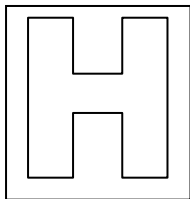


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PHYSICS

9646/01

Paper 1 Multiple Choice

18 September 2015

Additional Materials: Multiple Choice Answer Sheet

1 hour 15 minutes

READ THE INSTRUCTION FIRST

Write in soft pencil.

Do not use staples, paper clips, highlighters, glue or correction fluid.

Write your name, Centre number and index number on the Answer Sheet in the spaces provided unless this has been done for you.

There are **forty** questions on this paper. 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 separate Answer Sheet.

Read the instructions on the Answer Sheet very carefully.

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.

This document contains 18 printed pages, including this cover page.

1. The speed v of a liquid leaving a tube depends on the change in pressure ΔP and the density ρ the liquid. The speed is given by the equation

$$v = k \left(\frac{\Delta P}{\rho} \right)^n$$

where k is a constant that has no units.

What is the value of n ?

- A** 0.5 **B** 1 **C** 1.5 **D** 2

2. The young modulus of the material of a wire is to be found. The young modulus E is given by the equation below.

$$E = \frac{4Fl}{\pi d^2 x}$$

The wire is extended by a known force and the following measurements are made.

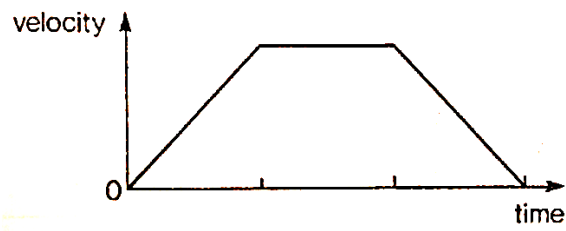
Which measurement has the largest effect on the uncertainty in the value of the calculated Young modulus?

	Measurement	symbol	value
A	length of wire before force applied	l	2.043 ± 0.002 m
B	diameter of wire	d	0.54 ± 0.02 mm
C	force applied	F	19.62 ± 0.01 N
D	extension of wire with force applied	x	5.2 ± 0.2 mm

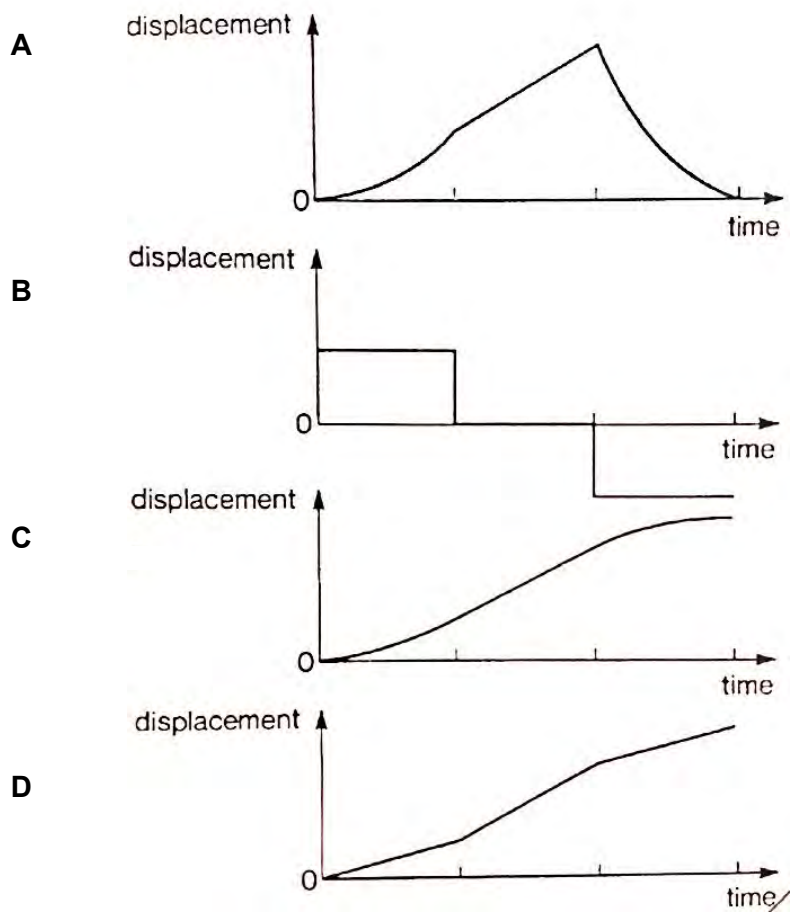
3. A stone is thrown from **P** and follows a parabolic path. The highest point reached is **T**. Neglecting air resistance, the acceleration of the stone

- A** is zero at **T**.
B is greatest at **P**.
C is greatest at **T**.
D is the same at **P** as at **T**.

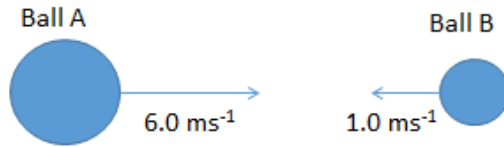
4. The graph of velocity against time for a car is shown below.



Which is the corresponding graph of displacement against time?



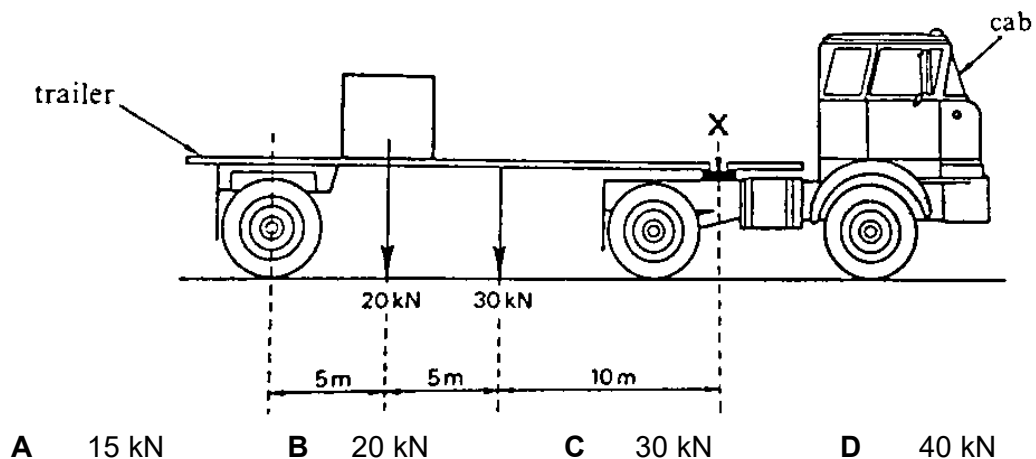
5. Ball **A** travelling at a speed of 6.0 ms^{-1} collides elastically with Ball **B** travelling at a speed of 1.0 ms^{-1}



Ball **A** has a larger mass than Ball **B**. Which are the velocities of the two balls after the collision?

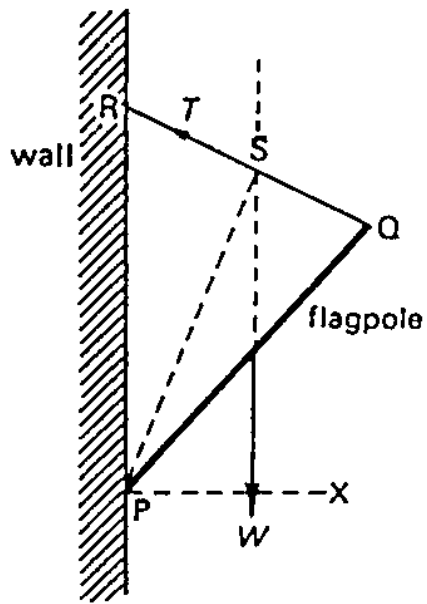
	Ball A 's velocity	Ball B 's velocity
A	1.0 ms^{-1} , to the right	6.0 ms^{-1} , to the right
B	1.0 ms^{-1} , to the left	6.0 ms^{-1} , to the right
C	1.3 ms^{-1} , to the right	8.3 ms^{-1} , to the right
D	1.3 ms^{-1} , to the left	8.3 ms^{-1} , to the right

6. Which of the following correctly describes an action-reaction pair?
- A** The weight of a book and the normal contact force acting on it.
 - B** The force by the rocket's thrusters and the gravitational force acting on the rocket.
 - C** The gravitational force exerted by a man on the earth and his weight.
 - D** The force by air resistance on a parachute and the weight of the parachutist.
7. What is the upward force by the cab on the trailer at Point **X**?

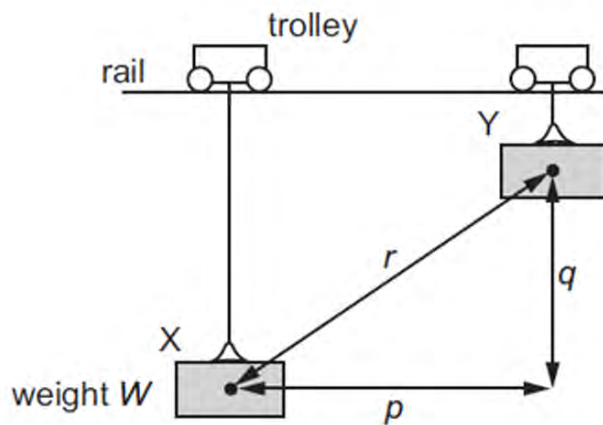


- A** 15 kN **B** 20 kN **C** 30 kN **D** 40 kN

8. What is the direction of the force exerted by the wall on the flagpole?



- A From **P** to **Q**
 B From **P** to **S**
 C From **P** to **X**
 D From **Q** to **P**
9. A block of weight ***W*** hangs from a trolley that runs along a rail. The trolley moves horizontally through a distance ***p*** and simultaneously raises the block through a height ***q***.



As a result, the block moves through a distance ***r*** from **X** to **Y**. It starts and finishes at rest.

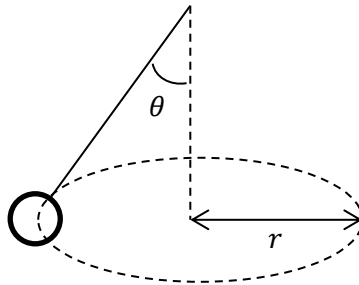
How much work is done on the block during this process?

- A Wp B $W(p+q)$ C Wq D Wr

10. For a toy car of mass 500 g to overcome the frictional forces on a rough floor moving at a constant speed 0.10 m s^{-1} , it develops an output power of 1.0 W. The resistive forces are constant at all speeds. Calculate the total output power developed by the car as it moves up the same rough slope shown below with the constant speed 0.20 m s^{-1} .

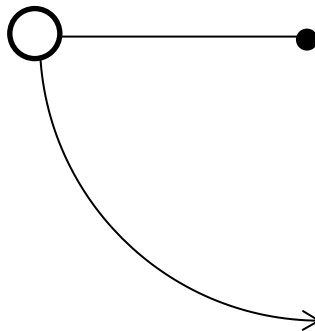


- A 2.0 W B 2.5 W C 2.8 W D 3.0 W
11. A mass m tied to a string is undergoing uniform circular motion of radius r as shown below.



What is the kinetic energy of the mass?

- A $mgr \tan \theta$ B $mgr \sin \theta$ C $\frac{mgr \tan \theta}{2}$ D $\frac{mgr}{2 \tan \theta}$
12. A pendulum of mass m is released from rest as shown below



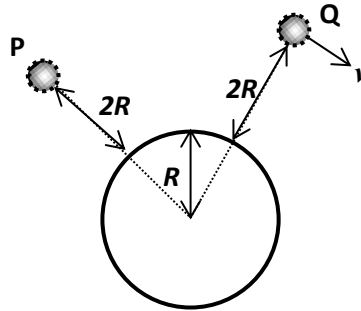
What is the minimum tension that the string must withstand such that the pendulum does not break away?

- A zero B mg C $2mg$ D $3mg$

13. A 50.0 kg man weighs himself using a bathroom scale at the equator as well as on the pole of planet Earth. What is the difference in the two readings due to the rotation of the earth? Assume the earth is a sphere with a radius 6400 km.

A 2.64×10^{-7} N B 0.0338 N C 1.69 N D 465 N

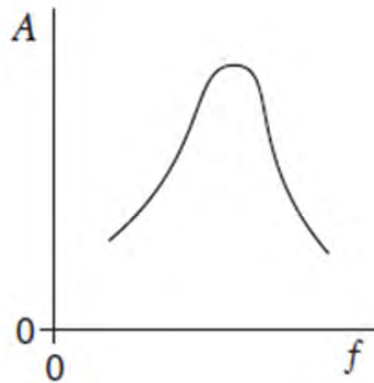
14. **P** and **Q** are two spheres with the same mass. They are both placed at a height $2R$ above the surface of Earth. Sphere **P** is released from rest while sphere **Q** is projected with a very small tangential velocity v perpendicular to the radial direction of Earth.



Which of the following best describes the gain in kinetic energy of the two spheres in their descent to surface of Earth? Neglect frictional forces.

- A Identical
B **P** is larger
C **Q** is larger
D Cannot be deduced

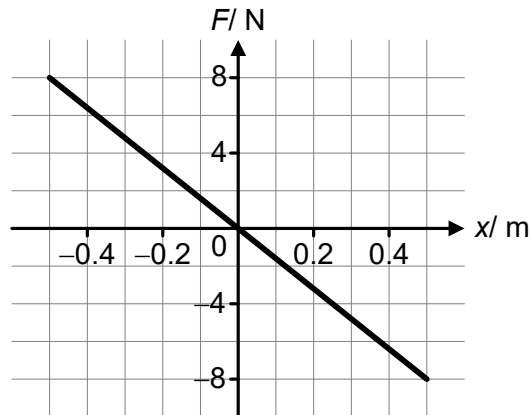
15. A periodic force is applied to a lightly-damped object causing the object to oscillate. The graph shows how the amplitude A of the oscillations varies with the frequency f of the periodic force.



Which one of the following statements best describes how the shape of the curve would differ if the damping had been greater?

- A The curve would be lower at all frequencies.
B The curve would be higher at all frequencies.
C The curve would be unchanged except at frequencies above the resonant frequency where it would be lower.
D The curve would be unchanged except at frequencies above the resonant frequency where it would be higher.

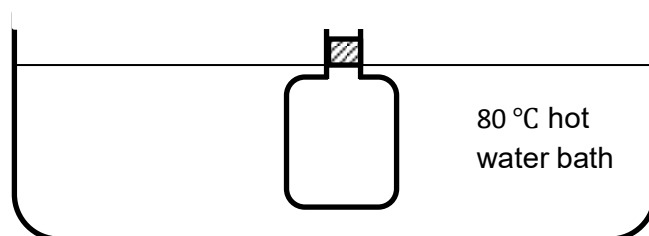
16. A mass of 2.0 kg is executing simple harmonic motion. The net force F acting on the mass varies with displacement x as shown. What is the maximum speed of the mass?



- A 1.0 m s⁻¹ B 1.3 m s⁻¹ C 1.4 m s⁻¹ D 2.0 m s⁻¹
17. Two masses X and Y , made of the same material, are at temperatures T_X and T_Y respectively, where T_X is greater than T_Y . The two masses are then brought into contact and reach a final temperature T . There is no exchange of heat between the masses and the surroundings.

Given that the mass of X is greater than the mass of Y , which of the following statements is correct?

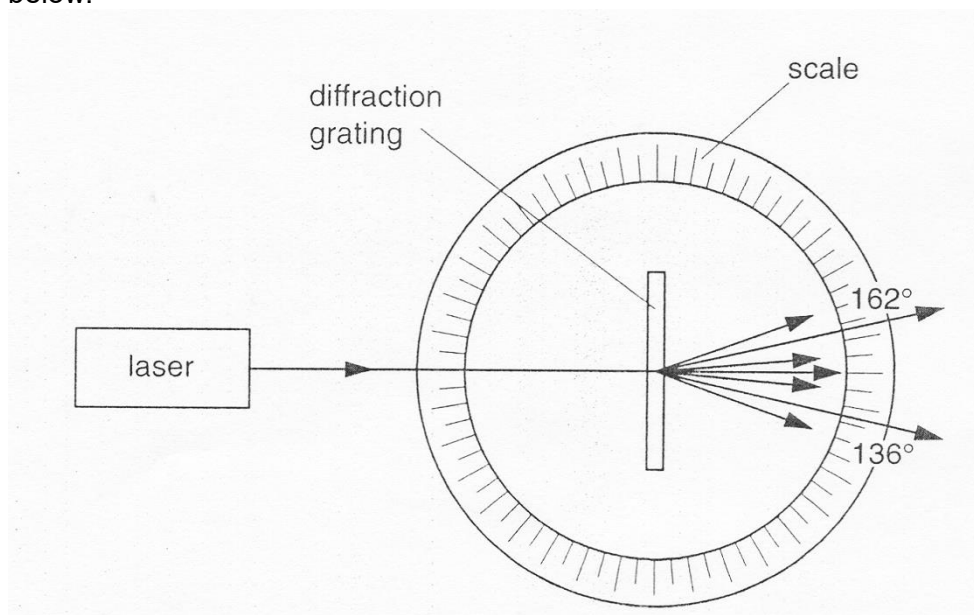
- A The final temperature T is the average of T_X and T_Y .
 B The final temperature T is closer to T_X than T_Y .
 C The final temperature T is closer to T_Y than T_X .
 D It is not possible to predict the relationship of the final temperature T to T_X and T_Y .
18. A closed container is filled with ideal gas initially at room temperature (27 °C) and atmospheric pressure. It was then placed into a hot water bath maintained at 80 °C where the container achieved thermal equilibrium with the hot water bath as shown below.



When the container is opened while immersed in the hot water bath, some of the gas escapes the container. What is the percentage of the original amount of ideal gas remaining in the container at equilibrium state?

- A 15% B 34% C 66% D 85%

19. The least distance between two points of a progressive transverse wave which have a phase difference of $\frac{\pi}{3}$ rad is 0.200 m. If the frequency of the wave is 400 Hz, what is the speed of the wave?
- A** 100 m s⁻¹ **B** 180 m s⁻¹ **C** 480 m s⁻¹ **D** 720 m s⁻¹
20. A small source of sound radiates energy equally in all directions. The intensity of the sound 3.0 m away from the source is 0.18 Wm⁻². If the power of the source is tripled, the intensity at a distance 4.5 m away from the source is
- A** 0.090 Wm⁻² **B** 0.14 Wm⁻² **C** 0.18 Wm⁻² **D** 0.24 Wm⁻²
21. A student observes interference fringes produced by red light of wavelength 700 nm using a Young's double-slit arrangement. The slits are 1.0 m away from the screen.
How should the student move the slits such that fringes of the same separation can be observed when using blue light of wavelength 400 nm?
- A** Move the slits 0.75 m towards the screen.
B Move the slits 0.75 m away from the screen.
C Move the slits 0.43 m towards the screen.
D Move the slits 0.43 m away from the screen.
22. Light from a laser is directed normally at a diffraction grating, as illustrated in figure below.

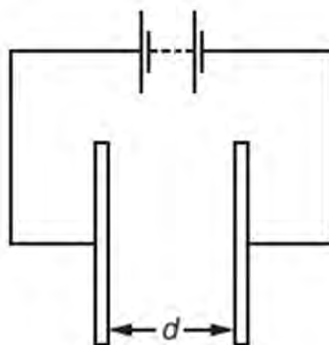


The diffraction grating is situated at the centre of a circular scale, marked in degrees. The readings on the scale for the second order diffracted beams are 136° and 162°.
The wavelength of the laser light is 630 nm. The spacing of the slits of the diffraction grating is

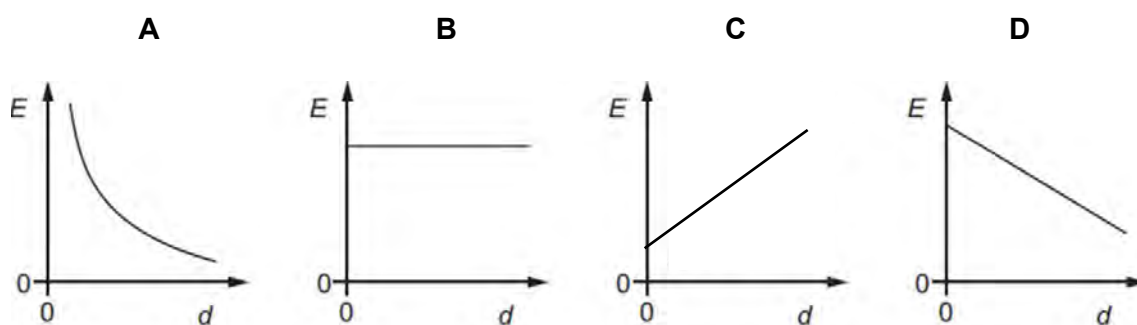
- A** 5.60×10^{-6} m **B** 2.87×10^{-6} m **C** 2.80×10^{-6} m **D** 1.40×10^{-6} m

Turn over

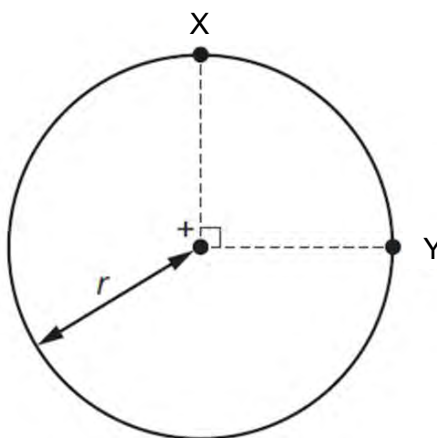
23. The diagram shows two metal plates connected to a constant high voltage.



Which graph shows the variation with d of the electric field strength E at the midpoint between the two plates is correct?



24. The diagram shows two points **X** and **Y** which lie 90° apart on a circle of radius r .



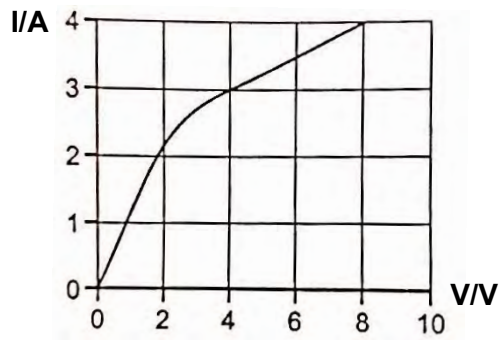
A positive point charge, Q at the centre of the circle creates an electric field of magnitude $\frac{Q}{4\pi\epsilon_0 r^2}$ at both point **X** and **Y**.

Which expression gives the work done in moving a unit positive charge from **X** to **Y**?

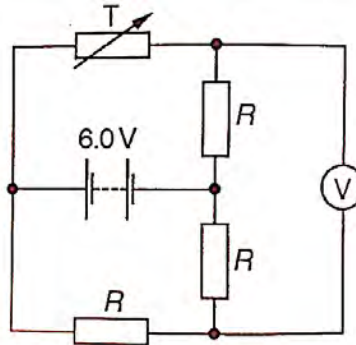
- A** 0 **B** $\frac{Q}{4\pi\epsilon_0 r}$ **C** $\frac{Q}{4\pi\epsilon_0 r^2} \left(\frac{\pi r}{2}\right)$ **D** $\frac{Q}{4\pi\epsilon_0 r^2}$

Turn over

25. What is the resistance when the potential difference is 6.0 V?

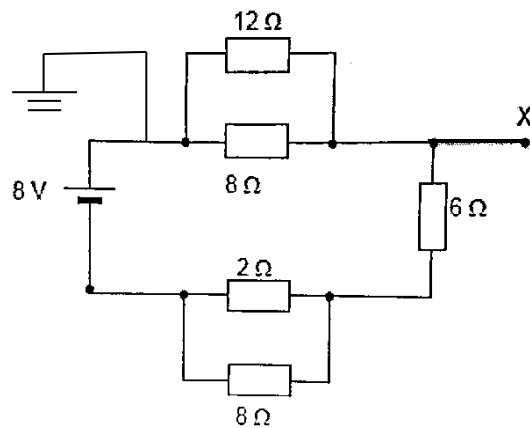


- A 0.50 Ω B 0.58 Ω C 1.71 Ω D 2.00 Ω
26. A lamp rated at 12 V and 24 W is used with a 10 V supply for 2 s. What is the energy transferred in the lamp?
- A 20 J B 24 J C 33 J D 40 J
27. A 6.0 V battery is connected to three resistors of resistance R , and a variable resistor T as shown. The resistance of T changes from R to 0Ω . What is the change in the reading of the high resistance voltmeter?

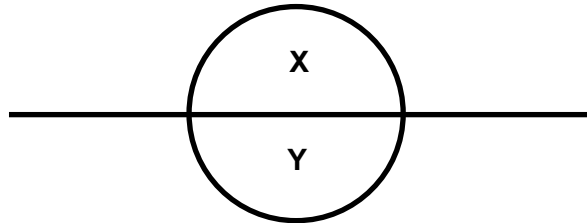


- A No change B 2.0 V C 3.0 V D 6.0 V

28. A circuit is set up as shown below. What is the potential at point **X**?



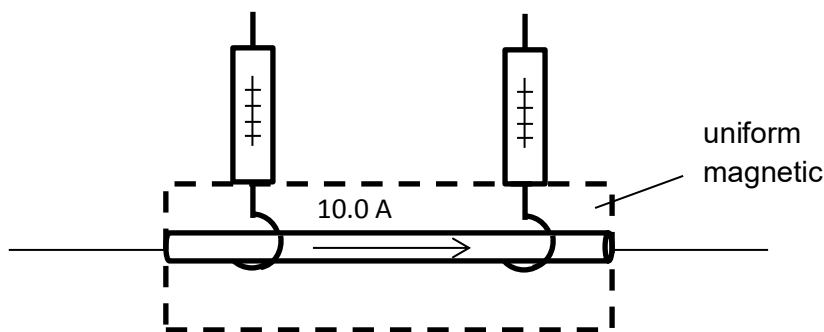
- A -3.1 V B 3.1 V C -4.9 V D 4.9 V
29. A straight current-carrying wire is placed along the plane of a current-carrying coil as shown below. There is no electrical contact between the coil and straight wire.



When the magnetic flux density in region **X** is at a maximum, which of the following is correct?

	Direction of Current in Coil	Direction of Current in Straight Wire	Magnetic Flux Density in Region Y
A	Clockwise	Left to Right	Maximum
B	Clockwise	Right to Left	Maximum
C	Anti-clockwise	Left to Right	Minimum
D	Anti-clockwise	Right to Left	Minimum

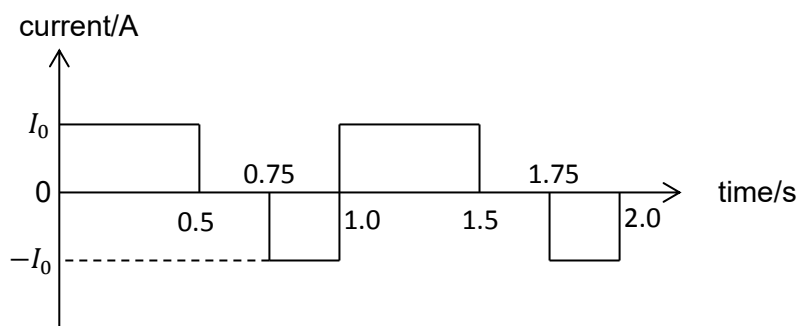
30. A 10.0 cm long wire is suspended from two spring balances as shown below.



The wire is placed in a region of uniform magnetic field. The direction of the magnetic field is pointing perpendicularly into the paper and the magnitude of the flux density is $1.00 \times 10^{-3} \text{ T}$.

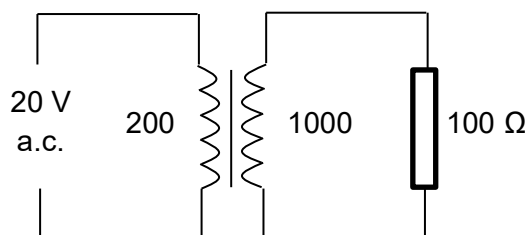
When there is no current in the wire, the reading on each spring balance is 10.00 g. What is the reading on the spring balance when a current of 10.0 A flows through the wire?

- A 9.90 g B 9.95 g C 10.05 g D 10.10 g
31. The graph shows an alternating current with the following waveform.



The peak value of the current is I_0 . What is its root-mean-square value?

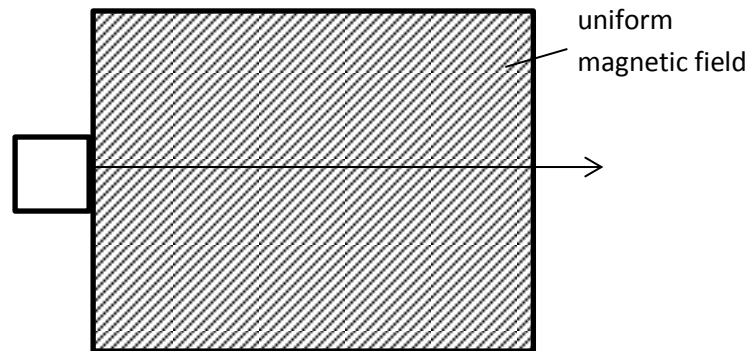
- A $\frac{I_0}{2}$ B $\frac{I_0}{\sqrt{2}}$ C $\frac{\sqrt{3}I_0}{2}$ D $\frac{3I_0}{4}$
32. The primary coil of an ideal transformer has 200 turns and is connected to a 20 V root-mean-square power supply. The secondary coil has 1000 turns and is connected to a resistor of resistance 100Ω as shown in the diagram.



What is the peak primary current?

- A 1.0 A B 1.4 A C 5.0 A D 7.1 A

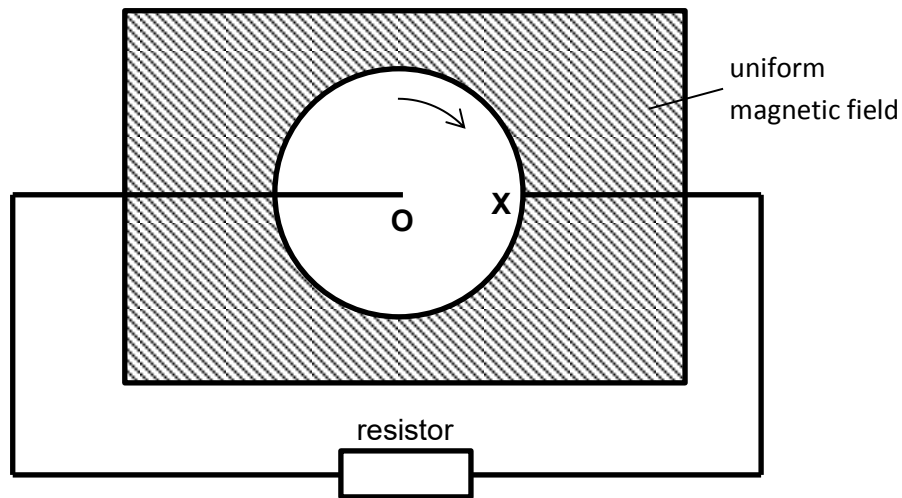
33. A square loop of wire is pulled through a region of uniform magnetic field at constant velocity as shown below.



Which graph best represents the work done per unit time against the magnetic field?

A	<p>work done per unit time /W</p> <p>time/s</p>
B	<p>work done per unit time /W</p> <p>time/s</p>
C	<p>work done per unit time /W</p> <p>time/s</p>
D	<p>work done per unit time /W</p> <p>time/s</p>

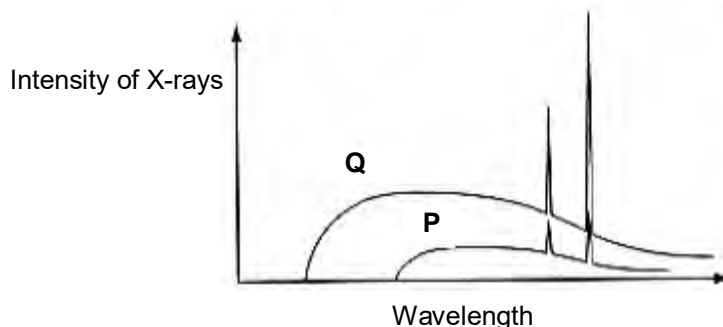
34. A copper disc is rotated clockwise at constant speed in a region where there is a uniform magnetic field perpendicular to the surface of the disc as shown below. The direction of the magnetic field is into the paper.



A circuit consisting of a resistor is connected to the disc at its center **O** and its rim at **X**. Which of the following diagrams show the correct direction of the induced current?

A		B	
C		D	

35. A simple model of the energy levels in an atom has only three levels; **X**, **Y** and **Z**. A transition from level **X** to level **Z** produces radiation of wavelength 280 nm; a transition from level **Y** to level **Z** produces a radiation of wavelength 200 nm. Which of the following deductions concerning this system of three energy levels is correct?
- A** The wavelength of radiation emitted in a transition between levels **X** and **Y** is 80 nm.
 - B** The wavelength of radiation absorbed in a transition between levels **X** and **Y** is 80 nm.
 - C** Level **Y** has a greater energy than levels **X** or **Z**.
 - D** Levels **X** has a greater energy than levels **Y** or **Z**.
36. Which of the following statements about a semiconductor diode in forward bias is incorrect?
- A** The applied potential difference from the source of e.m.f. opposes the junction potential.
 - B** Electrons and holes are urged away from the p-n junction.
 - C** The n-type material of the diode is connected to the negative terminal of the e.m.f. source.
 - D** Electrons in the n-type side of the diode will cross steadily to the p-type side.
37. X-ray spectra are taken from two X-ray tubes **P** and **Q**. The intensity of the X-rays is plotted against the wavelength in both cases and is shown below.



What deduction can be made from these plots?

- A** X-ray tube **Q** has the higher voltage applied to it and the target material in both tubes is the same.
- B** X-ray tube **Q** has the higher voltage applied to it and the target material in both tubes are different.
- C** X-ray tube **P** has the higher voltage applied to it and the target material in both tubes is the same.
- D** X-ray tube **P** has the higher voltage applied to it and the target material in both tubes are different.

38. At absolute zero temperature, the kinetic energy of the harmonic oscillator is not zero. This is the expected result of the
- A photoelectric effect.
 - B particulate nature of the oscillator.
 - C Heisenberg uncertainty principle.
 - D quantum tunnelling effect.
39. A radioactive source contains two species. One has a half-life of 4 days and decays by the emission of alpha particles whilst the other has a half-life of 3 days and emits beta particles. The initial count-rate is 352 min^{-1} , but when a sheet of paper is placed between the source and the detector this becomes 256 min^{-1} . The background count-rate is 16 min^{-1} . What will be the count-rate after 12 days, without the paper present?
- A 27 min^{-1} B 28 min^{-1} C 43 min^{-1} D 44 min^{-1}
40. A stationary nucleus of nucleon number A undergoes radioactive decay and emits an alpha particle. If the total energy released is U , what is the kinetic energy of the alpha particle?
- A $\left(\frac{4}{A}\right)U$ B $\left(\frac{4}{A-4}\right)U$ C $\left(\frac{A-4}{A}\right)U$ D $\left(\frac{A}{A+4}\right)U$

END OF PAPER

Prelim 2015 Answers

Paper 1

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

- Units of $\Delta P = kgm^{-1}s^{-2}$, units of $\rho = kgm^{-3}$
Units of $\frac{\Delta P}{\rho} = m^2s^{-2}$, hence $n = 0.5$
- $\frac{\Delta E}{E} = \frac{\Delta F}{F} + \frac{\Delta l}{l} + 2\frac{\Delta d}{d} + \frac{\Delta x}{x}$,
 $\frac{\Delta F}{F} = 0.00051, \frac{\Delta l}{l} = 0.00098, 2\frac{\Delta d}{d} = 0.074, \frac{\Delta x}{x} = 0.038$
- Only force acting weight
- Displacement given by area under graph. (Increasing at increasing rate, increasing at constant rate, increasing at decreasing rate)
- Relative speed of approach: $u_1 - u_2 = v_2 - v_1 = 6 - (-1) = 7$. Only B and C has $v_2 - v_1 = 7$
Conservation of linear momentum: Initial total momentum = $6M - m$ where M is mass of A and m mass of B
For option B: $6M - m = -1M + 6m \rightarrow 7M = 7m$ not possible as $M \neq m$
For option C: $6M - m = 1.3M + 8.3m \rightarrow 4.7M = 9.3m$ ok as $M > m$
- Equal and opposite and must be same type of force acting on different bodies
- Take left wheel as pivot, clockwise moment = $20k \times 5 + 30k \times 10 = 400k Nm$
Anticlockwise moment = $F \times 20 = 400k \rightarrow F = 20 kN$
- 3 forces must intersect.
- Work done = increase in gravitational potential energy. (no change in kinetic energy)
- Total output power = power in doing work against friction + power in gaining gravitational potential energy
 $P = Fv \rightarrow \text{resistive force} = \frac{P}{v} = \frac{1.0}{0.10} = 10N$
Power in overcoming friction = $Fv = 10 \times 0.20 = 2W$
Power in gaining gravitational potential energy = $mg \times \text{vertical component of speed} = 0.500 \times 9.81 \times 0.20 \times \sin 30^\circ = 0.49W$
Total output power = $2.5W$
- Vertical component of tension = weight, horizontal component of tension provides centripetal force
 $T \cos \theta = mg$
 $T \sin \theta = \frac{mv^2}{r}$
 $\tan \theta = \frac{mv^2}{mgr} \rightarrow \frac{1}{2}mv^2 = \frac{1}{2}mgr \tan \theta$
- Maximum tension experienced at bottom of the swing.
Centripetal force = tension – weight
Using conservation of energy, kinetic energy at the bottom = loss of GPE

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

$$\text{Centripetal force} = m \frac{v^2}{r} = \frac{2mgr}{r} = 2mg$$

$$2mg = \text{tension} - mg \rightarrow \text{tension} = 3mg$$

13. At the pole, no rotation, so weight = mg

At equator, centripetal force = weight – normal contact force

$$\text{Reading of scale} = \text{normal contact force} = mg - m\omega^2 r$$

$$\text{SO difference in reading is } m\omega^2 r = 50.0 \times \left(\frac{2\pi}{24 \times 3600}\right)^2 \times 6400000 = 1.69N$$

14. Since change in gravitational potential energy is the same for both, change in kinetic energy is the same.

15. Further damping causes amplitude to decrease at all frequencies

16. Maximum force = 8 N, amplitude = 0.5m

$$F = ma_0 = m\omega^2 x_0 \rightarrow \omega = \sqrt{8} \text{ rads}^{-1}$$

$$\text{maximum velocity} = \omega x_0 = \sqrt{8} \times 0.5 = 1.41 \text{ ms}^{-1}$$

17. Loss of heat = gain in heat

$$m_x c(T_X - T) = m_Y c(T - T_Y) \rightarrow \text{since } m_X > m_Y, (T - T_Y) > (T_X - T)$$

T is closer to T_X

18. Once gas is released, it expands and achieves atmospheric pressure eventually.

Using ideal gas equation, pressure is same before and after, but new temperature is 80°C

$$\frac{V}{T} = \frac{V'}{T'}$$

$$\frac{V}{273+27} = \frac{V'}{273+80} \rightarrow V' = \frac{353}{300} V$$

Since gas expands to $\frac{353}{300}$ of original volume, the volume of gas remaining in the original

bottle is still V , which means $\frac{V}{\frac{353}{300}V} = \frac{300}{353}$ of the original gas remains in the bottle which is 85%

19. Phase of $\frac{\pi}{3}$ is equivalent to 0.2 m, which means one full wavelength corresponding to phase of 2π is 1.2m

$$v = f\lambda = 480 \text{ ms}^{-1}$$

$$20. I = \frac{P}{4\pi r^2}$$

$$\text{At } 3.0 \text{ m, } P = 0.18 \times 4\pi \times 9 = 6.48\pi$$

Power is now tripled, new $P = 19.44\pi$

$$\text{At } 4.5 \text{ m, } I = \frac{P}{4\pi r^2} = \frac{19.44\pi}{4\pi 4.5^2} = 0.24 \text{ Wm}^{-2}$$

$$21. x = \frac{\lambda D}{a}$$

a remains constant. Since λ is reduced by $\frac{400}{700}$, D must increase by $\frac{700}{400}$ to 1.75m

$$22. n\lambda = d\sin\theta$$

$$\theta = \frac{162^\circ - 136^\circ}{2} = 13^\circ$$

$$2 \times 630 \times 10^{-9} = d\sin 13^\circ \rightarrow 5.60 \times 10^{-6} \text{ m}$$

$$23. E = \frac{V}{d} \text{ so inverse graph}$$

24. 0 because no change in electric potential

$$25. R = \frac{V}{I} = \frac{6}{3.5} = 1.71\Omega$$

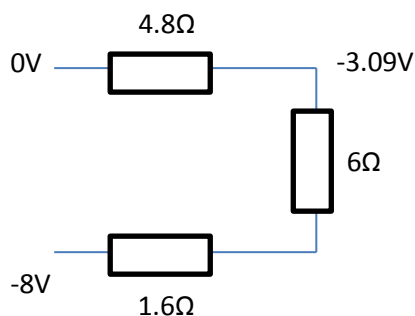
$$26. P = \frac{V^2}{R} \text{ based on power rating, resistance of bulb} = 6\Omega$$

$$\text{Energy transferred} = Pt = \frac{V^2}{R} t = \frac{10^2}{6} \times 2 = 33J$$

27. At resistance of R , potential at upper end and lower end are the same so, voltmeter reading is 0

At 0 resistance, potential at upper end is 6.0 V, while lower end is 3.0 V, hence voltmeter reading is now 3.0 V

28.



Potential difference across effective 4.8Ω resistor = $\frac{4.8}{4.8+1.6+6} \times 8 = 3.09V$

29. Use right hand grip rule

30. Total weight of wire = $0.02000 \times 9.81 = 0.1962N$

Magnetic force is upwards, so tension now = weight – magnetic force

Tension = $0.1962 - BIL = 0.1962 - 1 \times 10^{-3} \times 10.0 \times 0.10 = 0.1952N$

Reading on scale = $\frac{0.1952}{2 \times 9.81} = 9.95g$

31. Period is 1s

Area of I^2 graph over 1 period = $I_0^2 \times 0.5 + I_0^2 \times 0.25 = 0.75 I_0^2$

Mean $I^2 = \frac{0.75 I_0^2}{1}$

r.m.s. = $\sqrt{0.75} I_0$

32. Secondary r.m.s voltage = $\frac{1000}{200} 20 = 100V$

Secondary r.m.s current = $\frac{100}{100} = 1.00A$

Primary r.m.s. current = $\frac{1000}{200} 1.00 = 5.00A$

Primary peak current = $5 \times \sqrt{2} = 7.07V$

33. Work done against magnetic field = power dissipated by coil

As velocity is constant, rate of change of flux is constant and, induced e.m.f and current while entering and leaving the field is constant, so work done per unit time must be constant

No work done per unit time when in the field as no net induced e.m.f

34. Use Fleming's Right Hand Rule

35. X to Z $\rightarrow E = h \frac{c}{\lambda} = 7.10 \times 10^{-19}J$

Y to Z $\rightarrow E = 9.95 \times 10^{-19}J$

X to Y $\rightarrow 9.95 \times 10^{-19} - 7.10 \times 10^{-19} = 2.85 \times 10^{-19} \rightarrow \lambda = 700nm$

Y must have higher energy than X and Z

36. B

37. Higher voltage means greater gain in kinetic energy for the electron and hence minimum wavelength will be smaller. Q has higher voltage.

Spikes occur in same place, so same material.

38. C

39. Paper stops alpha particles, so

$\alpha + \beta + background = 352min^{-1}$

$\beta + background = 256min^{-1}$

Initial count of beta particle source = $256-16=240min^{-1}$

Initial count of alpha particle source = $352-256=96min^{-1}$

After 12 days, alpha particle source undergo 3 half-lives and beta particle source undergo 4 half-lives

Final count of alpha particle source = $\frac{96}{2^3} = 12min^{-1}$

Final count of beta particle source = $\frac{240}{2^4} = 15min^{-1}$

Total count = $12+15+16=43min^{-1}$

40. Principle of conservation of linear momentum

Momentum of daughter nucleus = momentum of alpha particle

$$(A - 4)uv = 4uv'$$

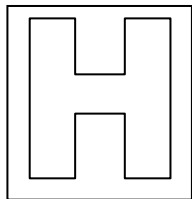
$$v = \frac{4}{A-4} v'$$

$$\text{KE of alpha particle} = \frac{1}{2} 4uv'^2$$

Total energy = U

$$\frac{1}{2}(A - 4)uv^2 + \frac{1}{2} 4uv'^2 = \frac{1}{2}(A - 4)u\left(\frac{4}{A-4} v'\right)^2 + \frac{1}{2} 4uv'^2 = \frac{8}{A-4} uv'^2 + 2uv'^2$$

$$\text{KE of alpha particle} = \frac{1}{2} 4uv'^2 = \frac{\frac{1}{2} 4uv'^2}{\frac{8}{A-4} uv'^2 + 2uv'^2} U = \frac{A-4}{A} U$$



NATIONAL JUNIOR COLLEGE
Preliminary Examination
 Higher 2

CANDIDATE
NAME

SUBJECT
CLASS

REGISTRATION
NUMBER

PHYSICS

Paper 2 Structured Questions
 Candidate answers on the Question Paper.

9646/02

31 August 2015
1 hour 45 minutes

No Additional Materials are required.

READ THE INSTRUCTION FIRST

Write your subject class, registration number and name on all the work you hand in.

Write in dark blue or black pen on both sides of the paper.

You may use a soft pencil for any diagrams, graphs or rough working.

Do not use staples, paper clips, highlighters, glue or correction fluid.

Answers **all** questions.

The number of marks is given in brackets [] at the end of each question or part question.

For Examiner's Use	
1	
2	
3	
4	
5	
6	
7	
Total (72m)	

Data

speed of light in free space,
 permeability of free space,
 permittivity of free space,
 elementary charge,
 the Planck constant,
 unified atomic mass constant,
 rest mass of electron,
 rest mass of proton,
 molar gas constant,
 the Avogadro constant,
 the Boltzmann constant,
 gravitational constant,
 acceleration of free fall,

Formulae

uniformly accelerated motion,

work done on/by a gas,

hydrostatic pressure

gravitational potential,

displacement of particle in s.h.m.,

velocity of particle in s.h.m.,

mean kinetic energy of a molecule of an ideal gas

resistors in series,

resistors in parallel,

electric potential,

alternating current/voltage,

Transmission coefficient

radioactive decay,

decay constant,

$$c = 3.00 \times 10^8 \text{ ms}^{-1}$$

$$\mu_0 = 4\pi \times 10^{-7} \text{ Hm}^{-1}$$

$$\epsilon_0 = 8.85 \times 10^{-12} \text{ Fm}^{-1} = (1/(36\pi)) \times 10^{-9} \text{ F m}^{-1}$$

$$e = 1.60 \times 10^{-19} \text{ C}$$

$$h = 6.63 \times 10^{-34} \text{ Js}$$

$$u = 1.66 \times 10^{-27} \text{ kg}$$

$$m_e = 9.11 \times 10^{-31} \text{ kg}$$

$$m_p = 1.67 \times 10^{-27} \text{ kg}$$

$$R = 8.31 \text{ JK}^{-1}\text{mol}^{-1}$$

$$N_A = 6.02 \times 10^{23} \text{ mol}^{-1}$$

$$k = 1.38 \times 10^{-23} \text{ JK}^{-1}$$

$$G = 6.67 \times 10^{-11} \text{ Nm}^2\text{kg}^{-2}$$

$$g = 9.81 \text{ ms}^{-2}$$

$$s = ut + \frac{1}{2}at^2, \quad v^2 = u^2 + 2as$$

$$W = p\Delta V$$

$$p = \rho gh$$

$$\phi = -\frac{Gm}{r}$$

$$x = x_0 \sin \omega t$$

$$v = v_0 \cos \omega t \quad \text{and} \quad v = \pm \omega \sqrt{x_0^2 - x^2}$$

$$E = \frac{3}{2}kT$$

$$R = R_1 + R_2 + \dots$$

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \dots$$

$$V = \frac{Q}{4\pi\epsilon_0 r}$$

$$x = x_0 \sin \omega t$$

$$T = \exp(-2kd) \quad \text{Where } k = \sqrt{\frac{8\pi^2 m(U - E)}{h^2}}$$

$$x = x_0 \exp(-\lambda t)$$

$$0.693/t_{1/2}$$

- 1 a) A baseball player throws a 2.0 kg ball upwards. The air resistance of the ball cannot be neglected. The air resistance is proportional to the speed of the ball..

Fig. 1 shows the velocity of the ball with respect to time.

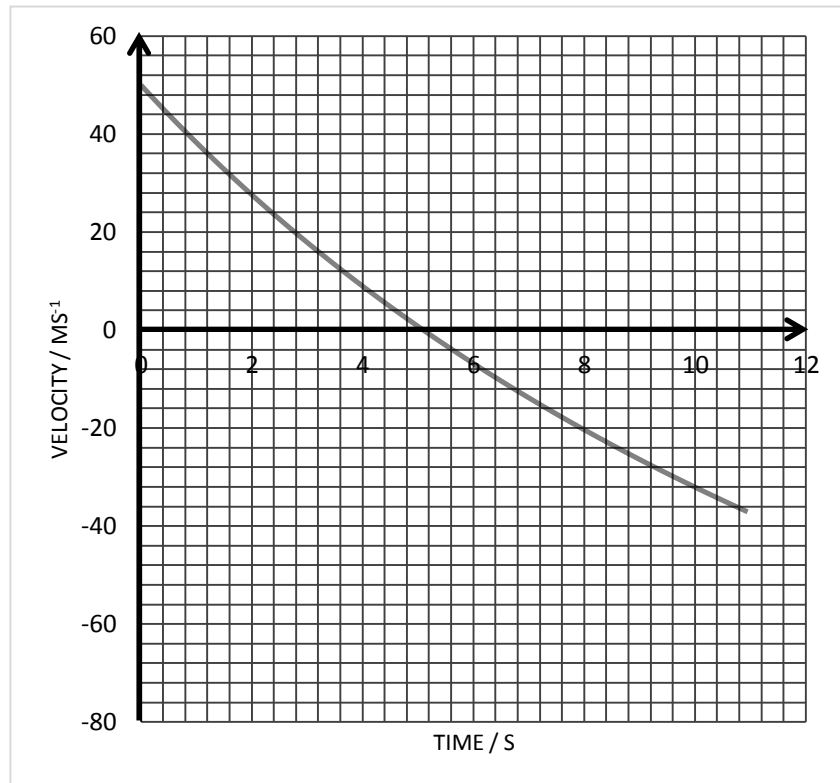


Fig. 1

- i) Determine the resultant force on the ball at $t = 0$ s. [1]

resultant force = _____ N

- ii) Determine the air resistance on the ball at $t = 0$ s. [2]

force = _____ N

- 1 b) Explain why the time taken for the ball to travel upwards is faster than the time taken to travel downwards. [2]

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- c) Explain how you will use **Fig. 1** to determine the gravitational acceleration due to the Earth. [2]

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- d) On **Fig. 1**, draw in the velocity time graph if air resistance can be neglected. [2]

- 2 a) State the principle of conservation of linear momentum. [1]

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- b) A 2.0 kg skateboard was initially travelling to the right at a constant speed of 1.50 ms^{-1} . A 60.0 kg skateboarder attempts a complex stunt as shown in **Fig. 2.1**.

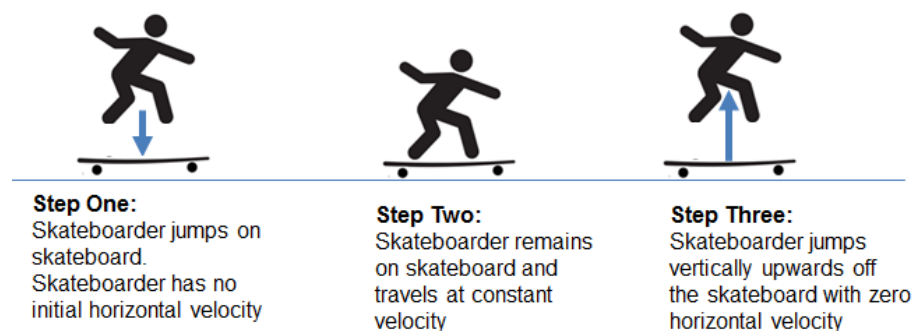


Fig. 2.1

- 2 b) i) Determine the new speed of the skateboard after the skateboarder has landed on it. State an assumption that you have made in your calculations. [3]

speed = _____ m s⁻¹

- ii) 1 Determine the kinetic energy of the skateboard at **step two**. [1]

kinetic energy = _____ J

- 2 The skateboarder does a vertical jump off the skateboard. Explain how the kinetic energy of the skateboard changes with time before and after the skateboarder has jumped off. [2]

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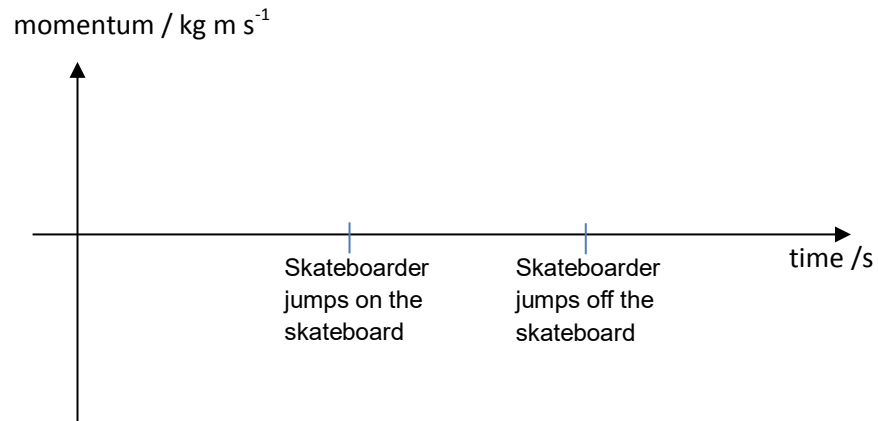
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- 2 b) iii) Draw a graph of momentum versus time for the skateboard on [2]
Fig. 2.2.



- 3 a) A small ball of mass 10 g rests at point **P** on a curved track of radius r , as shown in Fig. 3.1.

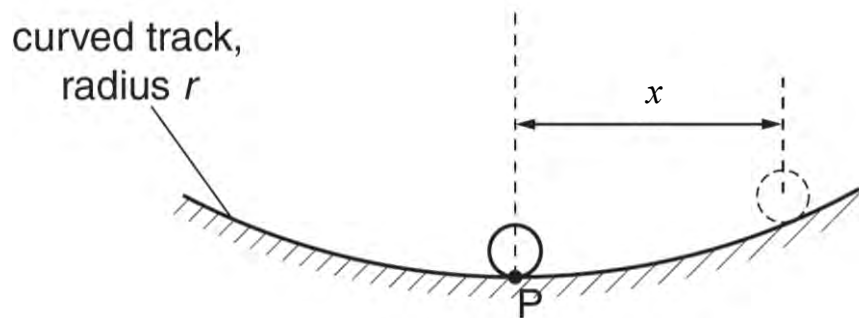


Fig. 3.1

The ball is moved a small distance to one side and is then released. The displacement x of the ball is related to its acceleration a towards **P** by the expression

$$a = -\frac{gx}{r}$$

where g is the acceleration of free fall.

- i) Explain why the ball undergoes simple harmonic motion. [2]

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- 3 a) ii) The radius r of curvature of the track is 28 cm. [2]
Determine the time interval τ between the ball passing point **P** and its first return to point **P**.

$$\tau = \text{_____ s}$$

- b) The variation with time t of the displacement x of the ball in (a) is shown in **Fig. 3.2**.

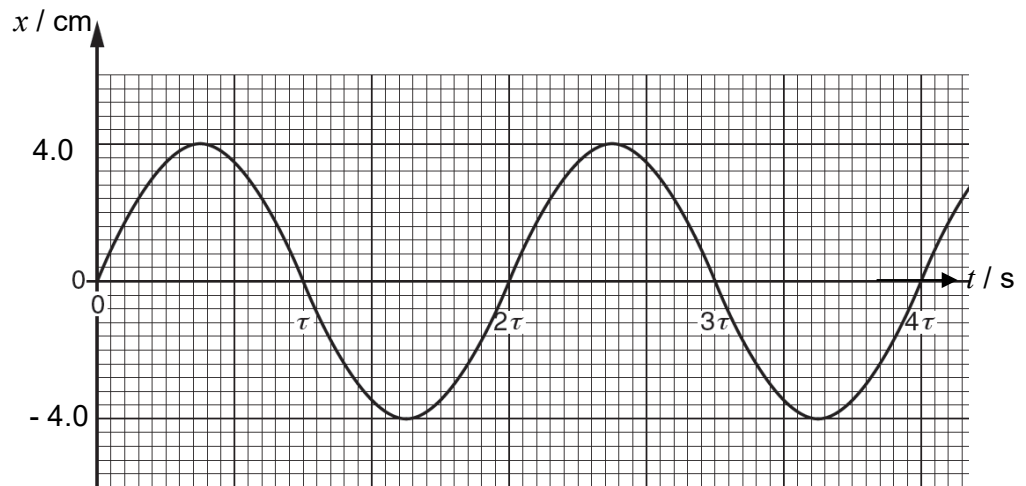


Fig. 3.2

- 3 b) i) Using the answer obtained from (a)(ii), on **Fig. 3.3**, sketch the variation with time t of kinetic energy E of the ball for the first 2 periods. Include a suitable scale on the energy axis. [2]

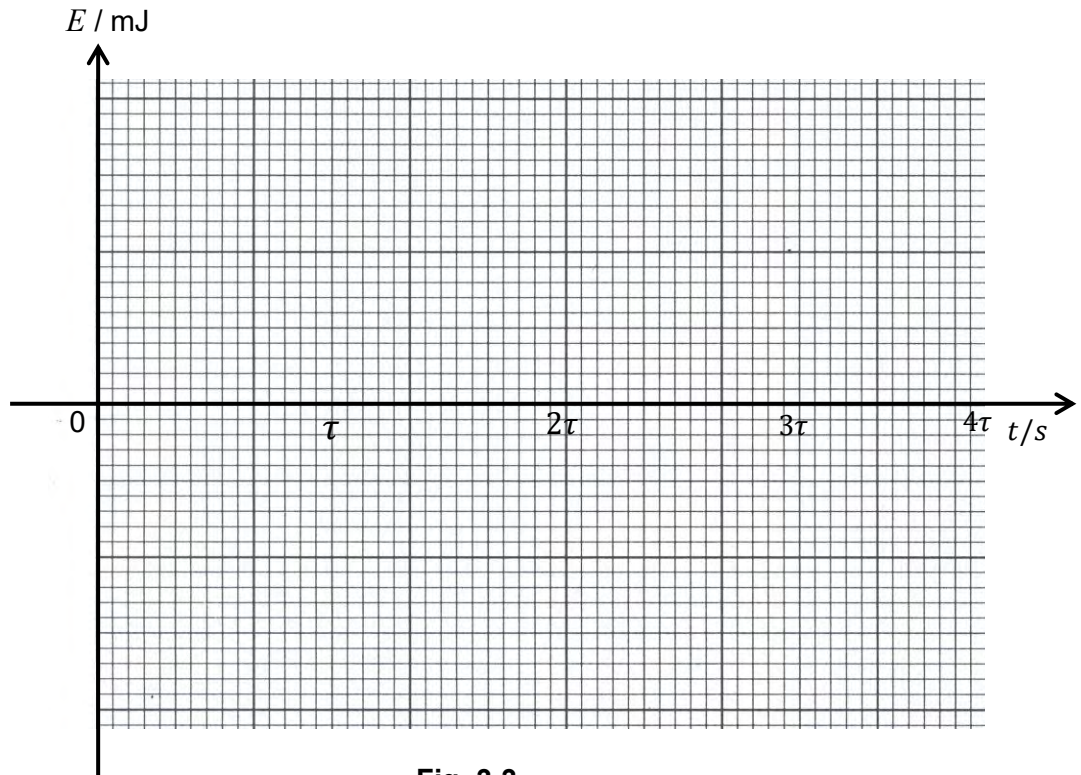


Fig. 3.3

- ii) Some moisture now forms on the track, causing the ball to come to rest after approximately after 15 oscillations. On the axes of **Fig. 3.2**, sketch the variation with time t of the displacement x of the ball for the first two periods after the moisture has formed. [2]
- 4 a) i) The ideal gas equation is $pV=NkT$. Explain why the temperature T cannot have the unit $^{\circ}\text{C}$. [1]
-
-
-
- ii) Show the relationship between k , the Boltzmann constant, R , the molar gas constant and N_A , the Avogadro's constant. [1]

- 4 b) Fig. 4.1 shows a fixed mass of ideal gas undergoing a cyclic process.

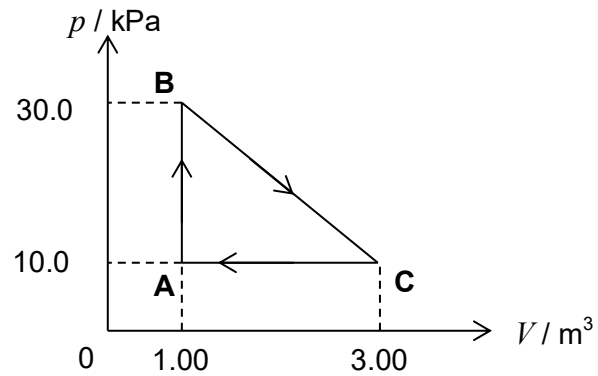


Fig.4.1

- i) Given that the temperature of the gas is 27.8°C . at state **A**, calculate [2]
the temperature of the gas at state **B**.

temperature= _____ $^{\circ}\text{C}$

- ii) Fig. 4.2 is a table of energy changes during one cycle. Complete Fig. 4.2.

[4]

section of cycle	heat supplied to the gas / kJ	work done on gas / kJ	increase in internal energy / kJ
A → B			30.0
B → C			zero
C → A			

Fig. 4.2

- 4 b) iii) Compare the root mean square speeds of the gas molecules at states **B** and **C**. Explain your comparison. [2]

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- 5 a) i) Define *electric potential* at a point. [1]

.....

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- ii) State the relation between electric field strength E and potential V . [1]

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- b) An isolated solid metal sphere is positively charged.
The variation of the potential V with distance x from centre of the sphere is shown in **Fig. 5.1**.

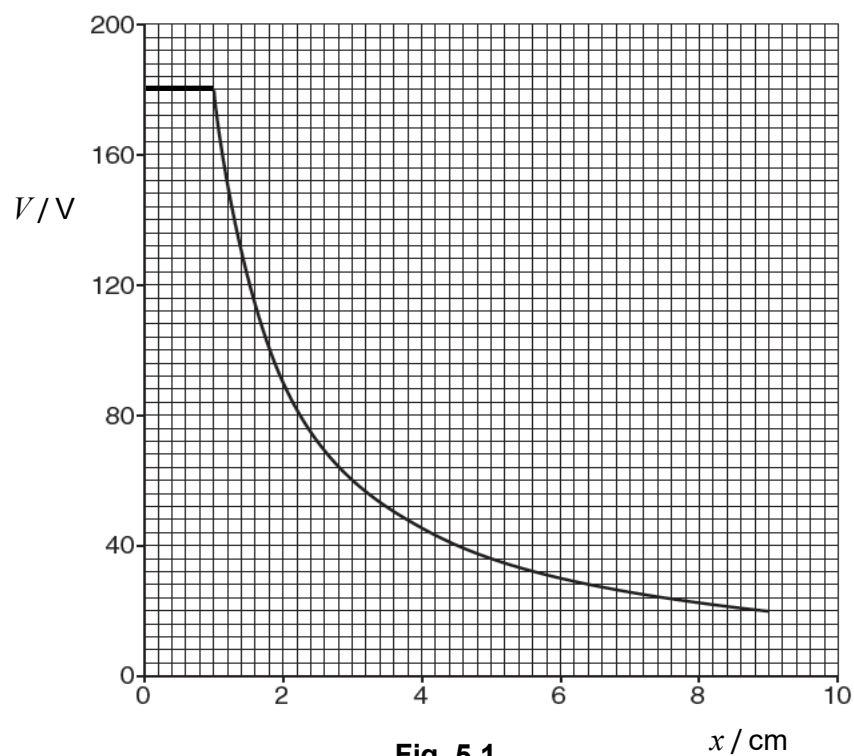


Fig. 5.1

- 5 b) i) Using **Fig. 5.1**, describe qualitatively the variation with x the electric field from $x = 0.0$ cm to $x = 9.0$ cm. [2]

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- ii) Show that the charged sphere behaves as if it is a point charge. [3]

- iii) Assuming that the charge on the sphere does behave as a point charge, calculate the work done by electric field when an alpha particle moves from $x = 6$ cm to $x = 3$ cm. [2]

work done = _____ J

- 6 a) A thermistor has a resistance R which varies with the Celsius temperature θ according to the equation

$$R = Ae^{\frac{n}{\theta + 273}}$$

where both A and n are constants.

The values of R and θ are given in **Fig. 6.1**.

Data Point	$\theta / ^\circ\text{C}$	R / Ω
1	0	5920
2	25	2360
3	50	1081
4	75	560
5	100	310

Fig. 6.1

- i) State the appropriate graph to plot to verify the equation in (a). [2]
- ii) Without plotting the graph, calculate A and n using data points 2 and 3 from **Fig 6.1**. Include appropriate units. [3]

$n =$ _____

$A =$ _____

6. a) iii) The thermistor is used as part of a circuit in a constant temperature hot water bath as shown in Fig. 6.2.

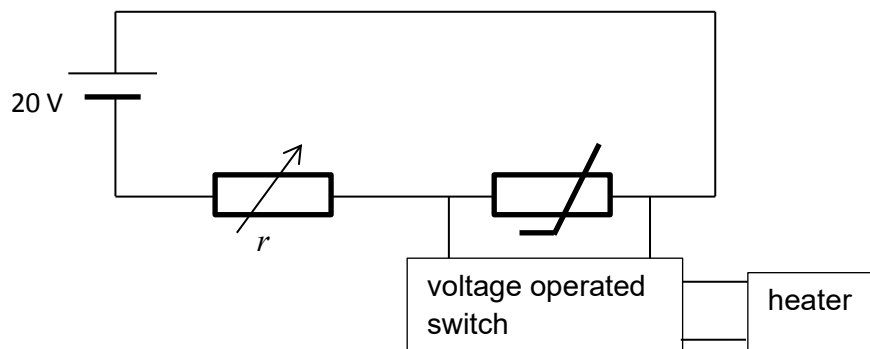


Fig. 6.2

The thermistor is placed in the hot water bath and is used to regulate the temperature of the hot water bath. When the potential difference of the thermistor falls below 10 V, the power supply to the heater is switched off until the temperature of the water bath falls below 1.0 °C of the desired temperature.

- 1 The hot water bath functions from 40.0 °C to 80.0 °C. Calculate the resistance of the thermistor at 40.0 °C and 80.0 °C. [2]

resistance at 40.0 °C = _____ Ω

resistance at 80.0 °C = _____ Ω

- 2 Hence, calculate the range of the variable resistor r . [2]

$r =$ _____ to _____ Ω

- 6 b) The thermistor is to be used as a resistance thermometer in the range 0°C to 100°C .

Fig. 6.3 shows the graph of R against θ based on the values given in **Fig. 6.1**.

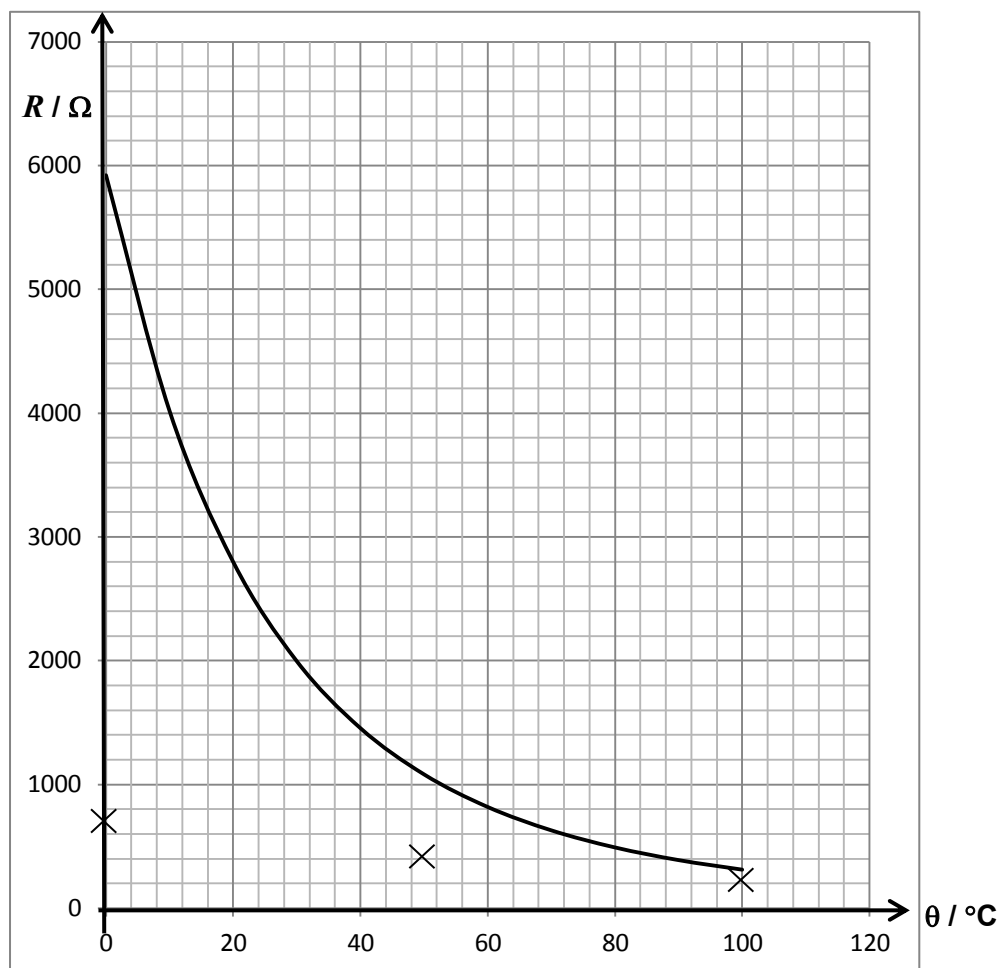


Fig. 6.3

- i) A resistor of resistance X is connected in parallel with the thermistor. [1]
 The material of this resistor has a resistivity which is constant over the range 0°C to 100°C . Their combined resistance at $\theta^{\circ}\text{C}$ is Y .
 Write down a mathematical equation relating R , X and Y .

- 6 b) ii) Complete the table below by calculating the values of Y when X is $750\ \Omega$. [1]

$\theta / ^\circ\text{C}$	R / Ω	Y / Ω
0	5920	666
25	2360	
50	1081	443
75	560	
100	310	219

- iii) Complete the graph of Y against θ on **Fig 6.3** and plot them. [1]

- iv) Comment on the suggestion that the combined resistance Y now shows a linear response. [1]

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- c) The use of the original non-linear thermistor as a resistance thermometer has advantages in some situations over this combination. State and explain one of these advantages. [2]

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- 7 A thin card is inserted between two separate iron cores. A coil is wound around one core as shown in **Fig. 7.1**.

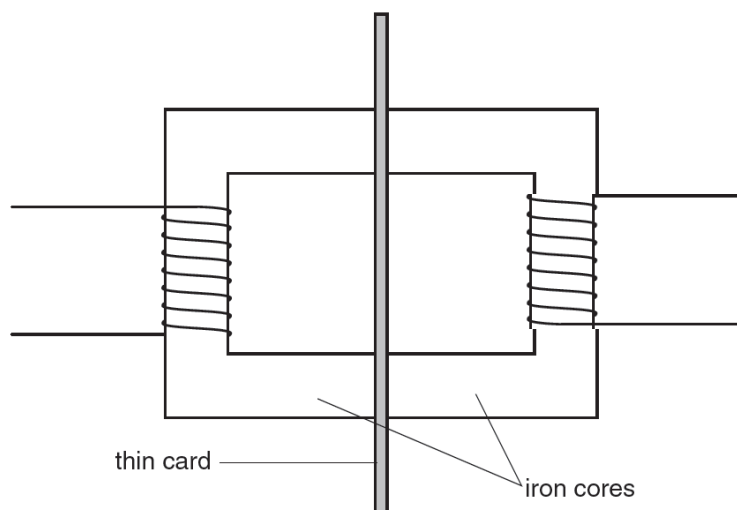


Fig. 7.1

A current in the coil may induce an e.m.f. in another coil wound on the other core. The induced e.m.f. V depends on the thickness t of the card.

A student suggests that $V = V_o e^{-\sigma t}$ where V_o is the induced e.m.f. without card between the cores and σ is a constant.

You are provided with the above iron cores. You may also use any of the other equipment usually found in a Physics laboratory.

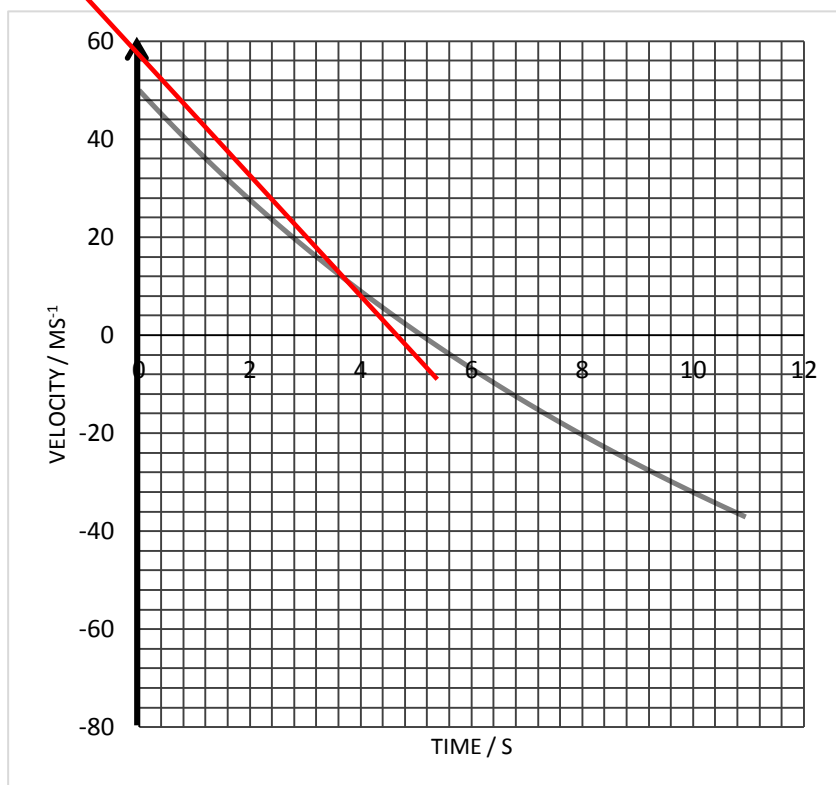
Design a laboratory experiment to test the relationship between V and t and determine the value of σ . You should draw a labelled diagram to show the arrangement of your apparatus. In your account you should pay particular attention to

- the identification and control of variables,
- the equipment you would use,
- the procedure to be followed,
- how the constant σ is determined,
- any precautions that would be taken to improve the accuracy and safety of the experiment.

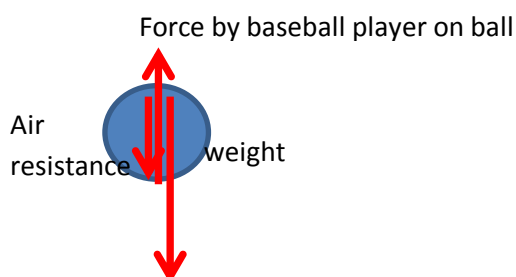
Diagram

[illegible]

1

a) i) Resultant Force = $ma = \text{mass} \times \text{gradient of curve at } t = 0$ 

Answer = $2 \times \text{gradient} = 2 \times 12.25 = -24.5 \text{ N}$ (negative sign indicates downwards)
 Q1aii.)



System is not in equilibrium because there is acceleration.

Resultant Force (downwards, because acceleration is negative)

= Weight + air resistance – Force by baseball player

$24.5 = 2 \times 9.81 + 0.150 \times 49 - \text{Force by baseball player}$

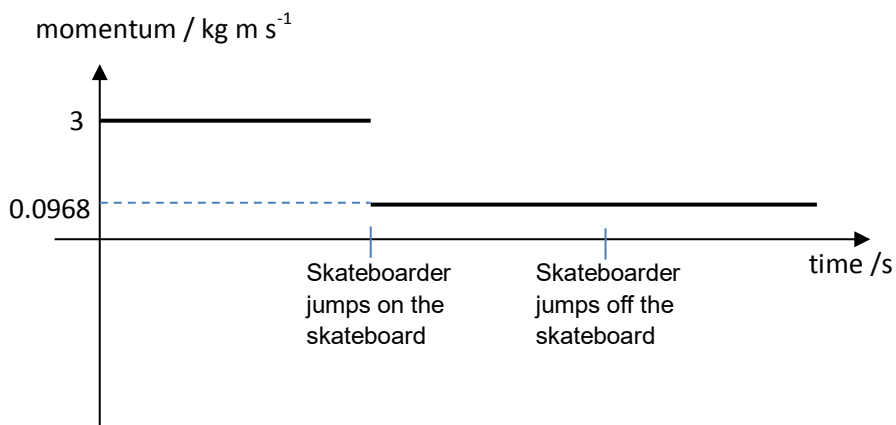
Weight, air resistance and resultant force must have the same sign (because they are all acting downwards)

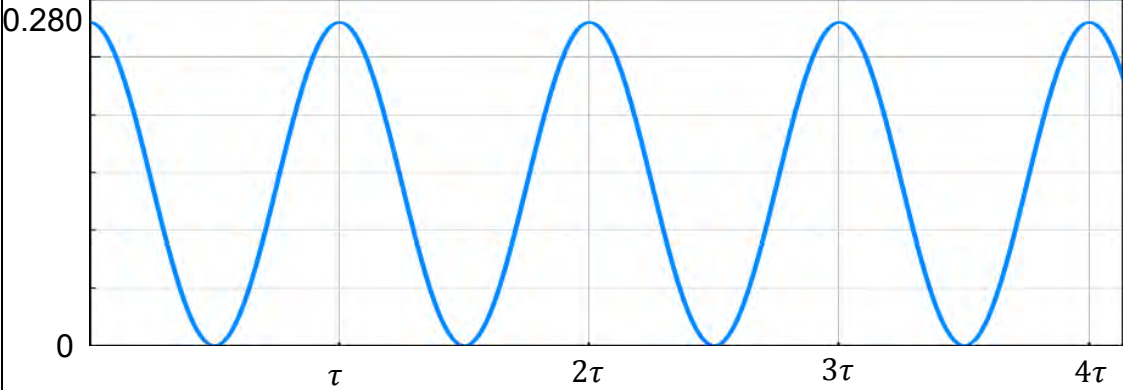
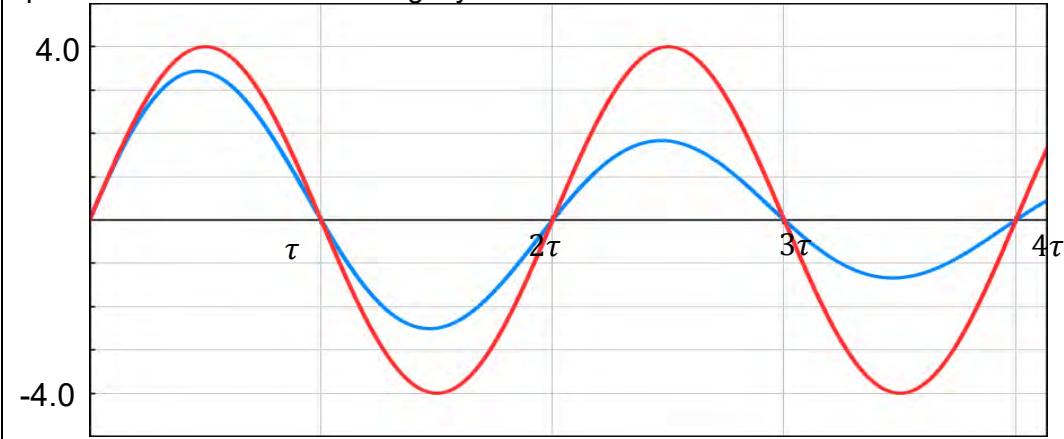
Force by baseball player = 2.47 N

b)

- Average upward velocity is larger than average downward velocity.
Time = Distance / Average Velocity. Same distance in both cases
- Lower average downward velocity due to continual loss of Kinetic energy due to work done against air resistance

	<p>c)</p> <ul style="list-style-type: none"> Find the gradient of the graph At $v = 0$ at $t=5s$ on the graph, because the only force on ball is gravity at that point <p>d)</p> <ul style="list-style-type: none"> Straight line graph Gradient of approximately $9.81ms^{-2}$
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2	<p>a)</p> <ul style="list-style-type: none"> no resultant external force total linear momentum of the system in any direction always remain constant.
	<p>b)i)</p> <p>Assumption: There is no resultant external force acting on the skateboard and the skateboarder. Examples are air resistance or friction.</p> <p>By the Principle of Conservation of Linear Momentum, $2(1.5) + 60(0) = 62(v)$ $v = 0.0484ms^{-1}$</p> <p>b) ii)</p> <p>1. $E_k = 0.5 \times 2 \times (0.0484)^2 = 2.34 \times 10^{-3} J$</p> <p>2. - The kinetic energy of the skateboard remains constant before and after the skateboarder has jumped off.</p> <p>- This is because the vertical motion of the skateboarder has no impact on the horizontal velocity (and hence the kinetic energy) of the skateboard.</p> <p>b) iii)</p>  <p>The graph shows momentum on the vertical axis and time on the horizontal axis. The vertical axis is labeled 'momentum / kg m s⁻¹' and has tick marks at 3 and 0.0968. The horizontal axis is labeled 'time /s'. A solid horizontal line is drawn at momentum = 3 from the y-axis to a vertical line labeled 'Skateboarder jumps on the skateboard'. At this point, the momentum drops to 0.0968, indicated by a dashed horizontal line. A second vertical line labeled 'Skateboarder jumps off the skateboard' is further to the right. From this second vertical line, a solid horizontal line continues at momentum = 0.0968 to the right edge of the graph.</p>

3	<p>a) (i)</p> <ul style="list-style-type: none"> - g and r are constant so acceleration, a is directly proportional to displacement, x. - negative sign shows a and x are in opposite directions. <p>(ii) $\omega^2 = g / r$, $\omega^2 = 9.81 / 0.28$ But $\omega = 2\pi / T$ $T = 2\pi / \sqrt{35} = 1.06 \text{ s}$ time interval $\tau = \frac{1}{2} T = 0.531 \text{ s}$</p>
	<p>b) (i) Maximum KE = $\frac{1}{2} (0.01) v_{\max}^2 = \frac{1}{2} (0.01) (9.81/0.28) (0.04)^2$ = 0.280 mJ</p>  <p>b) (ii) damping graph -amplitude must be decreasing -period is either constant or slightly increased</p> 
4	<p>a) pV is directly proportional to T in Kelvins. However, the Celsius scale is not directly proportional to the Kelvin scale, hence pV will not be directly proportional to T in $^{\circ}\text{C}$.</p> <p>T in degree Celsius can have negative values which when used in the ideal gas equation will result in negative values of pV which is not possible as neither p or V can be negative.</p>

b) (i) Using the ideal gas equation, since volume and amount of gas is constant.

$$\frac{P_A}{T_A} = \frac{P_B}{T_B}$$

$$T_B = \frac{30.0}{10.0} \times (273 + 27.8) = 902 \text{ K} = 629^\circ\text{C}$$

b) (ii) Most parts of the table can be found using the first law of thermodynamics

$$\Delta U = q + W$$

section of cycle	heat supplied to the gas / kJ	work done on gas / kJ	increase in internal energy / kJ
A → B	30.0 use $\Delta U = q + W$	0.0 no change in volume hence no work done	30.0
B → C	40.0 use $\Delta U = q + W$	-40.0 Calculate the area under line BC which is a trapezium $\frac{1}{2}(30 + 10) \times (3.00 - 1.00)$ Negative as the gas is expanding and doing work	zero
C → A	-50.0 use $\Delta U = q + W$	20.0 Calculate the area under line AC which is a trapezium $10 \times (3.00 - 1.00)$ Positive as the gas is being compressed and work is done on it	-30.0 For a cyclic process, the net change in internal energy must be zero

b) (iii) The temperature of the two states are the same as they have the same internal energy (increase in internal energy is zero)

Hence as the root mean square speed is dependent only on the temperature, the speeds are the same for both states.

5	<p>a) (i) The electric potential at a point in an electric field is the work done by external agent in bringing a unit positive charge from infinity to the point.</p> <p>(ii) $E = -\frac{dV}{dr}$ The electric field strength at a point is the negative potential gradient where r is the displacement in the direction of the field. (or negative of the rate of change of electric potential with respect to displacement in the direction of the field.)</p>
	<p>b) (i) When $0 < x < 1\text{cm}$, the electric field is zero. When $x > 1\text{cm}$, the electric field decreases from a maximum value to zero at $x = 9.0\text{ cm}$.</p> <p>Note: From $1.\text{cm} < x < 3.4\text{cm}$, electric field decreases at an increasing rate from a maximum value. From $3.4.\text{cm} < x < 9\text{ cm}$, electric field decreases at an decreasing rate to a minimum value at 9.0cm.</p> <p>(ii) For a point charge, $V = \frac{q}{4\pi\epsilon_0 x}$, thus Vx is constant.</p> <ul style="list-style-type: none"> - 3 pairs of co-ordinates written clearly. Determines three values of Vx , At $x=1.8\text{cm}$, $V=100\text{ V}$, $Vx= 180\text{Vcm}$ At $x=5.0\text{cm}$, $V=36\text{ V}$, $Vx= 180\text{Vcm}$ At $x=9.0\text{cm}$, $V=20\text{ V}$, $Vx= 180\text{Vcm}$ Average value of $Vx = 180\text{ Vcm}$. - Since the 3 values of Vx is the same, it is a point charge. <p>(iii) Work done by external agent $= 2(1.6 \times 10^{-19})(60-30) = 9.60 \times 10^{-18}\text{ J}$ Work done by electric field $= -9.60 \times 10^{-18}\text{ J}$</p>
6	<p>a)(i)</p> <p>Plot $\ln R$ against $\frac{1}{\theta + 273}$</p>
	<p>a)(ii)</p> <p>From data point 2: $2360 = Ae^{\frac{n}{25+273}}$ $\ln 2360 = \ln A + \frac{n}{298}$ ----- (1)</p> <p>From data point 3: $1081 = Ae^{\frac{n}{50+273}}$ $\ln 1081 = \ln A + \frac{n}{323}$ ----- (2)</p> <p>(1) – (2) gives: $\ln 2360 - \ln 1081 = \frac{n}{298} - \frac{n}{323}$</p> <p>$n = 3006 \approx 3010\text{ K}$</p> <p>From (1): $\ln A = \ln 2360 - \frac{3006}{298}$, $A = 0.0982\ \Omega$</p>

	<p>a) (iii)1.</p> $R = 0.0982 e^{\frac{3006}{\theta+273}}$ <p>At 40°C, $R = 0.0982 e^{\frac{3006}{40+273}} = 1455 \approx 1460 \Omega$</p> <p>At 80°C, $R = 0.0982 e^{\frac{3006}{80+273}} = 490 \Omega$</p>																		
	<p>a) (iii)2.</p> <p>Since the potential difference across the thermistor is 10V, the potential difference across the variable resistor must be 20 – 10 = 10V</p> <p>By potential divider rule, r = resistance of the thermistor.</p> <p>Range of values of r: 490 Ω to 1460 Ω</p>																		
	<p>b) (i)</p> $Y = \frac{RX}{R + X}$																		
	<p>b) (ii)</p> <table><tr><td>$\theta / ^\circ\text{C}$</td><td>R / Ω</td><td>Y / Ω</td></tr><tr><td>0</td><td>5920</td><td>666</td></tr><tr><td>25</td><td>2360</td><td>569</td></tr><tr><td>50</td><td>1081</td><td>443</td></tr><tr><td>75</td><td>560</td><td>321</td></tr><tr><td>100</td><td>310</td><td>219</td></tr></table>	$\theta / ^\circ\text{C}$	R / Ω	Y / Ω	0	5920	666	25	2360	569	50	1081	443	75	560	321	100	310	219
$\theta / ^\circ\text{C}$	R / Ω	Y / Ω																	
0	5920	666																	
25	2360	569																	
50	1081	443																	
75	560	321																	
100	310	219																	

b)(iii)

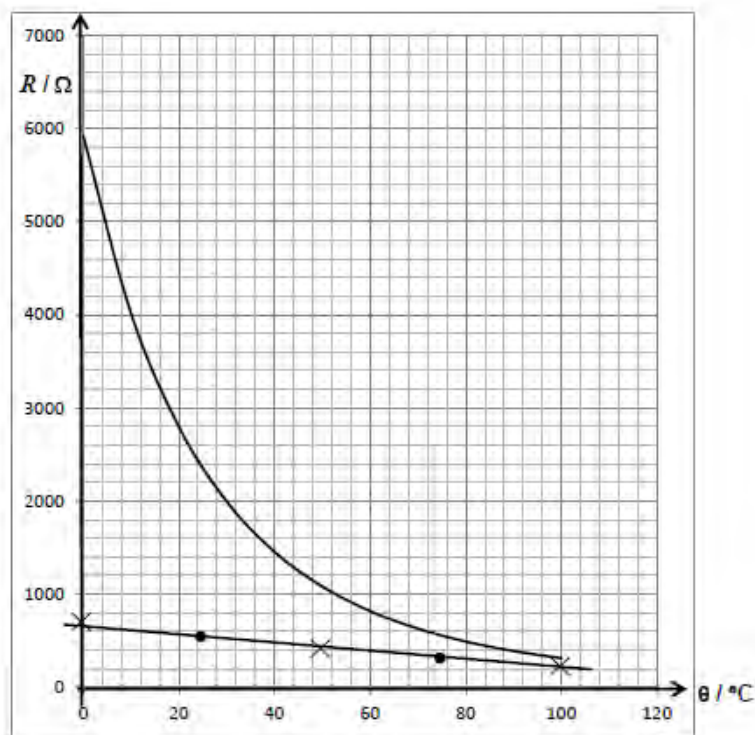


Fig. 6.3

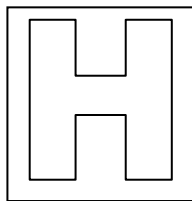
b)
(iv) Since a straight line is obtained, with points lying close to or on the best fit line, the suggestion is valid (based on the range of temperature given).

c) It is more sensitive to changes in temperature for temperature readings between 0 $^\circ\text{C}$ to about 80 $^\circ\text{C}$ because the gradient is steeper compared to that of the combination of resistors.

7.

Suggested Mark scheme	
Description	Points
A cap of 6 marks is awarded to students if a dc supply is used as experiment is unworkable.	
1. Diagram (3m)	
- AC power supply / signal generator connected to primary coil and switch. Note: If switch is not in diagram, but mention in procedure, mark should also be awarded	1m
- AC ammeter/ ac voltmeter and resistor(or rheostat) connected to primary coil. If variable ac supply is used, no resistor is required. (presence of voltmeter and ammeter is to ensure the current or power of ac supply is constant)	1m
Either - AC Voltmeter / oscilloscope connected to the secondary coil. (student will not be penalised if there is no resistor across the secondary coil)	1m
Or - two iron core must be clamped by retort stand or g-clamp. (student can mention in procedure if it is not stated or drawn in diagram)	
2. Variables (1m)	
<u>Independent Variable</u> : thickness of card, t	
<u>Dependent Variable</u> : induced emf, V	
<u>Control Variables</u> :	
- constant ac power supply/ ac current/ ac voltage connected to primary coil (can ignore ac if ac supply is indicated in the diagram)	1m (At least 1 must be present)
- no of turns in primary coil and secondary coil	
Do not accept no of coils.	
3.Procedure (5m)	
- Place a thin card between the two iron core. Use a micrometer screw gauge or Vernier calipers to measure and record the thickness of the card, t.	1m
- Measure and record emf induced (or voltage across) by secondary coil, V using the A.C voltmeter.	1m
- To vary the thickness of card, increase the thickness of card by placing one more card between the two iron core or use different thickness of card of same material.	1m

- Repeat steps 3 and 5 to obtain 10 sets of readings.	
The relationship is of the form $V = V_0 e^{-\sigma t}$. Tabulate V, t, and ln V. Plot a graph of ln V vs t.	1m
If a straight line is obtained from the graph, the relation is valid. The gradient of the line is the σ .	1m
4. Safety Precaution (1m) - Precaution linked to hot coil(s) e.g. switch off when not in use // wear thermal gloves. - Wear insulated gloves/do not touch the coil to prevent electrocution since high current is used in the circuit of the primary coil - The rheostat in the circuit of primary coil is set to maximum to prevent high current flowing in the circuit. This will prevent high current flowing through the circuit which might damage the ammeter or voltmeter. - A retort stand stabiliser is placed at base of retort stand to prevent it from toppling as the iron core is heavy. (Can only give if retort stand is drawn or mentioned in the procedure)	1m (only if they give a detailed precaution)
5. Additional Details (2m) - Conduct a preliminary experiment to determine the range of current to be supplied to the primary coil to achieve measurable V in the secondary coil.). - Keep frequency of ac power supply constant (by connected the power supply to CRO). From the CRO, we can observe whether if the period is constant or not. - Repeat measurements of t at different positions of card and calculate average. This is to reduce random errors of t. - Discussion of compression of card / measure t when secured.	Any two.



NATIONAL JUNIOR COLLEGE
PRELIMINARY EXAMINATIONS
 Higher 2

CANDIDATE
NAME

SUBJECT
CLASS

REGISTRATION
NUMBER

PHYSICS (Section A)

Paper 3 Longer Structured Questions

9646/03

15 Sep 2015

2 hours

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

READ THE INSTRUCTION FIRST

Write your subject class, registration number and name on all the work you hand in.

Write in dark blue or black pen on both sides of the paper.

You may use an HB pencil for any diagrams or graphs.

Do not use staples, paper clips, glue or correction fluid.

DO NOT WRITE IN ANY BARCODES.

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

Section A

Answer **all** 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	
1	
2	
3	
4	
5	
Total	

Data

speed of light in free space,
 permeability of free space,
 permittivity of free space,
 elementary charge,
 the Planck constant,
 unified atomic mass constant,
 rest mass of electron,
 rest mass of proton,
 molar gas constant,
 the Avogadro constant,
 the Boltzmann constant,
 gravitational constant,
 acceleration of free fall,

$$\begin{aligned} c &= 3.00 \times 10^8 \text{ ms}^{-1} \\ \mu_0 &= 4\pi \times 10^{-7} \text{ Hm}^{-1} \\ \epsilon_0 &= 8.85 \times 10^{-12} \text{ Fm}^{-1} = (1/(36\pi)) \times 10^{-9} \text{ F m}^{-1} \\ e &= 1.60 \times 10^{-19} \text{ C} \\ h &= 6.63 \times 10^{-34} \text{ Js} \\ u &= 1.66 \times 10^{-27} \text{ kg} \\ m_e &= 9.11 \times 10^{-31} \text{ kg} \\ m_p &= 1.67 \times 10^{-27} \text{ kg} \\ R &= 8.31 \text{ JK}^{-1}\text{mol}^{-1} \\ N_A &= 6.02 \times 10^{23} \text{ mol}^{-1} \\ k &= 1.38 \times 10^{-23} \text{ JK}^{-1} \\ G &= 6.67 \times 10^{-11} \text{ Nm}^2\text{kg}^{-2} \\ g &= 9.81 \text{ ms}^{-2} \end{aligned}$$

Formulae

uniformly accelerated motion,

$$s = ut + \frac{1}{2}at^2, \quad v^2 = u^2 + 2as$$

work done on/by a gas,

$$W = p\Delta V$$

hydrostatic pressure

$$p = \rho gh$$

gravitational potential,

$$\phi = -\frac{GM}{r}$$

displacement of particle in s.h.m.,
 velocity of particle in s.h.m.,

$$\begin{aligned} x &= x_0 \sin \omega t \\ v &= v_0 \cos \omega t \text{ and } v = \pm \omega \sqrt{(x_0^2 - x^2)} \end{aligned}$$

mean kinetic energy of a molecule of an ideal gas

$$E = \frac{3}{2} kT$$

resistors in series,
 resistors in parallel,

$$\begin{aligned} R &= R_1 + R_2 + \dots \\ \frac{1}{R} &= \frac{1}{R_1} + \frac{1}{R_2} + \dots \end{aligned}$$

electric potential,

$$V = \frac{Q}{4\pi\epsilon_0 r}$$

alternating current/voltage,

$$x = x_0 \sin \omega t$$

transmission coefficient

$$T \propto \exp(-2kd) \text{ where } k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$$

radioactive decay,

$$x = x_0 \exp(-\lambda t)$$

decay constant,

$$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$$

Section A

Answer all the questions in the spaces provided.

- 1 (a) Explain the origin of upthrust.

.....

 [1]

- (b) A block is hung on a spring as shown in **Fig. 1.1**. The system is initially in equilibrium. The block is immersed into a beaker that contains a mixture of oil and water as shown below. The bottom half of the block is in contact with water while the top half of the block is in contact with oil.

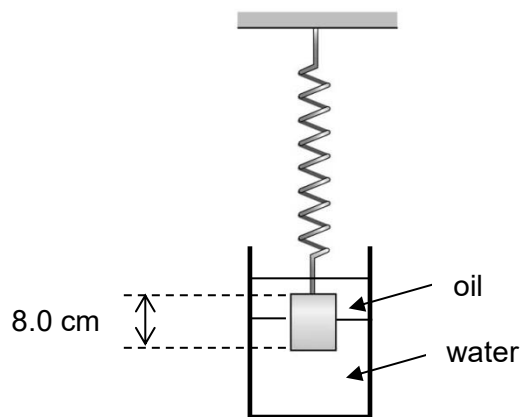


Fig. 1.1

The dimensions of the block are 5.0 cm x 5.0 cm x 8.0 cm where 8.0 cm is the height.

Density of block	7.13 g cm^{-3}
Density of water	1.0 g cm^{-3}
Density of oil	0.790 g cm^{-3}

- (i) Calculate the upthrust acting on the immersed block.

upthrust = N [2]

- 1 (b) (ii) The spring constant is 1.00 N cm^{-1} and the un-stretched length of spring is 0.10 m . Determine the length of the spring before the block was submerged into the beaker of oil and water.

length of the spring = m [2]

- (iii) Determine the change in length of the spring after the block is submerged into the beaker.

change in length of the spring = m [2]

- 2 Fig. 2.1 shows the top view of a 1500 kg car going round a frictionless banked circular track. Fig. 2.2 shows the side view.

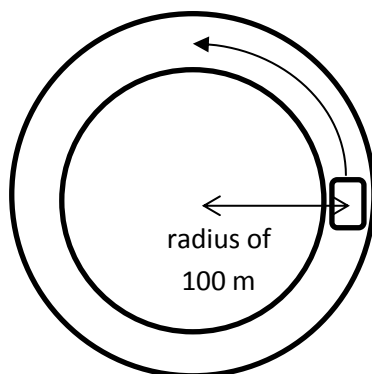


Fig. 2.1 (Top View)

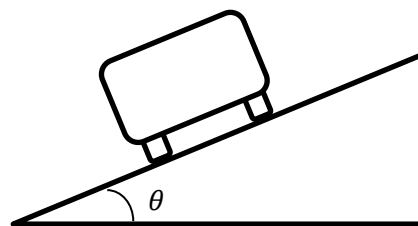


Fig. 2.2 (Side View)

- (a) Given that the car is travelling at 60 km h^{-1} , calculate the centripetal force on the car.

centripetal force = N [1]

- 2 (b) Draw the free-body diagram of the car in Fig. 2.3.

[1]

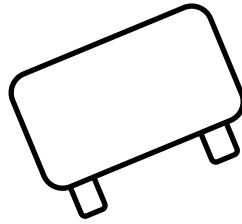


Fig. 2.3

- (c) Calculate the minimum angle θ of the banked track to prevent the car from skidding off the track.

minimum angle = ° [2]

- (d) If the car now experiences a frictional force between its tires and the track, explain what will happen to the minimum angle of the banked track required to prevent skidding.

.....

 [2]

- (e) Explain why the speed limit for curved flat roads is generally lower than the speed limit for straight flat roads.

.....

 [3]

- 3 (a) A 10.0 V battery is connected to a circuit as shown in the **Fig. 3.1**. Both resistance wires **A** and **B** have a length of 10.0 cm.

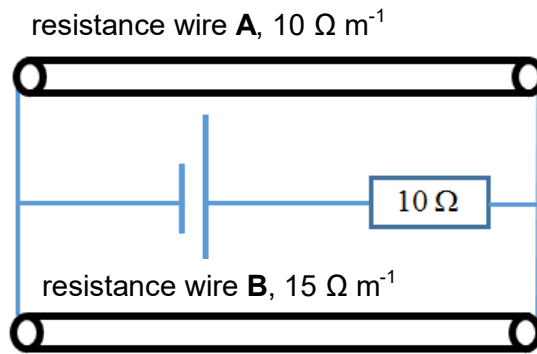


Fig. 3.1

- (i) Determine the effective resistance of the circuit.

effective resistance = Ω [1]

- (ii) Determine the potential difference across resistance wire **B**.

potential difference = V [2]

- (iii) Determine the current flowing through the 10 Ω resistor.

current = A [2]

- 3 (b) An ideal voltmeter is connected across Point **C** and Point **D** as shown in **Fig. 3.2**.

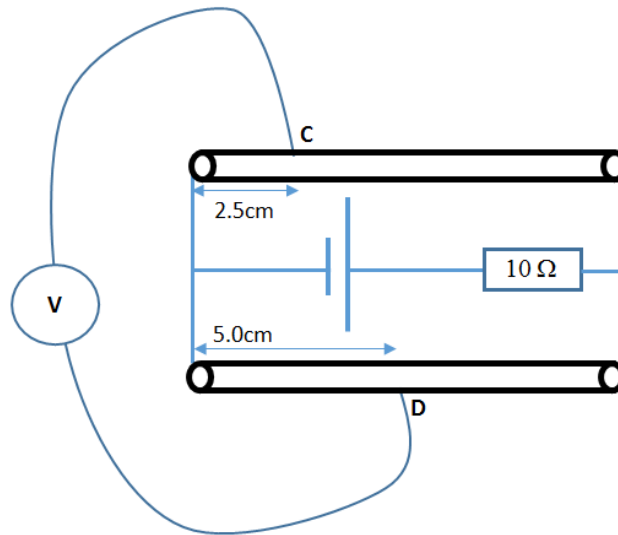


Fig. 3.2

Determine the reading on the voltmeter. In your answer, state clearly which point, **C** or **D**, has the higher potential.

voltmeter reading = V .

potential is higher at point [3]

- 4 (a) On 16 July 1994, a fragment of the comet Shoemaker-Levy 9 entered the gravitational field of the planet Jupiter. The fragment had an estimated mass of 5.5×10^{13} kg.

Fig. 4.1 shows the gravitational field strength around Jupiter as calculated by a keen physics student.

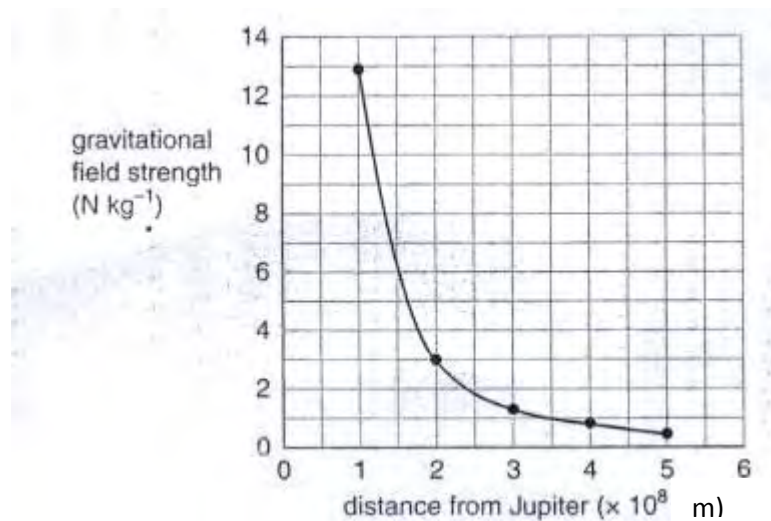


Fig. 4.1

- (i) Calculate the gravitational force acting on the fragment of the comet when it is 4.0×10^8 m from Jupiter.

Distance from Jupiter/ 10^8 m

gravitational force = N [1]

- (ii) Estimate the amount of kinetic energy gained by the comet fragment as it moves from 4.0×10^8 m to 2.0×10^8 m from the Jupiter. Show your working clearly.

kinetic energy gained = J [2]

- 4 (b) A new geostationary satellite called SKY 7 is to be placed in orbit above the Earth's equator (of mass 6.0×10^{24} kg).
Show that the orbital radius for SKY 7 is 4.23×10^4 km. [1]

- (c) Determine the minimum energy required to put the satellite (of mass 1000 kg) in geostationary orbit from the surface of the earth when it is launched from the equator.

minimum energy = J [3]

- 5 (a) Fig. 5.1 shows the path of an alpha particle as it scatters off a gold nucleus from a thin gold foil in the Rutherford's scattering experiment.

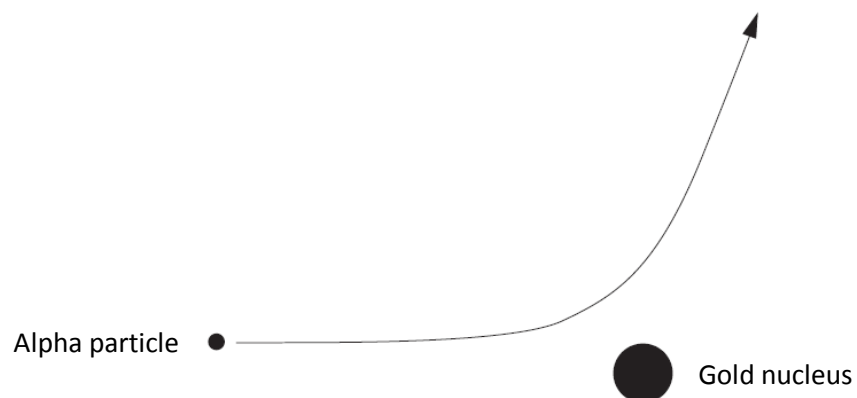


Fig. 5.1

- (i) Explain why the alpha particle follows the path as shown in Fig. 5.1.

.....
..... [1]

- 5 (b) (ii) On **Fig. 5.1**, sketch the path of an alpha particle with the same initial path, but less kinetic energy and label it **(ii)**. [1]

(iii) Explain why a thin gold foil is required for this experiment.

.....

..... [1]

- (iv) On **Fig. 5.1**, sketch the path of an alpha particle if the gold nucleus is now changed to an iron nucleus and label it **(iv)**. Atomic number of gold is 79 and atomic number of iron is 26.

[1]

- (c) In **Fig. 5.2**, an alpha particle on path **Q** has a head-on collision with a lithium nucleus ${}^7_3\text{Li}$.

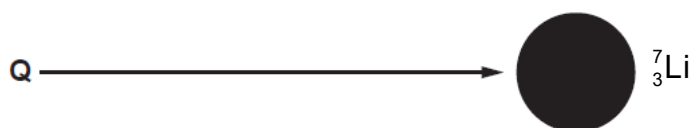


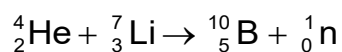
Fig. 5.2

The energy of alpha particle changes as it moves towards the centre of the nucleus. This alpha particle gets to within a distance of 4.2×10^{-15} m from the centre of the nucleus.

- (i) Show that the **minimum** energy needed for the alpha particle gets so close to the centre of the nucleus is 3.3×10^{-13} J.

[2]

- 5 (c) (ii) When the alpha particle gets to within 4.2×10^{-15} m of the centre of the nucleus, the following nuclear reaction takes place.

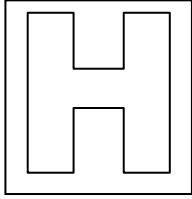


The masses of the particles involved in the nuclear reaction are as follows:

Particle	mass / u
${}^4_2\text{He}$	4.0015
${}^7_3\text{Li}$	7.0144
${}^{10}_5\text{B}$	10.0011
${}^1_0\text{n}$	1.0087

Calculate the maximum possible energy of a neutron ejected from the target when the alpha particles in the beam have energy of 3.3×10^{-13} J.

maximum possible energy = J [3]



NATIONAL JUNIOR COLLEGE
PRELIMINARY EXAMINATIONS
 Higher 2

CANDIDATE
NAME

SUBJECT
CLASS

REGISTRATION
NUMBER

PHYSICS (Section B)

Paper 3 Longer Structured Questions

9646/03

15 Sep 2015

2 hours

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

READ THE INSTRUCTION FIRST

Write your subject class, registration number and name on all the work you hand in.

Write in dark blue or black pen on both sides of the paper.

You may use an HB pencil for any diagrams or graphs.

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DO NOT WRITE IN ANY BARCODES.

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

For Examiner's Use	
6	
7	
8	
Total	

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.

Data

speed of light in free space,
 permeability of free space,
 permittivity of free space,
 elementary charge,
 the Planck constant,
 unified atomic mass constant,
 rest mass of electron,
 rest mass of proton,
 molar gas constant,
 the Avogadro constant,
 the Boltzmann constant,
 gravitational constant,
 acceleration of free fall,

$$\begin{aligned} c &= 3.00 \times 10^8 \text{ ms}^{-1} \\ \mu_0 &= 4\pi \times 10^{-7} \text{ Hm}^{-1} \\ \epsilon_0 &= 8.85 \times 10^{-12} \text{ Fm}^{-1} = (1/(36\pi)) \times 10^{-9} \text{ F m}^{-1} \\ e &= 1.60 \times 10^{-19} \text{ C} \\ h &= 6.63 \times 10^{-34} \text{ Js} \\ u &= 1.66 \times 10^{-27} \text{ kg} \\ m_e &= 9.11 \times 10^{-31} \text{ kg} \\ m_p &= 1.67 \times 10^{-27} \text{ kg} \\ R &= 8.31 \text{ JK}^{-1}\text{mol}^{-1} \\ N_A &= 6.02 \times 10^{23} \text{ mol}^{-1} \\ k &= 1.38 \times 10^{-23} \text{ JK}^{-1} \\ G &= 6.67 \times 10^{-11} \text{ Nm}^2\text{kg}^{-2} \\ g &= 9.81 \text{ ms}^{-2} \end{aligned}$$

Formulae

uniformly accelerated motion,

$$s = ut + \frac{1}{2}at^2, \quad v^2 = u^2 + 2as$$

work done on/by a gas,

$$W = p\Delta V$$

hydrostatic pressure

$$p = \rho gh$$

gravitational potential,

$$\phi = -\frac{GM}{r}$$

displacement of particle in s.h.m.,
 velocity of particle in s.h.m.,

$$\begin{aligned} x &= x_0 \sin \omega t \\ v &= v_0 \cos \omega t \text{ and } v = \pm \omega \sqrt{(x_0^2 - x^2)} \end{aligned}$$

mean kinetic energy of a molecule of an ideal gas

$$E = \frac{3}{2} kT$$

resistors in series,
 resistors in parallel,

$$\begin{aligned} R &= R_1 + R_2 + \dots \\ \frac{1}{R} &= \frac{1}{R_1} + \frac{1}{R_2} + \dots \end{aligned}$$

electric potential,

$$V = \frac{Q}{4\pi\epsilon_0 r}$$

alternating current/voltage,

$$x = x_0 \sin \omega t$$

transmission coefficient

$$T \propto \exp(-2kd) \text{ where } k = \sqrt{\frac{8\pi^2 m(U-E)}{h^2}}$$

radioactive decay,

$$x = x_0 \exp(-\lambda t)$$

decay constant,

$$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$$

Section B

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

- 6** When a laser beam passes through a narrow slit, the beam spreads out and produces broad patches of light on a screen beyond the slit as shown in **Fig. 6.1** below.



Fig. 6.1

This phenomenon can be explained in terms of waves or quantum physics.

- (a)** Complete the **Table 6.2** by filling in the missing explanation in each cell.

[3]

Wave Explanation	Quantum Explanation
The energy is carried to the screen by electromagnetic waves.	The energy is carried to the screen by photons.
The energy arrives continuously at the screen.	
The energy of the electromagnetic wave is proportional to (amplitude) ² of the wave.	
	Where the patch of light on the screen is brighter, the probability of arrival of photons is greater.

Table 6.2

- (b)** The laser emits a short pulse of ultraviolet radiation. The energy of each photon in the beam is $5.60 \times 10^{-19} \text{ J}$.
- (i)** Calculate the frequency of an ultraviolet photon of the laser light.

frequency = Hz [1]

- 6 (b) (ii) A photon of the laser light strikes the clean surface of a sheet of metal. This causes a photoelectron to be emitted from the metal surface.

1. The work function energy of the metal is 4.80×10^{-19} J. Define *work function energy*

.....

..... [1]

2. Determine the maximum kinetic energy of the emitted photoelectron.

maximum kinetic energy = J [2]

- (c) Air is transparent because it is unable to absorb visible photons. The majority of air molecules are made from pairs of atoms as shown in **Fig. 6.3** below. Some electrons are able to transfer freely between the atoms. These electrons can be modelled as particles trapped in a box of length 0.40 nm

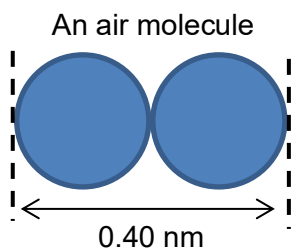


Fig. 6.3

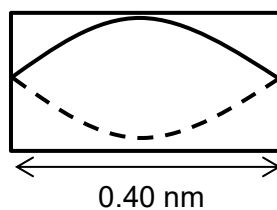
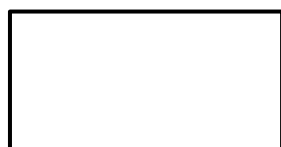


Fig. 6.4

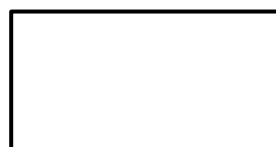
Fig. 6.4 shows the standing wave for an electron trapped in a box when it is in its lowest energy state ($n = 1$).

- (i) Complete the boxes in **Fig 6.5** below to show the standing waves for $n = 2$ and $n = 3$

[2]



$n = 2$



$n = 3$

Fig. 6.5

- 6 (c) (ii) The energy E of an electron of mass m and momentum p is given by

$$E = \frac{p^2}{2m}$$

1. Derive an expression for the de Broglie wavelength of this electron in terms of m , E and Planck constant h .

[1]

2. Hence derive an expression for the energy E , of the electron in state n in a box of length L in terms of n , m , L and Planck constant h .

[2]

3. The first 3 energy levels of the molecule (not to scale) is given in **Fig 6.6** below.

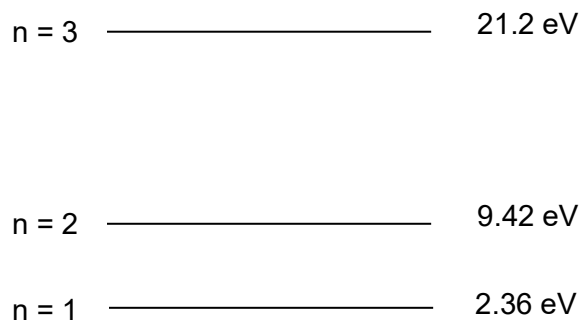


Fig. 6.6

A sample of these air molecules is bombarded by a beam of electrons from a particle accelerator. Each electron in the beam has energy of 32×10^{-19} J when it approaches the sample.

- (I) If the electrons are initially at rest, determine the minimum accelerating voltage used in the particle accelerator.

minimum accelerating voltage = V [2]

- 6 (c) (ii) 3. (II) In practice, the voltage required to produce electrons of kinetic energy $32 \times 10^{-19} \text{ J}$ is greater than the value calculated in (I) above. Suggest a reason why this is so.

.....

 [1]

- (III) Determine the wavelength(s) of the photons emitted by the sample of air molecules.

wavelength(s) = nm [2]

- (d) Fig. 6.7 below shows an electron's wave function incident on a potential barrier of height $U = 7.0 \text{ eV}$ and width $= 0.80 \text{ nm}$

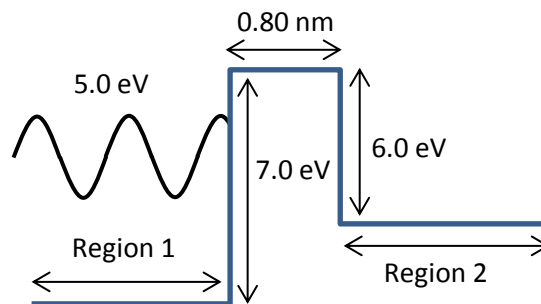


Fig. 6.7

The electron has energy 5.0 eV .

- (i) Calculate the probability that the electron will be reflected by the barrier. Assume the $T = \exp(-2kd)$.

probability of reflection = % [2]

- (ii) Explain why there is no force on the electron in region 2.

.....
 [1]

- 7 (a) A student vigorously shakes the end of a slinky spring stretched to 12 m, the other end of which is firmly fastened to a table leg, as shown in the **Fig. 7.1**. He begins slowly and then increases the rate of shake. A stationary wave pattern, with one node between the student and the table leg, appears when he is shaking the end (which is a point of *maximum* amplitude) three times per second.

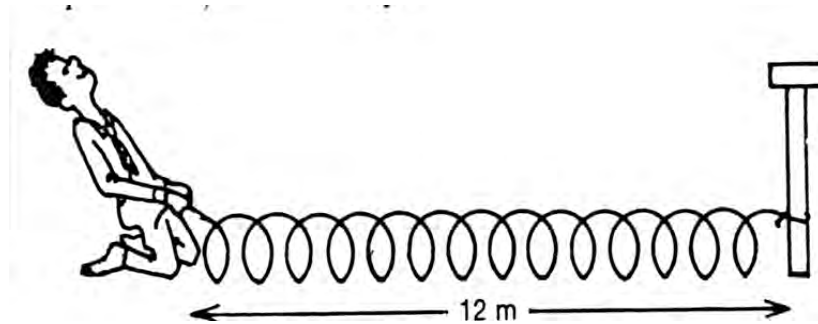


Fig. 7.1

- (i) Explain how stationary waves are formed along the spring.

.....

 [2]

- (ii) Calculate the wavelength of the wave produced.

wavelength = m [2]

- (iii) Calculate the speed of the wave propagation along the spring.

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

- 7 (a) (iv) If a point **P** on the spring undergoes exactly the same motion at the same time as a point 3.0 m from the table leg, determine the distance of **P** from the table leg.

distance of P from the table leg = m [2]

- (v) As the student gradually speeds up his shaking, calculate the frequency at which the next stationary pattern will be obtained.

frequency = Hz [1]

- (b) In an experiment, light from two monochromatic coherent sources **P₁** and **P₂** overlaps to form a stationary interference pattern.

- (i) Explain why it is necessary for the two sources to be coherent.

.....
 [1]

- (ii) **P₁** and **P₂** are a distance *a* apart. The point O on a screen, distance *d* from the sources, is opposite the midpoint of **P₁** and **P₂** as shown in the **Fig. 7.2**.

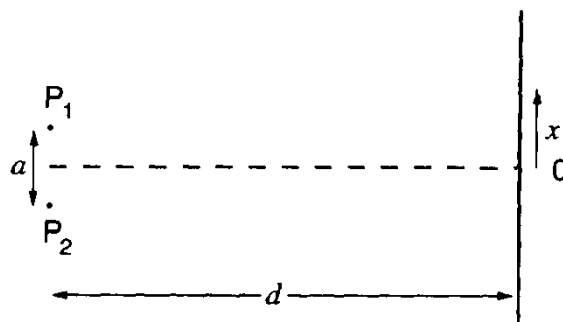
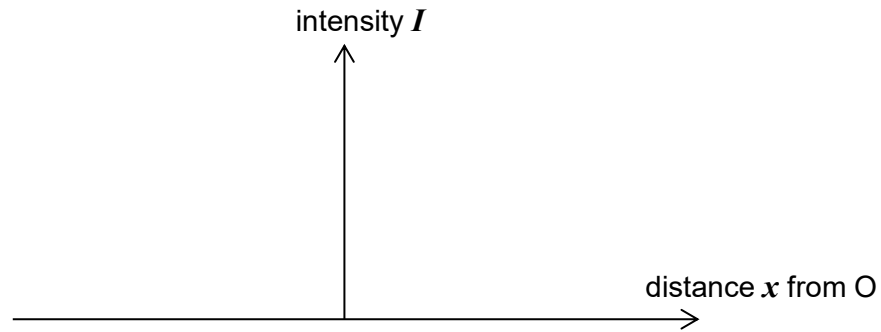


Fig. 7.2

- 7 (b) (ii) 1. Sketch the variation of intensity I of light on the screen with the distance x from O.

[1]



2. State the necessary condition on the path length difference between two waves for destructive interference.

.....

..... [1]

3. Derive an expression for x in terms of a , d and λ required to produce a minimum value of intensity on the screen, where x represents the position of all minima and λ represents the wavelength of the waves.

[2]

- (iii) **Fig. 7.3** shows the interference pattern produced on a screen 2.0 m from a pair of slits 1.0 mm apart.

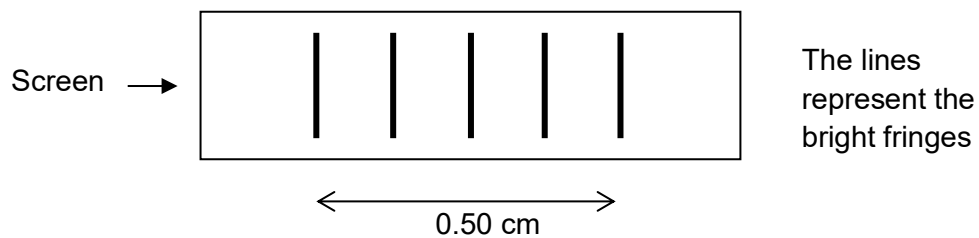


Fig. 7.3

1. Mark on **Fig. 7.3** a point **Y** where the path difference of waves from the two slits is two wavelengths and a point **Z** where the phase difference of waves is 2π radian

[2]

- 7 (b) (iii) 2. Find the wavelength of the emitted light.

wavelength = nm [1]

3. Explain the main problem that will arise if the source used is violet light? Suggest how this problem can be overcome.

.....

.....

..... [2]

- (iv) Both slits P_1 and P_2 are now each covered with a polarizing sheet. The axis of polarization is the same initially. Describe what happens to the fringes when one of the polarizing sheet in front of one of the slits is slowly rotated.

.....

.....

.....

..... [2]

- 8 (a) Define magnetic flux density and state its SI unit.

.....

 [2]

- (b) Charged particles, of speed 5000 m s^{-1} and mass $2.66 \times 10^{-26} \text{ kg}$, are travelling in a narrow beam in a vacuum as shown in **Fig. 8.1**.

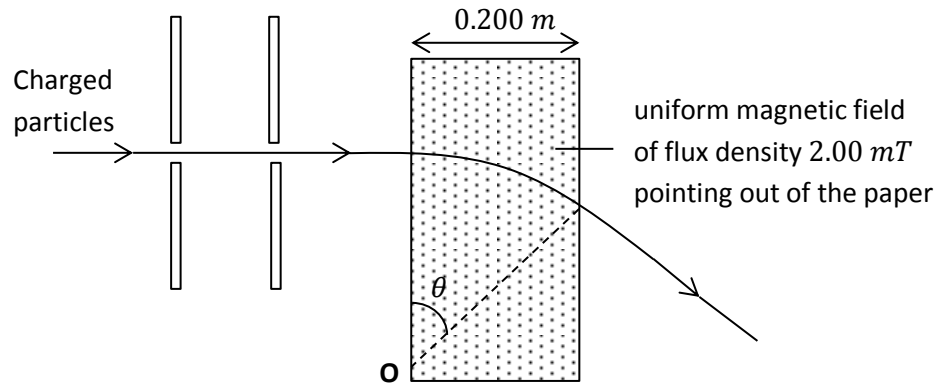


Fig. 8.1

The charged particles enter a uniform magnetic field which is 0.200 m wide. The direction of the magnetic field is pointing out of the paper.

- (i) State whether the particles are positively or negatively charged.

[1]

- (ii) Given that the magnitude of the charge of the particles is the charge of an electron, calculate the radius of the circular motion of the charged particles in the uniform magnetic field.

radius = m [2]

- 8 (b) (iii) Hence, calculate the angular velocity of the charged particles in the uniform magnetic field.

angular velocity = rad s^{-1} [2]

- (iv) Point **O** is the center of the circular motion of the charged particles as shown in **Fig. 8.1**. Show that the angle θ is 0.502 rad.

[1]

- (v) Hence calculate the time taken for the charged particles to travel through the magnetic field.

time taken = s [1]

- (vi) State the direction of the electric field to be applied to prevent the charged particle from being deflected by the magnetic field.

[1]

- (c) **Fig. 8.2** shows a circular metal ring in a magnetic field and **Fig. 8.3** shows the view from above the circular metal ring. The direction of the magnetic field is perpendicular to the plane of the metal ring.

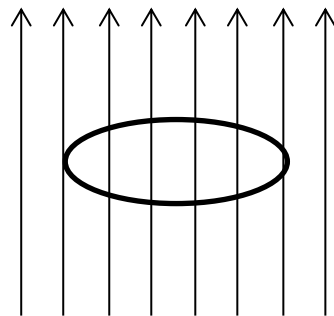


Fig. 8.2

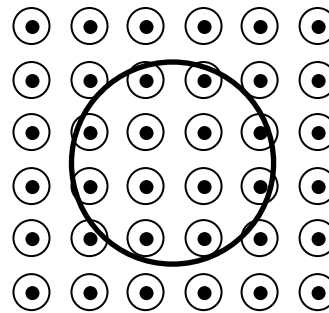


Fig. 8.3

- 8 (c) The magnetic field varies sinusoidally over time as shown in **Fig. 8.4**. A positive magnetic field means that the magnetic field is pointing upwards.

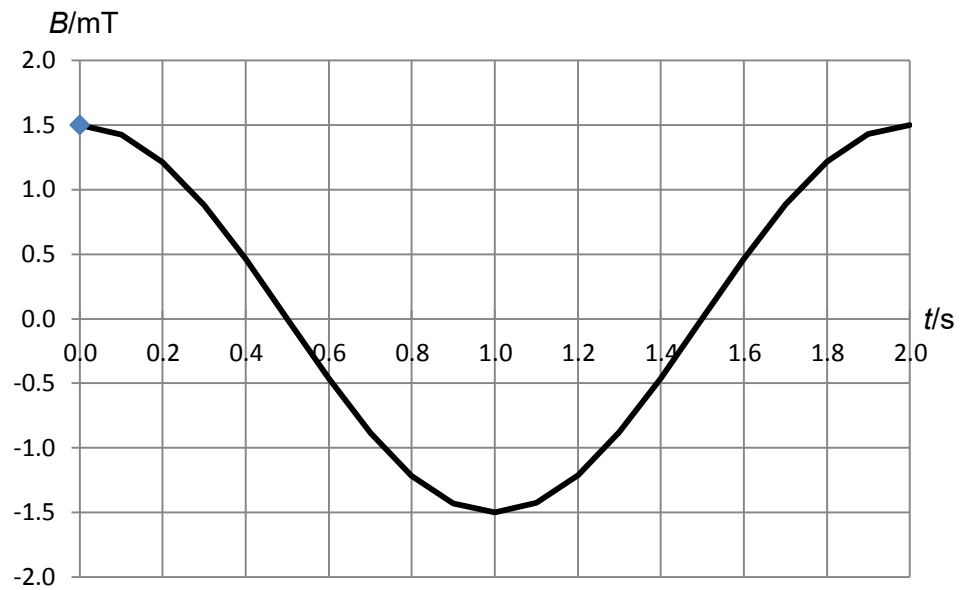


Fig. 8.4

- (i) State the magnitude of the induced current in Fig. 8.4 at $t = 1.0$ s.

magnitude of induced current = A [1]

- (ii) State and explain the direction of the induced current in **Fig. 8.3** at $t = 0.4$ s and $t = 0.8$ s.

.....

.....

.....

.....

.....

.....

..... [3]

- 8 (c) (iii) Sketch the graph of the induced current with time in **Fig. 8.5** below and label it **X**. Take clockwise direction as positive and anticlockwise direction as negative [2]

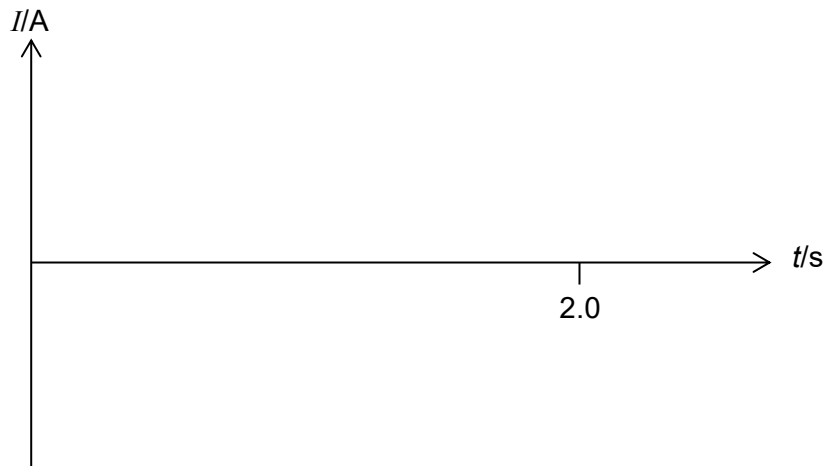


Fig. 8.5

- (iv) The area of the circular metal ring is now doubled. Its resistivity and thickness remain the same. Calculate the change in the maximum induced current. [3]

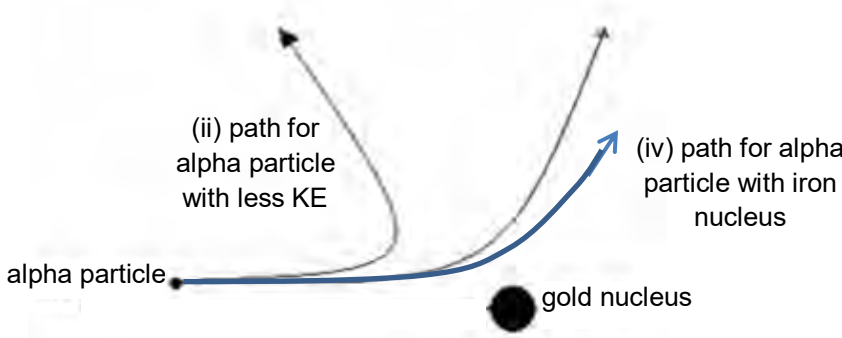
- (v) Sketch on **Fig. 8.5** the graph of the induced current with time if the area of the coil is returned to its original size and the coil was placed at a small angle less than 90° relative to the magnetic field and label it **Y**. [1]

END OF PAPER

2015 NJC Prelim Paper 3

1	a) Force due to pressure difference between top and bottom surface of object
	<p>1bi) Upthrust = Upthrust due to oil + Upthrust due to water = $(5.0 \text{ cm} \times 5.0 \text{ cm} \times 4.0 \text{ cm} \times 0.790)g + (5.0 \text{ cm} \times 5.0 \text{ cm} \times 4.0 \text{ cm} \times 1)g = 1.76\text{N}$</p> <p>1bii) Weight of block = $mg = 13.989\text{N}$ $F = kx$ $x = F/k = 13.989 / 100 = 0.13989 \text{ m}$ Total length = $0.13989 + 0.10 = 0.240 \text{ m}$</p> <p>1biii) New Force on spring after submersion = $13.989 - 1.7560 = 12.233$ New Extension = $F/k = 0.12233\text{m}$ Change in length = $0.13989 - 0.12233 = 0.0176 \text{ m}$</p>
2	a) $F_c = m \frac{v^2}{r} = 1500 \times \frac{16.7^2}{100} = 4170 \text{ N}$
	b) Weight and normal contact force (normal contact force should be longer than weight)
	<p>c)</p> $mg = N \cos \theta$ $F_c \leq N \sin \theta$ [1] $F_c \leq mg \tan \theta$ $\tan \theta \geq \frac{F_c}{mg} \rightarrow \theta \geq \tan^{-1} \frac{4170}{1500 \times 9.81} \rightarrow \theta \geq 15.8^\circ$ [1]
	<p>d) Frictional force opposes the motion of the object and is downwards along the bank. It will provide a horizontal component of force in the direction of the centripetal force. [1] Hence, the angle of the bank can be reduced as $F_c \leq mg \tan \theta$ and m and g are constants. [1]</p>
	<p>e)</p> <p>Since $F_c = m \frac{v^2}{r}$, the centripetal force required is large when the speed is high [1]</p> <p>For sharp turns involving a large change in direction in a short period of time (r is small, F_c is large due to $m \frac{v^2}{r}$), the centripetal force required is also large. [1]</p> <p>As a result, the frictional force (centripetal force) must also be very large. However, there is a physical limit to the frictional force [1]</p> <p>Thus a low speed limit must be established for curved roads.</p>
3	<p>ai) Effective Resistance = $\left[\frac{1}{1.5} + \frac{1}{1} \right]^{-1} + 10 = 10.6 \Omega$</p> <p>aii) By potential divider rule [1 – accept any reasonable method] ,</p> <p>aiii) $V = RI$ $10 = 10.6 (I)$ $I = 0.943\text{A}$</p>

	<p>we have $\frac{0.6}{10.6} \times 10 = 0.566V$ [1 –answer]</p>
	<p>b) The pd across the resistance wire is proportional to it's length. Assuming negative terminal of battery is 0V.</p> <p>Hence, potential at point C = $\frac{2.5}{10} \times 0.566 = 0.1415V$</p> <p>Hence, potential at point D = $\frac{5}{10} \times 0.566 = 0.283$</p> <p>Voltmeter reading = $0.283 - 0.1415 = 0.142V$ D has the higher potential.</p>
4	<p>a) i) From the graph, at $4.0 \times 10^{-8}m$, $g = 0.9 Nkg^{-1}$ gravitational force, $F = mg = (5.5 \times 10^{13})(0.9) = 4.95 \times 10^{13} N$</p> <p>ii) Area under graph from $2.0 \times 10^8 m$ to $4.0 \times 10^8 m$ $= 6(0.5 \times 10^8)(1) = 3.0 \times 10^8$</p> <p>By Conservation of energy, KE gained = GPE lost $= 5.5 \times 10^{13} (\text{area under } g\text{-distance graph})$ $= 5.5 \times 10^{13} (3.0 \times 10^8)$ $= 1.65 \times 10^{22} J$</p>
	<p>b) Period of rotation of geostationary satellite = $24 \times 3600 = 8.64 \times 10^3 s$ Gravitational force provides centripetal force for satellite to orbit around earth.</p> $\frac{GMm}{r_{geo}^2} = mr_{geo} \left(\frac{2\pi}{T} \right)^2$ $r_{geo} = \left[\frac{(6.67 \times 10^{-11})(6.0 \times 10^{24})(8.64 \times 10^3)^2}{(2\pi)^2} \right]^{1/3}$ $r_{geo} = 4.23 \times 10^7 m \text{ (Must write in metres first)}$ $\approx 4.23 \times 10^4 km$
	<p>c) At the surface of earth,</p> $g = \frac{GM}{r_{sur}^2}$ $9.81 = \frac{(6.67 \times 10^{-11})(6.0 \times 10^{24})}{r_{sur}^2}$ <p>radius of Earth, $r_{sur} = 6.39 \times 10^6 m$</p> <p>Kinetic energy of satellite at the equator = $\frac{1}{2} mv^2 = \frac{1}{2} (1000) \left((6.39 \times 10^6) \frac{2\pi}{8.64 \times 10^3} \right)^2$</p>

	$= 1.08 \times 10^{10} \text{ J}$ <p>Total energy of satellite at the equator = KE + GPE</p> $= 1.08 \times 10^{10} + \left(-\frac{6.67 \times 10^{-11} (1000)(6.0 \times 10^{24})}{6.39 \times 10^6} \right)$ $= -5.183 \times 10^{10}$ <p>Note: Total energy of satellite in a geostationary orbit = $-\frac{GMm}{2r}$</p> <p>Min energy required = total energy of satellite in geostationary orbit – total energy of satellite at the surface of earth</p> $= -\frac{GMm}{2r_{geo}} - (-5.183 \times 10^{10})$ $= -\left(\frac{1}{2}\right)(6.67 \times 10^{-11})(6.0 \times 10^{24})(1000) \left(\frac{1}{4.23 \times 10^7} \right) - (-5.183 \times 10^{10})$ $= 4.71 \times 10^{10} \text{ J}$
5	<p>a) <u>Gold nucleus and alpha particle are positive charged</u>. Thus the gold nucleus repels the alpha particle.</p> <p>b)</p> <p>(ii) lesser deflection of final path and final path has smaller distance of closest approach</p>  <p>(iii) A thin gold foil is required as to ensure one alpha particle to collide with a single gold nucleus or to avoid multiple collisions of one alpha particle with many gold nuclei.</p> <p>(iv) greater deflection of final path and final path has greater distance of closest approach</p>
	<p>c)</p> <p>As alpha particle approaches nucleus, KE is converted to EPE, At this <u>distance of closest approach</u>, alpha particle must possess <u>a certain amount of EPE and zero kinetic energy.</u></p> <p>Hence alpha particle must possess minimum energy U to be this close to Li</p> <p>By conservation of energy, Loss in KE = Gain in EPE</p> $U = (1/4\pi\epsilon_0) (Q_1 Q_2 / r)$ $= (9 \times 10^9) \times [(2 \times 1.6 \times 10^{-19}) \times (3 \times 1.6 \times 10^{-19}) / (4.2 \times 10^{-15})]$ $= 3.3 \times 10^{-13} \text{ J}$

6 a)

Wave Explanation	Quantum Explanation
The energy is carried to the screen by electromagnetic waves.	The energy is carried to the screen by photons.
The energy arrives continuously at the screen.	The energy arrives in discrete <u>packets</u> or discrete <u>quanta</u> .
The energy of the electromagnetic wave is proportional to (amplitude) ² of the wave.	The <u>energy of each packet</u> is <u>proportional to the frequency</u> of the wave.
Where the patch of light on the screen is bright, the <u>wave arriving there are in phase</u> . OR The wave <u>superpose/interfere constructively</u> / <u>constructive interference occurs</u>	Where the patch of light on the screen is brighter, the probability of arrival of photons is greater.

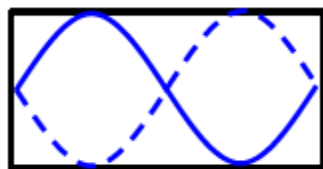
Table 6.2

b)(i) $f = \frac{5.60 \times 10^{-19}}{6.63 \times 10^{-34}} = 8.45 \times 10^{14} \text{ Hz}$

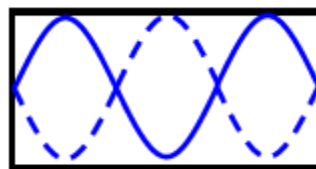
b)(ii) 1. It is the minimum energy required for photoelectric emission / to emit an electron from the surface of the metal.

b)(ii) 2. Maximum kinetic energy = $hf - \Phi$
 $= 5.60 \times 10^{-19} - 4.80 \times 10^{-19} = 8.0 \times 10^{-20} \text{ J}$

c)(i)



$n = 2$



$n = 3$

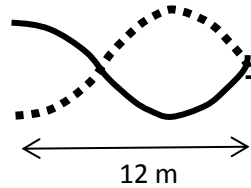
c)(ii) 1. $\lambda = \frac{h}{p}$ and since $p = \sqrt{2mE}$

	$\lambda = \frac{h}{\sqrt{2mE}}$
	<p>c)(ii) 2. Since $L = n \left(\frac{\lambda}{2} \right)$, $\lambda = \left(\frac{2L}{n} \right)$</p> <p>From $\lambda = \frac{h}{\sqrt{2mE}}$ $\frac{2L}{n} = \frac{h}{\sqrt{2mE}}$ $E = \frac{n^2 h^2}{8mL^2}$</p>
	<p>c)(iii) 3I. $32 \times 10^{-19} - 0 = (1.6 \times 10^{-19})V$</p> $V = \frac{32 \times 10^{-19}}{1.6 \times 10^{-19}} = 20V$
	<p>c)(iii) 3II. Accelerating electrons radiate electromagnetic waves, losing energy in the process.</p>
	<p>c)(iii) 3III.</p> $\lambda_1 = \frac{hc}{(21.2 - 2.36) \times 1.6 \times 10^{-19}} = 6.60 \times 10^{-8} = 66 \text{ nm}$ $\lambda_2 = \frac{hc}{(21.2 - 9.42) \times 1.6 \times 10^{-19}} = 1.06 \times 10^{-7} = 106 \text{ nm}$ $\lambda_3 = \frac{hc}{(9.42 - 2.36) \times 1.6 \times 10^{-19}} = 1.76 \times 10^{-7} = 176 \text{ nm}$
	<p>d)(i)</p> $k = \sqrt{\frac{8\pi^2 \times 9.11 \times 10^{-31} \times (7-5) \times 1.6 \times 10^{-19}}{(6.63 \times 10^{-34})^2}} = 7.236\,283 \times 10^9$ $T = e^{-2kd} = e^{-2 \times 7.236283 \times 10^9 \times 0.8 \times 10^{-9}} = 9.37 \times 10^{-6}$ <p>R = 1 - T = 99.999 1 %</p>
	<p>d)(ii)</p> <p>The potential energy is constant in region 2 and since force = negative of the potential energy gradient, force is zero since potential energy gradient is zero.</p>

7 (a)(i)

Stationary waves are formed as a result of the superposition of incident wave from student and reflected wave from table leg and these waves have same frequency and amplitude travelling at the same speed in opposite direction.

(a)(ii)



$$\begin{aligned} 3\lambda/4 &= 12 \\ \lambda &= 16 \text{ m} \end{aligned}$$

(a)(iii)

$$V = f\lambda = 3 \times 16 = 48 \text{ m}$$

(a)(iv)

P is 5 m from the table leg.

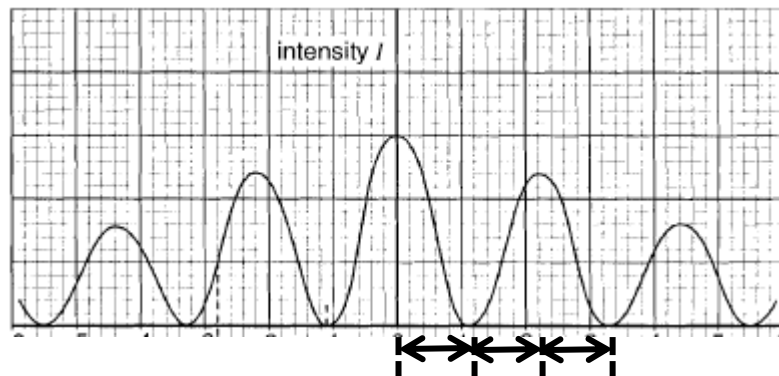
(a)(v)

As fundamental mode of vibration gives frequency of $3/3 = 1 \text{ Hz}$.

The new frequency will be $5 \times 1 \text{ Hz} = 5 \text{ Hz}$.

(b)(i) Coherent sources have constant phase difference which does not change with time so the positions of constructive and destructive interference remain unchanged with time.

(b)(ii)1.



(b)(ii)2.

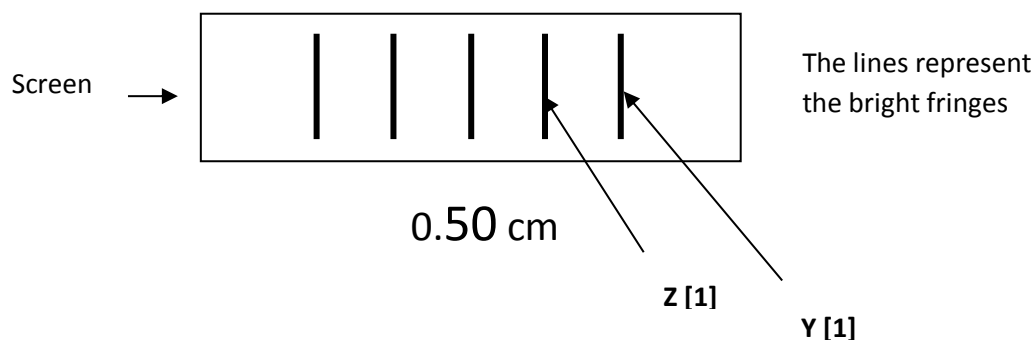
path length diff = odd integral multiple of half a wavelength
(i.e. path diff = $\frac{1}{2}\lambda$, $\frac{3}{2}\lambda$, $\frac{5}{2}\lambda$, ..)

(b)(ii)3.

$$X = \frac{1}{2} \left(\frac{\lambda d}{a} \right) + (n-1) \left(\frac{\lambda d}{a} \right)$$

$$x = (n - \frac{1}{2}) \left(\frac{\lambda d}{a} \right) \quad \text{where } n=1,2,3,\dots$$

(b)(iii)1.



(b)(iii)2.

Fringe separation, $x = \lambda D/a$

$$0.005/4 = \lambda (2.0)/0.001$$

$$\lambda = 625 \text{ nm}$$

(b)(iii)3.

main problem:

bright fringes are closer to each other, difficult to count the number of bright fringes.

Solution:

move the screen away from the two slits to increase separation of fringes,

or reduce the separation of two slits to increase separation of fringes.

(b)(iv)

The rotating of one of the polarizing sheets leads to a varying amplitude of light wave arriving at the screen. There is no total cancellation of waves for destructive interference now. **The dark fringes become brighter and brighter; and the intensity of bright fringes drops.**

The screen will have **uniform brightness** when the axis of polarisation of one sheet is perpendicular to other.

- 8 a) Magnetic flux density is defined as the force per unit length per unit current acting on a conductor carrying a current placed at right angle to the magnetic field.

$$B = \frac{F}{IL} \text{ SI units} = \text{kgms}^{-2}\text{A}^{-1}\text{m}^{-1} = \text{kg s}^{-2}\text{A}^{-1}$$

b) (i) positive

b) (ii) Using Newton's 2nd law

Magnetic force = centripetal force

$$Bqv = m \frac{v^2}{r}$$

$$r = \frac{mv}{Bq} = \frac{2.66 \times 10^{-26} \times 5000}{2.00 \times 10^{-3} \times 1.6 \times 10^{-19}} = 0.416 \text{ m}$$

b) (iii) Using Newton's 2nd law

Magnetic force = centripetal force

$$Bqv = m\omega^2 r$$

$$\omega = \sqrt{\frac{Bqv}{mr}} = \sqrt{\frac{2.00 \times 10^{-3} \times 1.6 \times 10^{-19} \times 5000}{2.66 \times 10^{-26} \times 0.416}} = 1.20 \times 10^4 \text{ rad s}^{-1}$$

Or use $v = r\omega$

$$\text{b) (iv) } \frac{\text{width of magnetic field}}{\text{radius}} = \sin\theta$$

$$\frac{0.200}{0.416} = \sin\theta \rightarrow \theta = 0.502 \text{ rad}$$

$$\text{b) (v) } t = \frac{\theta}{\omega} = \frac{0.502}{1.20 \times 10^4} = 4.18 \times 10^{-5} \text{ s}$$

b) (vi) upwards

c) (i) 0A

c) (ii) At $t = 0.4 \text{ s}$, the magnetic field is pointing upwards and decreasing. According to Lenz's Law, the direction of the induced current will be such to oppose the change in magnetic flux, hence, the induced must flow to create a magnetic field pointing upwards. Using the right hand grip rule, the induced current is flowing anti-clockwise in Fig. 8.4

At $t = 0.8 \text{ s}$, the magnetic field is pointing downwards and increasing. According to Lenz's Law, the direction of the induced current will be such to oppose the change in magnetic flux, hence, the induced must flow to create a magnetic field pointing upwards. Using the right hand grip rule, the induced current is flowing anti-clockwise in Fig. 8.4

c) (iii) Negative sine curve

c) (iv) As the area is doubled, the magnetic flux will double. The induced emf $\frac{d(BAN)}{dt}$ is doubled. Hence the new e.m.f. is $2E$.

However, as area is doubled, the radius increase by $\sqrt{2}$ and hence the circumference increases by $\sqrt{2}$. As $R = \frac{\rho l}{A}$, the resistance increases by $\sqrt{2}$.

The induced current $I = \frac{2E}{\sqrt{2}R} = \sqrt{2} \frac{E}{R}$. Hence, the maximum induced current increases by

$\sqrt{2}$.

c) (v) Same graph as (iii) but reduced magnitude