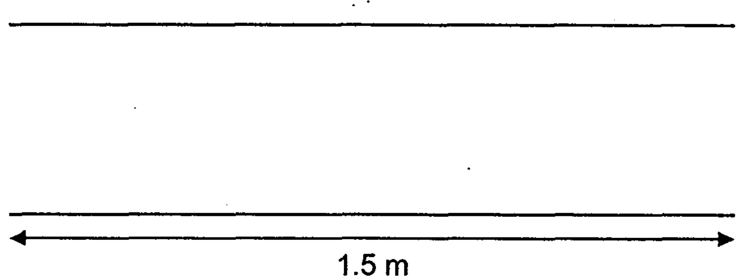


Fig. 2.3

frequency = ... Hz [2]

3 Five identical electrical devices of resistance 10 Ω and three switches, S_A, S_B and S_C, are arranged in a network as shown in Fig. 3.1. S_A is open while S_B and S_C are closed.

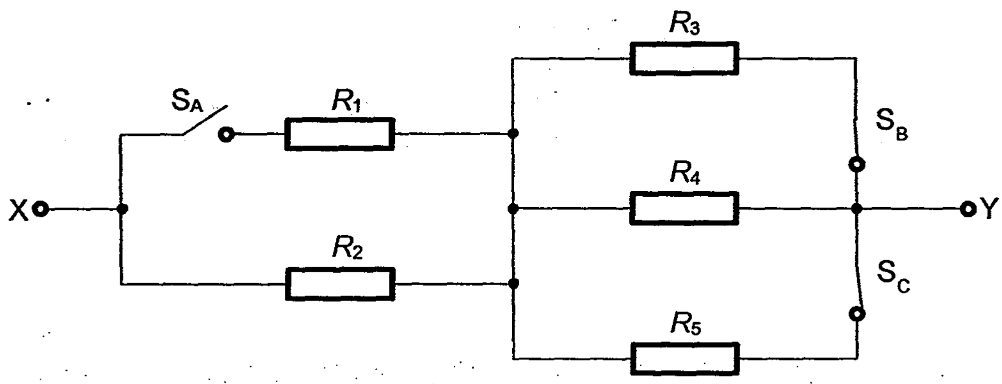


Fig. 3.1

(a) Determine the value of R_{XY}, the resistance between terminals X and Y.

R_{XY} = ... Ω [2]

(b) The network is now connected to a cell of e.m.f. 3.0 V with an internal resistance of 0.40 Ω as shown in Fig. 3.2.

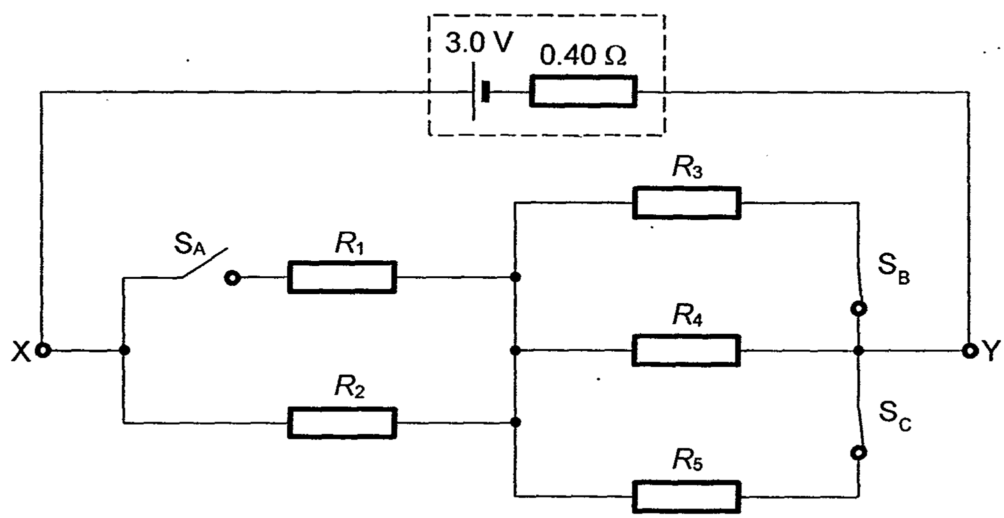


Fig. 3.2

(i) Determine the current supplied by the cell.

current = ... A [2]

(ii) Calculate the power dissipated in R_3.

power = ... W [2]

(c) Ideal diodes have infinite resistance when they are in reverse bias and zero resistance when they are in forward bias. The switches in Fig. 3.2 can be replaced with ideal diodes to obtain the same circuit.

Complete Fig. 3.3 below with the diodes in suitable orientations. [2]

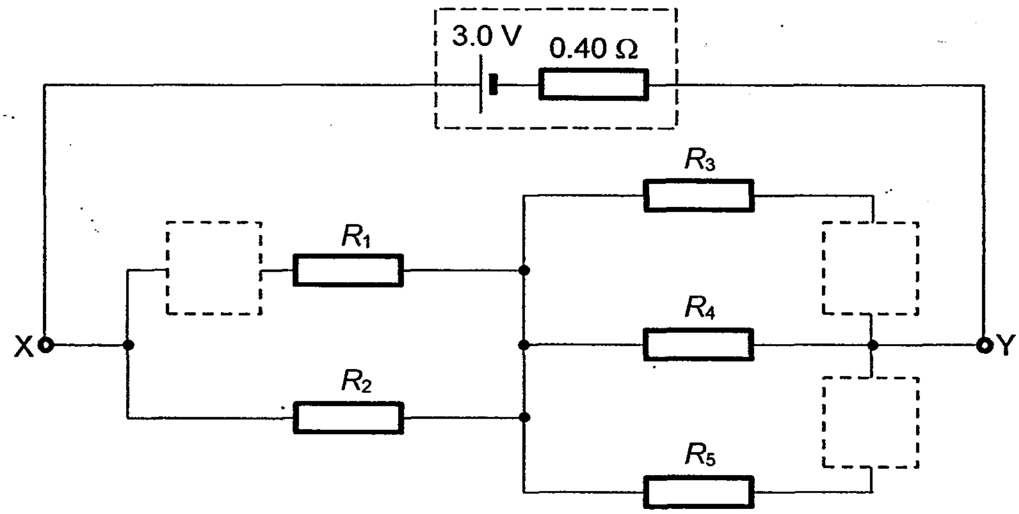


Fig. 3.3

(d) Briefly explain why, in practice, a diode requires a small forward biased potential difference across its terminals before current can flow through it.

....

....

....

.... [2]

4 **(a)** Distinguish between a line emission spectrum and a line absorption spectrum in terms of their appearance.

....

....

....[2]

(b) Explain how a line emission spectrum is obtained.

....

....

....

....

....

....[3]

(c) Explain how a line spectrum can be used to identify the elements in a sample of gas.

....

....

....[2]

(d) Some of the energy levels of a particular atom X are shown in Fig. 4.1.

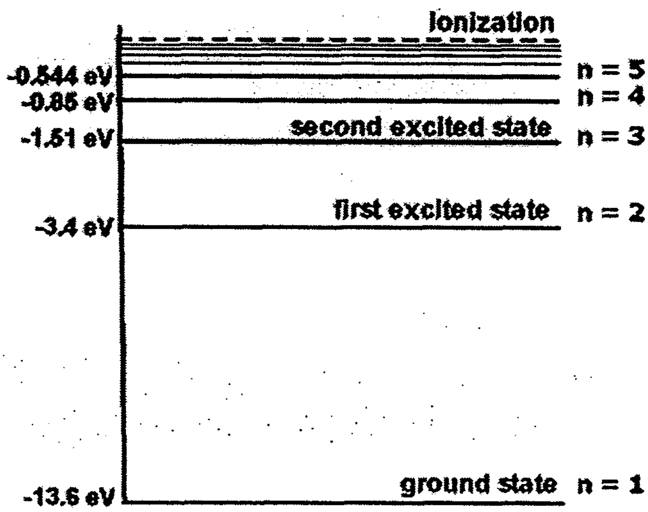


Fig. 4.1

(i) State the ionisation energy of atom X.

....[1]

(ii) Cool vapour of X at low pressure is bombarded with electrons of kinetic energy 2.00×10^{-18} J. With appropriate calculations, state and explain the transition(s) you would expect to observe.

....

....[2]

(iii) If the electrons were replaced with photons of the same energy, state and explain on the difference in your observation.

....

....

....[2]

Section B

Answer **two** questions from this Section in the spaces provided.

5 **(a)** **(i)** State Newton's law of gravitation.

....

....

....[1]

(ii) Explain why the gravitational forces are significant only with celestial objects like stars and planets but not with atoms or molecules.

....

....[1]

(iii) A man stands on a weighing machine at the pole and then at the equator. Assuming Earth to be a perfect sphere, explain with the help of diagrams why there is a difference in the readings of the weighing machine.

....

....

....

....[3]

(b) A satellite of mass m is in a circular orbit about the Earth with a constant speed.

(i) Explain whether the satellite is in equilibrium.

....

....[1]

(ii) Derive the expression of kinetic energy of the satellite in terms of the mass of Earth M, the mass of the satellite m, and the orbital radius r. [2]

(iii) The potential energy of a satellite at the surface of the Earth is -9.6×10^{10} J. A satellite is launched close to one of the poles of the Earth. Calculate the minimum energy supplied to the satellite to put it into an orbit of radius 4.3×10^4 km. The radius of the Earth is 6.4×10^3 km.

minimum energy = ... J [4]

(iv) The same satellite is now launched from the surface of the Earth at the equator to the same orbit. Explain why the minimum energy supplied to the satellite will be lower compared to that calculated in **(b)(iii)**.

....

....[1]

(v) A satellite in a low orbit around the Earth will experience resistive forces due to the Earth's atmosphere. State and explain what will happen to the height of the satellite and its speed.

....

....

....

....[2]

(c) (i) Show that for any satellite in an orbit of radius R,

$$\frac{R^3}{T^2} = \text{constant}$$

where T is the orbital period of the satellite. [1]

(ii) A satellite orbiting at a height of $0.1R_E$ above the surface of the Earth has a rotating period of 5100 s. Using **(c)(i)**, calculate the orbital radius of a geostationary satellite in terms of R_E, the radius of the Earth.

orbital radius = ... [2]

(iii) List one advantage and one disadvantage of a geostationary satellite.

Advantage: ....

....

Disadvantage: ....

....[2]

6 **(a)** A sinusoidal alternating supply voltage is connected across the primary coil of an ideal iron-cored transformer. The secondary coil is connected to a resistor. This is shown in Fig. 6.1.

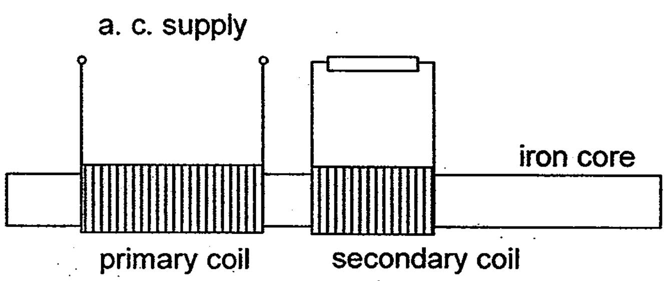


Fig. 6.1

(i) State Faraday's law of electromagnetic induction.

....

....

....[2]

The secondary coil has 500 turns and cross-sectional area of 0.010 m^2. With the a.c. supply connected, it is subjected to a changing magnetic field. The variation with time of magnetic flux density in the secondary coil is shown in Fig. 6.2.

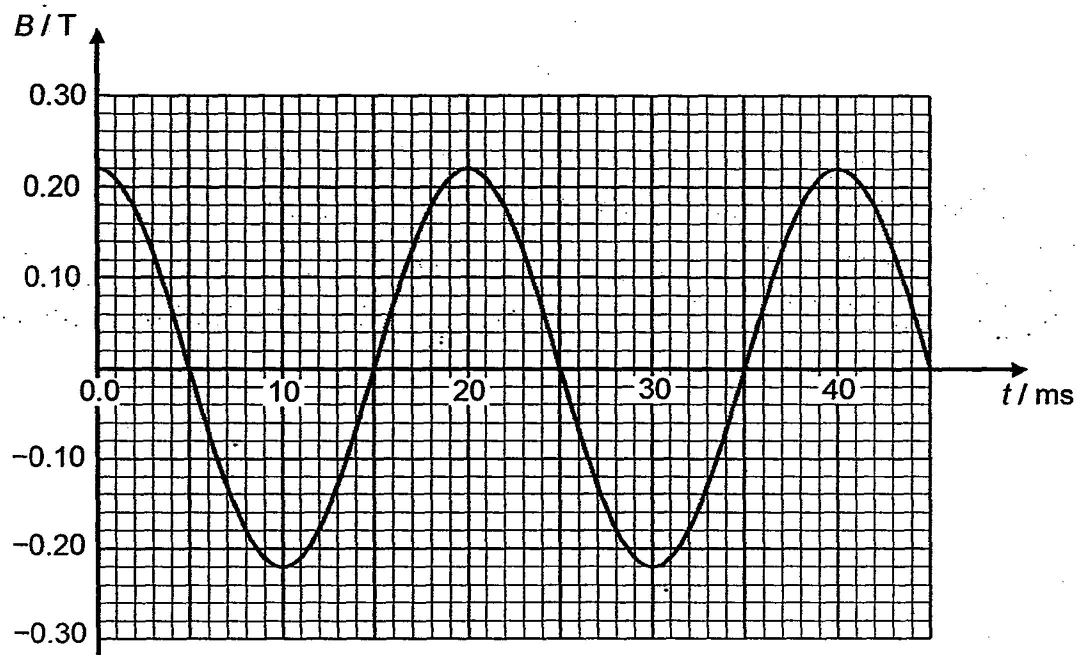


Fig. 6.2

(ii) Estimate the maximum value of the induced e.m.f.

maximum e.m.f. = ... V [3]

(iii) Sketch and label in Fig. 6.3 the corresponding graph of the induced e.m.f. against time from $t = 0$ to $t = 40$ ms. [2]

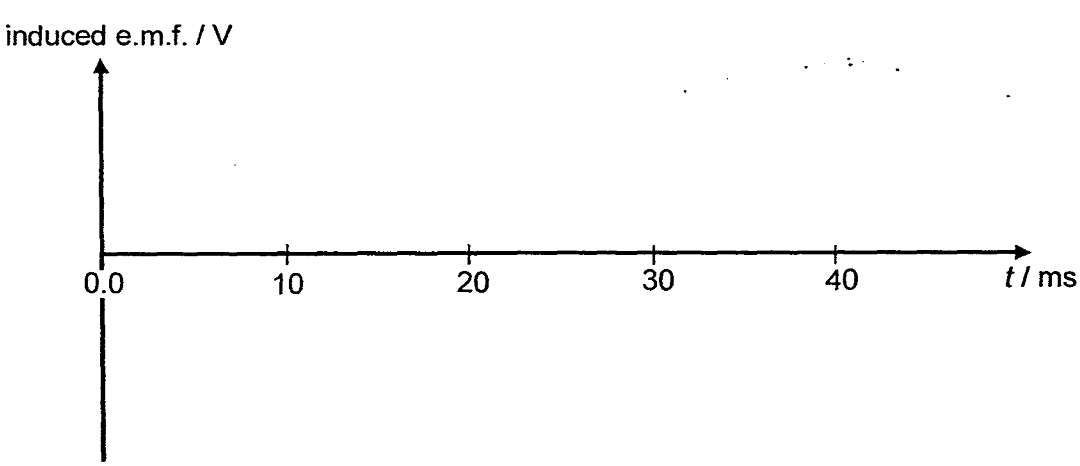


Fig. 6.3

(iv) The resistor in the secondary coil has a resistance of 8.0 Ω. Calculate the root-mean-squared current passing through the resistor.

root-mean-squared current = ... A [3]

(v) The primary coil contains 3200 turns. Calculate the value of the peak e.m.f. in the primary coil.

peak e.m.f. = ... V [2]

(vi) The iron core is now removed. Explain why the peak e.m.f. in the secondary coil decreases.

....

....

....[2]

(b) **(i)** Define *magnetic flux density*.

....

....[1]

A particle of charge q and mass m is moving in a helical path inside a uniform magnetic field of magnetic flux density B. It has a velocity of v and makes an angle of θ with the magnetic field as shown in Fig. 6.4.

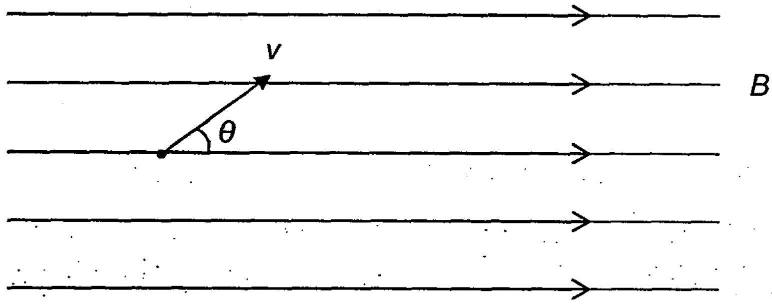


Fig. 6.4

(ii) Show that the radius of the helical path r is given by the expression [2]

$$r = \frac{mv\sin\theta}{Bq}$$

(iii) Hence, or otherwise, show that the period of each cycle of the helical path is independent of θ. [2]

(iv) Explain why there is no work done by the magnetic field on the electron.

....

.... [1]

7 **(a)** It is said that, in theory, 3 bottles of water and a few rocks can power an average home for a year. The water and rocks can be used to obtain raw materials for nuclear fusion reactions between deuterium and tritium.

The following data list the masses of various nuclei used in these reactions:

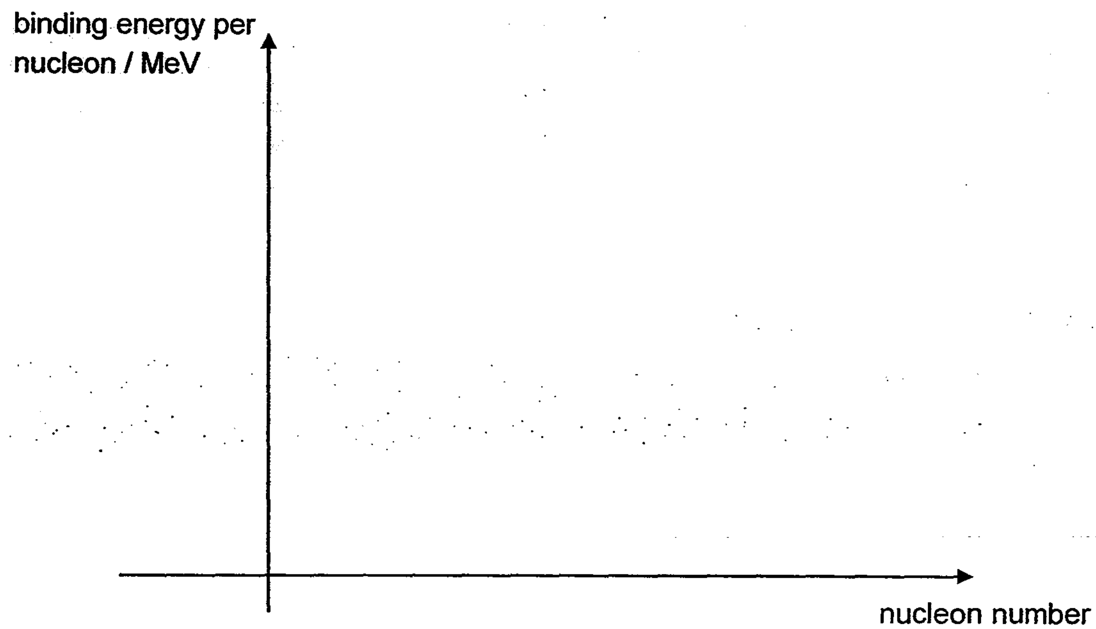
neutron		1.008664 u
proton		1.007276 u
deuterium	$^{2}_{1}H$	2.014102 u
tritium	$^{3}_{1}H$	3.016049 u
helium-4	$^{4}_{2}He$	4.002602 u
lithium-6	$^{6}_{3}Li$	6.015122 u

Tritium $^{3}_{1}H$ can be made from lithium $^{6}_{3}Li$ which can be extracted from the rocks.

(i) Calculate the binding energy per nucleon of a $^{6}_{3}Li$ nucleus.

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

(ii) Sketch on the axes below, a labelled graph to show the variation of binding energy per nucleon with nucleon number. [1]



(iii) Deuterium can be extracted from the water. Thermonuclear reactors heat a mixture of deuterium and tritium to 100 million degrees Celsius to produce the reaction:

$$^{2}_{1}H + ^{3}_{1}H \rightarrow ^{4}_{2}He + ^{1}_{0}n + \gamma$$

Calculate the amount of energy in MeV produced in one such reaction.

energy produced = ... MeV [2]

(iv) Explain why it is necessary for the temperature of the reaction to be so high.

....

....

.... [2]

(b) Technetium-99* $\left({}^{99}_{43}Tc\,^*\right)$ is a common isotope used in nuclear medicine. The mass of ${}^{99}_{43}Tc\,^*$ is 98.9063u. The symbol * means it is an excited state.

Technetium-99* can be introduced into the body. The gamma rays that it produces are detected outside the body and used to make images of various organs.

Technetium-99* decays with a half-life of x hrs as follows:

$${}^{99}_{43}Tc^* \rightarrow {}^{99}_{43}Tc + \gamma$$

The product, Technetium-99, then further decays by emitting low energy beta particles.

$${}^{99}_{43}Tc \rightarrow {}^{99}_{44}Ru + {}^{0}_{-1}e$$

The half-life of Technetium-99 is 211000 years.

(i) The radioactive decay of the isotope Tc-99* is both spontaneous and random.

Explain what is meant by

1. radioactive decay,

....

....

....[2]

2. spontaneous process,

....

....

....[1]

3. random process.

....

....

....[1]

Fig. 7.1 shows the decay curve of a freshly administered dose of Technetium-99*.

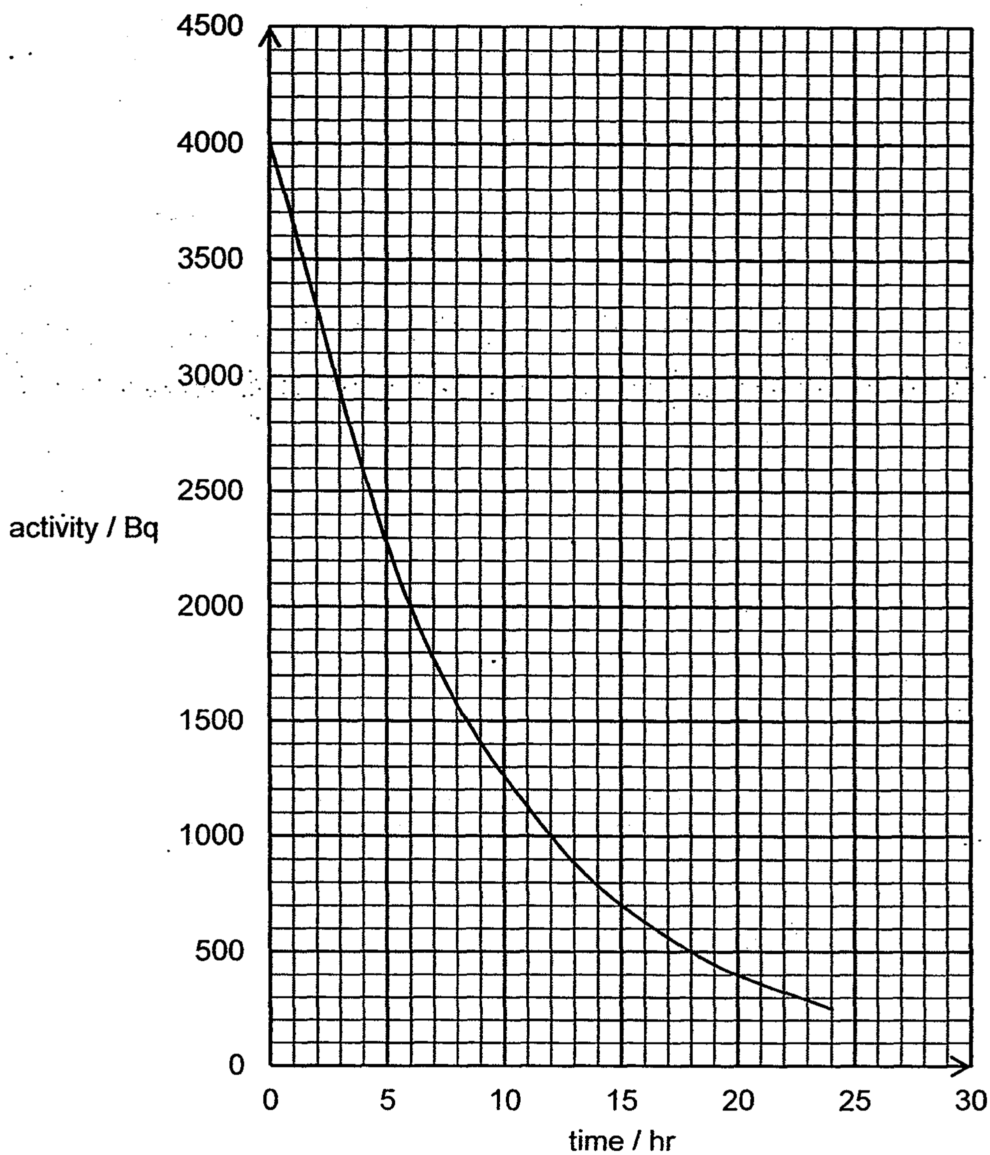


Fig 7.1

(ii) State the half-life of Technetium-99*, x, in terms of hours.

x = ... hours [1]

(iii) Determine the mass of Technetium-99* remaining in the body after 30.0 hours.

mass = ... kg [4]

(iv) With reference to the half-lives of both Technetium-99* and Technetium-99, explain why Technetium-99* is suitable for use in medical imaging.

....

....

....

.... [2]

(v) Explain why it is safer to use gamma-emitting radioisotopes than alpha-emitting radioisotopes in nuclear medicine.

....

.... [1]

Proposed solutions to JC2 H2 Physics Prelim Paper 3

1 (a)

Average speed = 0.200 / 0.06428 = 3.11139 m s^{-1}
[C1 for value of v]

Max = 0.202 / 0.06427 = 3.14299 m s^{-1}
Min = 0.198 / 0.06429 = 3.07979 m s^{-1}
Δv = (3.14299−3.07979) / 2 = 0.0316 m s^{-1} [C1 for value of Δv]

OR:

$$\frac{\Delta v}{v} = \frac{\Delta d}{d} + \frac{\Delta t}{t} = \frac{0.002}{0.200} + \frac{0.00001}{0.06428} = 0.01016$$

Δv = 0.01016 × 3.11139 = 0.0316 m s^{-1} [C1 for value of Δv]

Final answer = (3.11 ± 0.03) m s^{-1}
[A1 for Δv expressed to 1 s.f., v expressed to 2 d.p. (same number of d.p. as Δv]

(b)

Idea 1: "Average" vs "instantaneous" [B1]
There is an increase in speed as the card is falling through the light gate, so the measured speed is only an average value (based on total distance / total time) and this is not equal to the instantaneous value.

Idea 2: "Speed" vs "velocity" [B1]
The light gate only detects the duration of the obstruction, and thus cannot detect direction of travel (which direction the card is moving).

(c)

Card does not fall straight (e.g. rotates) and this affects the effective length of the card that obstructs the infrared beam.

2 (a) (i)

In polarised transverse wave, the wave oscillates in only one plane that is perpendicular to the direction of wave propagation. [B1]
In unpolarised transverse wave, the wave oscillates in all possible planes perpendicular to direction of wave propagation. [B1]

(ii)

While shining a laser beam through the polariser perpendicularly, rotate the polariser through an axis parallel to the beam. [B1]
The intensity of the laser light exiting the polariser should vary as the polariser is rotated.

(b)

Since the speed of light can be determined from $v = f\lambda$, [B1] the <u>period / frequency</u> of the wave has to be known. [B1]

(c) (i)

A laser source ensures that the waves from the two slits are <u>coherent</u>, i.e. there is a constant phase difference between the two waves emerging from the slits.

(ii)

$$x = \frac{D\lambda}{a}$$

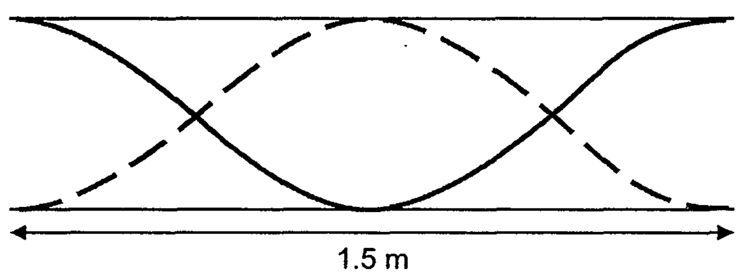
$$5.0\times10^{-3} = \frac{6.2\lambda}{0.80\times10^{-3}} \qquad \text{[M1]}$$

$$\lambda = 6.45\times10^{-7}\text{ m or } 645\text{ nm} \qquad \text{[A1]}$$

(iii)

Since intensity of wave propagating away from a point source is inversely proportional to the square of the distance from the point source, [M1]
the intensity will decrease when the screen is moved further. [A1]
Further from the point source, the energy of the wave is spread over a larger surface area and hence intensity decreases.

(d)



[B1]

$$f = \frac{v}{\lambda} = \frac{330}{1.5} = 220\text{ Hz} \qquad \text{[B1]}$$

3 (a)

$$R_{XY} = R + \left(\frac{1}{R}+\frac{1}{R}+\frac{1}{R}\right)^{-1} = R + \frac{R}{3} = 10 + \frac{10}{3} \qquad \text{[M1]}$$

$$= 13.3\ \Omega \qquad \text{[A1]}$$

(b) (i)

$$I = \frac{V}{R_{total}} = \frac{3.0}{13.3 + 0.40} \quad \text{[M1]}$$
$$= 0.219 \text{ A} \quad \text{[A1]}$$

(ii)

Since the resistors R_3, R_4 and R_5 are identical and in parallel,

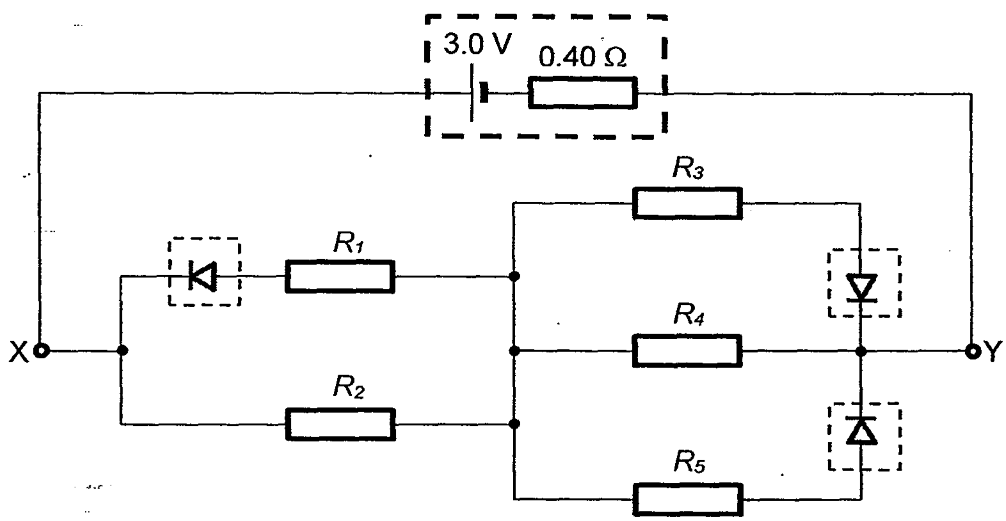
Current through $R_3 = \frac{0.219}{3} = 0.073$ [C1]

$P = I^2R_3 = (0.073)^2(10)$

$= 0.0532$ W [A1]

Alternatively; use potential divider to find p.d. across R_3; use $P = \frac{V^2}{R}$

(c)



[M1] Correct orientation (Not accepting just arrows, students should at least draw the triangle to indicate direction of allowed current flow)
[A1] Correct symbol (⊣▷⊢, circle optional, with lines to connect to the rest of the circuit)

(d)

A small internal electric field across the depletion region of a P-N junction prevents the movement of majority charge carriers through the junction

The small forward biased potential difference across the terminals reduces the internal electric field and depletion region [B1] and allow the (majority) charge carriers to move [B1] and constitutes to a current flowing through the diode.

4 (a)

Emission line spectrum consists of discrete bright coloured lines on a dark background. [B1]
Absorption spectrum consists of dark lines against a continuous spectrum of white light. [B1]

(b)

Summary of important points (3 main points):
1) Thermal excitation / electrical discharge / white light source which causes the atoms of the gas to be excited [B1]

Gases such as hydrogen or neon can be placed in a discharge tube at low pressure. A voltage (several kilo-volts) is applied between metal electrodes in the tube which is large enough to produce an electric current in the gas. The gas becomes excited by the collisions with the electrons passing through the tube, from cathode to anode of the discharge tube.

2) Photons emitted due to de-excitation of atoms (from a higher energy level to a lower energy level) [B1]

The excited gas atoms are unstable. When the gas atoms undergoes a transition to a lower energy level, the excess energy is emitted as electromagnetic radiation (photon) with a specific frequency.

3) Each discrete bright line in the spectrum corresponds to one particular photon energy of specific frequency or wavelength. [B1]

OR

The frequency f of the emission line is dependent on the difference between the high and low energy levels, $\Delta E = hf$. Due to the discrete energy levels, only certain high-to-low energy level transitions are possible within the atom, therefore only certain frequency lines are present in the spectrum. [B1]

(c)

No two gases/ elements give the same exact line spectrum. [B1]
Hence by comparing the line spectrum of the given sample with that of known elements, we can identify the elements in that sample. [B1]

(d) (i)

13.6 eV or 2.176×10^{-18} J [B1]

(ii)

Kinetic energy of electrons = $2.00 \times 10^{-18} / 1.60 \times 10^{-19} = 12.5$ eV hence the highest state that the atom can be excited to is n=3. [B1]

Hence only the following transitions are observed
From n =3 to n=2
From n =2 to n=1
From n =3 to n=1
[B1 for all three correct transitions – no mark will be given if excitation instead of de-excitations were mentioned.]

(iii)

The energy of the photon does not match exactly any of the energies required for the atom to get excited from the ground state to higher excited state hence the photons incident will not be absorbed by the atom. [M1]
No emission lines will be observed or no transition occurs (atoms still remain at ground state). [A1]

5 (a) (i)

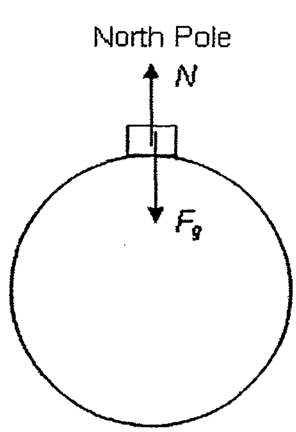
Newton's Law of Universal Gravitation states that any two point masses attract each other with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

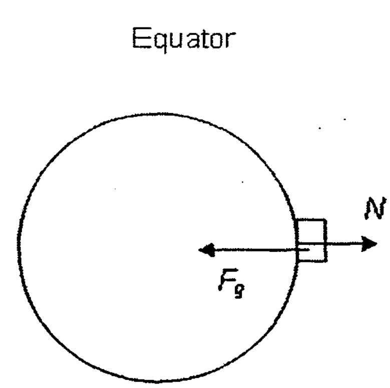
(ii)

Gravitational forces are only significant when the masses involved are massive. This is because of the magnitude of Newton's universal gravitational constant, <u>G whose magnitude is very small</u>. [B1]

Hence atoms and molecules whose masses are very small would result in insignificant magnitude of gravitational forces.

(iii)





Free Body diagram (include N and F_g) [B1]
At the pole, it is not rotating.
At the equator, it is <u>rotating with an angular velocity being constant</u>, centripetal acceleration ($a = r\omega$) and hence centripetal force ($F = ma$) are not constant.
<u>Centripetal acceleration/force is maximum at the equator and is zero at the poles</u>.
[B1]
Fg – N = Fc
N = Fg - Fc
Fg is constant assuming that earth is spherical in shape.
Hence at the equator the weight measured (N) will be smaller compared to the poles due to a larger centripetal acceleration/force. [B1]

(b) (i)

The satellite is travelling with constant speed but its direction is changing, hence it experiences acceleration so it is not in equilibrium.
Or
The satellite experience a net force (centripetal force) hence it is not in equilibrium
[B1]

(ii)

Gravitational force provides for centripetal force

$$\frac{GMm}{r^2} = \frac{mv^2}{r}$$

$$v = \sqrt{\frac{GM}{r}} \qquad \text{[M1]}$$

$$E_K = \frac{1}{2}mv^2$$

$$= \frac{1}{2}m\left(\sqrt{\frac{GM}{r}}\right)^2$$

$$= \frac{1}{2}\frac{GMm}{r} \qquad \text{[A1]}$$

(iii)

$E_P = -\frac{GMm}{R}$, hence $E_P \propto \frac{1}{R}$

$\frac{E_P}{E_{Psurface}} = \frac{R_{surface}}{R}$

$E_P = \frac{6.4\times10^6}{4.3\times10^7}\times -9.6\times10^{10}$ [M1]

$= -1.43\times10^{10}$ J

From (b)(i): $E_K = +\frac{1}{2}(1.43\times10^{10})$ [M1]

Energy supplied $+ E_{Psurface} = E_{Porbit} + E_{Korbit}$

Energy supplied $= (E_{Porbit} - E_{Psurface}) + E_{Korbit}$

$= (-1.43\times10^{10} + 9.6\times10^{10}) + \frac{1}{2}(1.43\times10^{10})$ [M1]

$= 8.9\times10^{10}$ J [A1]

(iv)

If the satellite is launched at the equator, it will have an initial kinetic energy since it has an initial (angular) speed at the equator. [M1]

(v)

Height of the satellite will decrease as friction will cause the total energy of the satellite to decrease. $E_{total} = -\frac{GMm}{2r}$, as total energy will be more negative, hence height will decrease. [B1]

Speed of the satellite will increase as $E_K = \frac{GMm}{2r}$, so with a decrease in height, kinetic energy increase, hence speed increase. [B1]

(c) (i)

$$\frac{GMm}{R^2} = mR\omega^2 = mR\left(\frac{2\pi}{T}\right)^2$$

$$\frac{R^3}{T^2} = \frac{GM}{4\pi^2} \quad \text{[M1]}$$

$$= \text{constant} \quad \text{[A0]}$$

(ii)

orbital period of geostationary satellite $= 24 \times 60 \times 60 = 86400$ s [M1]

$$\frac{R_{0.1R_E}{}^3}{T_{0.1R_E}{}^2} = \frac{R_{geo}{}^3}{T_{geo}{}^2}$$

$$\frac{(1.1R_E)^3}{5100^2} = \frac{(R_{geo})^3}{86400^2}$$

$$R_{geo} = 7.3R_E$$

$\therefore$ orbital radius of geostationary satellite $= 7.3R_E$ [A1]

(iii)

Advantages:
1. As they remain stationary above the same point on Earth, they are ideal for use as communication satellites as it requires no tracking to receive its downlink signal. This is why there is no need to keep adjusting the satellite dish to receive TV signal from a particular geostationary satellite.
2. As geostationary satellites are positioned at such a high altitude they can view the whole earth disc below them, rather than a small subsection, and they can scan the same area very frequently. They are ideal for meteorological applications and remote imaging.

Disadvantages:
1. Since they are positioned at such a high altitude, the spatial resolution (i.e. the amount of detail shown) of their images tends to be not as good.
2. Since they are positioned above the equator they cannot see the north or south poles and are of limited use for latitudes greater than 60 -70 degrees north or south. The further from the equator the lower, the spatial resolution of each pixel and the greater the possibility of being hidden by the earth's curvature.

6 (a) (i)

Faraday's Law of Electromagnetic Induction states that
the magnitude of induced e.m.f. is directly proportional to the rate of change of magnetic flux linkage or the rate of cutting of magnetic flux. [B2]

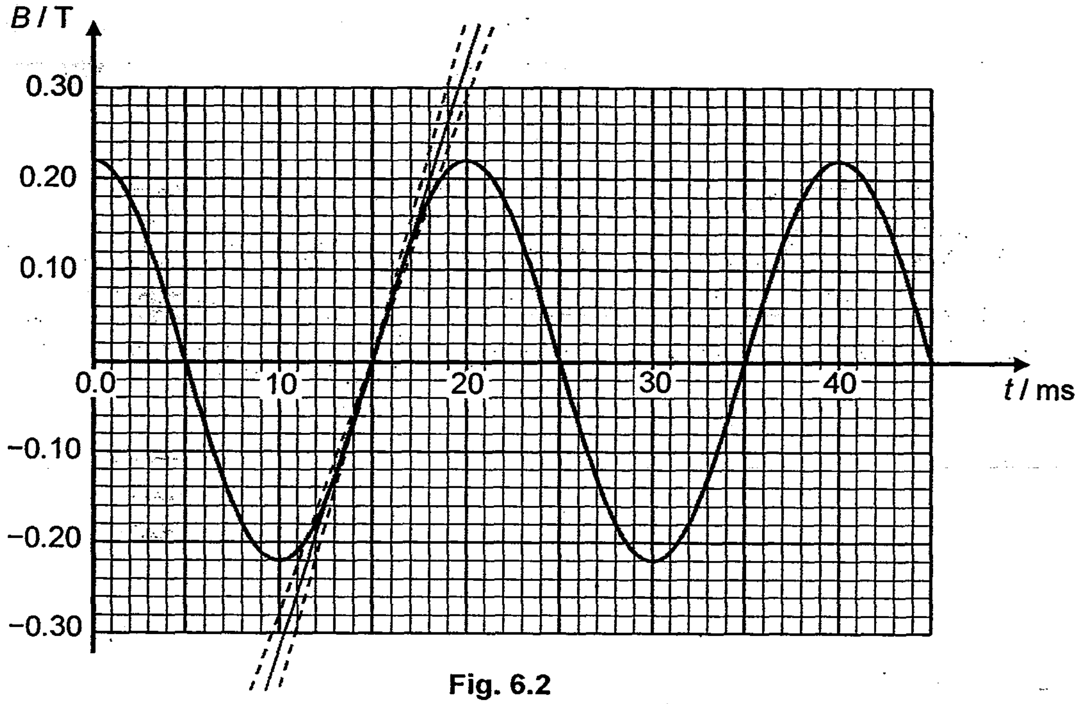


Fig. 6.2

Must draw tangent line

(ii)

Since Faraday's law state that $\varepsilon = -\frac{d\phi}{dt}$, taking the gradient at t = 15 s (tangent drawn correctly) [M1]

$$\varepsilon = \left| -\frac{\phi_2 - \phi_1}{t_2 - t_1} \right| = NA\left| -\frac{B_2 - B_1}{t_2 - t_1} \right|$$

$$= 500 \times 0.010 \times \left| \frac{[0.26 - (-0.26)]}{(19 - 11) \times 10^{-3}} \right| \quad \text{[M1]}$$

$= 325$ V [A1]

accept range between 280 and 375 (dotted lines)

(iii)

shape: Positive sine curve [B1]
labels: correct period and max/min emf [B1]

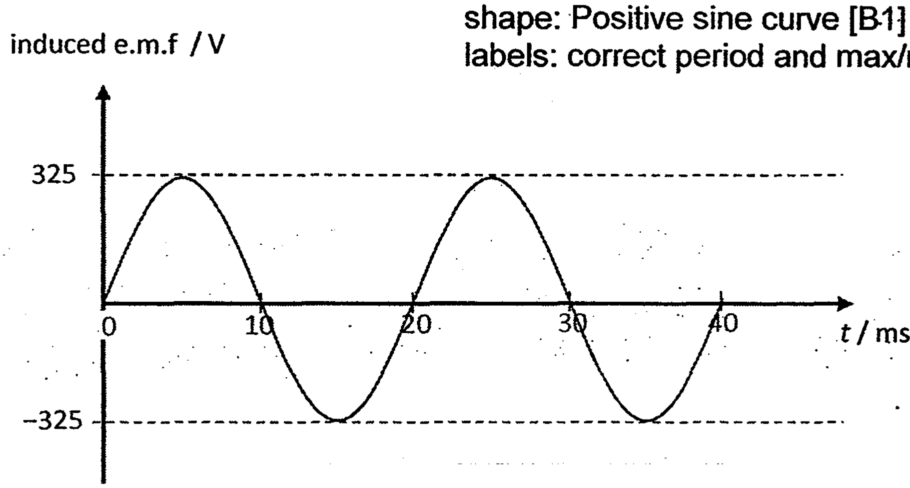


Fig. 6.2

(iv)

$$I_{peak,secondary} = \frac{V_{peak,secondary}}{R} = \frac{325}{8} = 40.625 \text{ A} \qquad \text{[M1]}$$

$$I_{rms,secondary} = \frac{I_{peak,secondary}}{\sqrt{2}}$$

$$= \frac{1}{\sqrt{2}}(40.625) \qquad \text{[M1]}$$

$$= 28.7 \text{ A} \qquad \text{[A1]}$$

(v)

Using value in (ii)

$$\frac{V_P}{V_S} = \frac{N_P}{N_S}$$

$$V_P = V_S \frac{N_P}{N_S} = 325 \times \frac{3200}{500} \qquad \text{[M1]}$$

$$= 2080 \text{ V} \qquad \text{[A1]}$$

(vi)

The peak e.m.f decreases.
Without the soft iron rod, less of the magnetic flux from the primary coil links to the secondary coil. [B1]
The rate of change of magnetic flux linkage in the secondary coil decreases [B1],
Thus by Faraday's law, the peak e.m.f decreases. [A0]

(b) **(i)**

Magnetic flux density is the force acting per unit current per unit length on a conductor placed at right angles to a magnetic field. [B1]

(ii)

Linear velocity for circular motion is $v_{\perp} = v\sin\theta$
Magnetic field perpendicular to charge motion is $B_{\perp} = B\sin\theta$ [M1]

$F_{net} = ma$

$$F_{magnetic} = \frac{mv^2}{r}$$

$$B_{\perp}qv = \frac{mv_{\perp}^{2}}{r} \qquad \text{[M1]}$$

$$r = \frac{mv_{\perp}^{2}}{B_{\perp}q} = \frac{mv\sin\theta}{Bq}$$

(iii)

$$\omega = \frac{v_{\perp}}{r} = \frac{Bq}{m} \qquad \left(\text{from } r = \frac{mv_{\perp}}{Bq}\right) \qquad \text{[M1: invoking } v_{\perp} = r\omega\text{]}$$

$$T = \frac{2\pi m}{Bq} \qquad \text{[M1: invoking } \omega = \frac{2\pi}{T}\text{]}$$

(iv)

The <u>magnetic force experienced is always perpendicular to the velocity of the electron. [B1]</u>

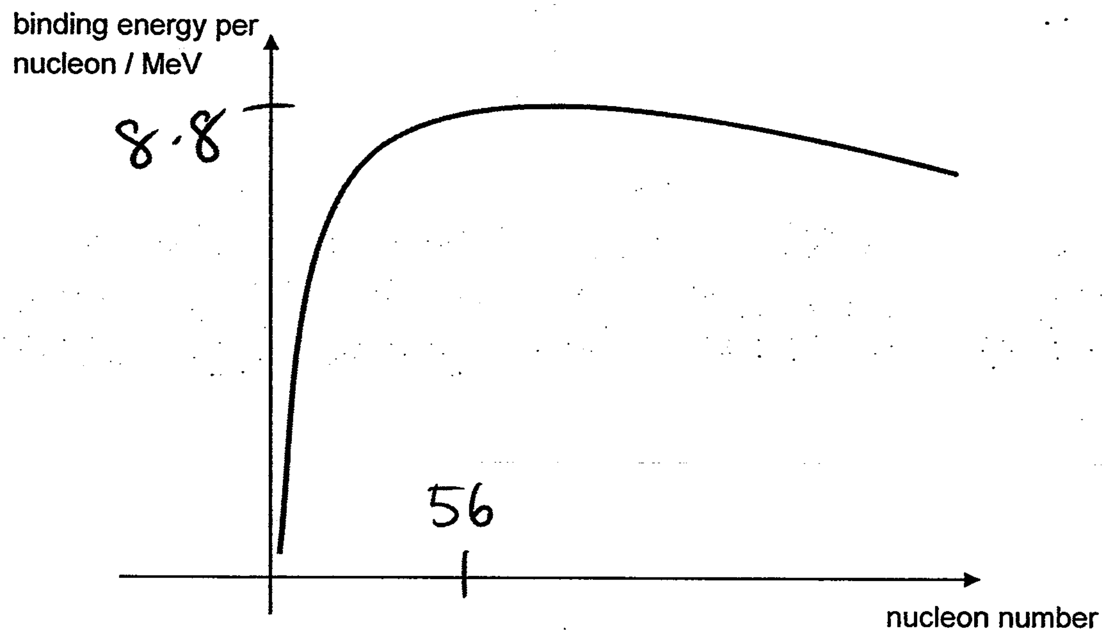
7(a) **(i)**

mass defect = [3 (1.008664) +3 (1.007276) – 6.015122] (1.66 x 10^{-27})
= 5.427868 x 10^{-29} kg [C1]

$$\text{binding energy per nucleon} = \frac{5.427868\times10^{-29}\times\left(3.0\times10^{8}\right)^{2}}{6} \quad \text{[M1]}$$

= 8.14 x 10^{-13} J [A1]

(ii)



1 mark for correct shape and label for Fe-56, 8.8 MeV must be given

(iii)

Energy required
= [2.014102 + 3.016049 – (4.002602 + 1.008664)] x 1.66 x 10^{-27} x $(3.0 \times 10^8)^2$ [M1]
= 2.821419 x 10^{-12} J

= 17.6 MeV
[A1]

(iv)

Fusion is a difficult process to achieve because of the <u>strong electrical repulsion between the nuclei when they are close to each other</u>. [B1] At extremely high temperatures (in excess of 10^8K) the nuclei have <u>enough kinetic energy to overcome the repulsion</u>. [B1]

(b) (i)

1.

Radioactive decay is the <u>spontaneous emission of particles</u> (α or β particles) <u>and/or</u> <u>radiation</u> (γ ray) [B1] from an <u>unstable nucleus</u> so that it becomes <u>more stable</u>. [B1]

2.

The rate of decay of the nuclei is <u>not affected by external environmental conditions</u> [B1] (e.g. physical factors such as pressure, temperature, magnetic and electric fields or chemical conditions)

3.

In a random process, it is impossible to predict *which nucleus* will decay next. There is a constant probability that a nucleus will decay in any fixed period of time. [B1]

(ii)

from the graph, 2 $t_{1/2}$ = 12 hr, therefore $t_{1/2}$ = 6.0 hr [A1]

(iii)

$A_{30hr} = \left(\frac{1}{2}\right)^5 4000 = 125$ Bq [M1]

$A = 125 = \lambda N = \frac{\ln 2}{6 \times 60 \times 60} N$ [M1]

Therefore, N = 3895276.61 nuclei

mass = N x m_{nuclei} = 3895276.61 x 98.9063 x 1.66 x 10^{-27} [M1]

= 6.39543879 x 10^{-19} kg = 6.40 x 10^{-19} kg (3sf) [A1]

(iv)

Technetium-99* has a half-life of six hours which is long enough for medical imaging [B1] yet short enough to minimise the radiation dose to the patient. [alt B1] ---- maximum 1 mark

The product has a very long half-life, much longer than average life expectancies, hence, it is unlikely that it will decay to form beta particles that would do damage to the cells in the body in the patient's lifetime. [B1]---- longer half-live, The product has a long half life and hence will have a much lower activity, making the product relatively safe [alt B1] ---- maximum 1 mark

(v)

gamma is least ionising and therefore less damaging to cells than alpha. [B1]