Di Keith, A Riddle

NZEST

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EDUCATION & SCHOLARSHIP TRUST

NZEST SCHOLARSHIP EXAMINATION

1992 EXAMINER'S REPORT AND SOLUTIONS

PHYSICS

NEW ZEALAND EDUCATION & SCHOLARSHIP TRUST

PHYSICS

Examiner's Report 1992

Statistics

There is no scaling.
The mean mark was 45.2 with a standard deviation of 17.
The median was 44 with quartiles of 32 and 58.
The tenth and ninetieth percentiles were 24 and 69.
The top three students had marks of 88, 84, 84.
Nineteen student achieved marks of 74 or better and have been awarded Distinction.

General comments

Feedback indicates that some teachers felt that some parts of the paper were outside the syllabus. This will always be a problem when the syllabus is indicative rather than specific. The examiner was working from the 1991 University Bursaries/Entrance Scholarships Physics prescription.
Multichoice question 12 was cited as an example of a question which was outside the syllabus. However, the examiner disagrees because the syllabus requires "construction and use of displacement-time graphs for wave motion at a given position". A student who can draw such a graph should be able to identify the equation which describes it.
Question 4(a)(iii) was also cited as being outside the syllabus. However, the syllabus states "description and analysis of . . . transient and sinusoidal currents in series resistor-capacitor and series resistor-inductor circuits".

When multiple steps are involved in a problem it is generally easier to retain symbols through the steps and to substitute numerical values at the end. Many students substitute too early and create extra work for themselves.

Rounding of answers continues to be a problem. Rounding to the number of significant figures in the data given is often nonsense e.g. in Part III Question 1(a)(i) 48 $kg.m.s^{-1}$ should not be rounded to 50 on the grounds that the data i.e 50 $m.s^{-1}$, 30$m.s^{-1}$ and 0.6 kg are all given to one significant figure. A good rule of thumb is to carry four figures in any calculation and round the answer to three significant figures. The exception is when integers are involved and an integer answer is obtained.

Individual questions

Section II

1(a) Poorly done. Setting out was very poor with poor use of a clear diagram. Many forgot the reaction at the wall. Many attempted a solution using forces only rather than torques (or moments).

(b) Mostly well done. Some students attempted a solution without considering each mass separately. Some assumed that no acceleration implied no forces at all.

2(a) Too many students tried to answer by quoting a formula and inserting numbers.

(b) (i)The interference pattern was generally well drawn but many had difficulty calculating the fringe separation.

(ii)Too difficult for most students. Many misread the question as if the separation had doubled. The key points are that the fringes are at the same place but there is imperfect cancellation. The bright fringes are brighter and the dark fringes are not totally dark.

3 Common errors were
the assumption that the orbit is at the Earth's surface,
the assumption that horizon to horizon is half the circle,
misquoting formulae.

4 Generally well done.

5(a) Many candidates drew electron orbits instead of the energy level diagram which was requested. A few thought the energy levels (rather than the level differences) corresponded to the photon energies.

(b) This question proved to be ambiguous with some students answering, correctly, that the electrons in level $n = 1$ are in the ground state and therefore cannot emit energy.

(c) Quite a few candidates answered part (a) well but could not handle part (c). Many failed to convert from electron volts to joules.

Section III

1 Most candidates attempted this question. Many found it straightforward.
Common errors were
failure to note that the ball changed direction and thereby getting an incorrect value for its change of momentum,
using standard symbols such as L, m, r several times with different meanings and thereby inserting incorrect values,
neglecting to include all the terms in conservation of momentum and conservation of energy equations.
A few students were not aware that the angular momentum of a particle travelling in a straight line can have angular momentum mvr about a point.
The value given for the moment of inertia of the rod is not consistent with the values given for its mass and length but fortunately this did not seem to cause any difficulties.

2 Few students were familiar with Archimedes principle.
Few were able to deduce that if the restoring force (or acceleration) is proportional to the displacement then the motion will be SHM.
Many used the shortcut that

$$\Delta\text{upthrust} = \rho_f\, g\, \Delta\text{volume}$$

followed by

$$T = 2\pi\sqrt{m/k} \qquad F = -kx \qquad k = \Delta\text{upthrust}/x$$

this works well provided it is understood that k is given by the restoring force divided by the displacement.

3 Generally well done.

(a) 'Show units' could have be more explicitly stated as 'show values and units'.
In part (ii) many students found the speed of the pulse along the string instead of the velocity of the centre element of the string.

(b) Most found parts (ii) and (iii) straightforward.

(c) Generally easy though common errors were
taking $\lambda = 0.7$ m and
taking $f = 600$ Hz.

4(a) There were some very imprecise explanations in part (i).
Part (iii) was too difficult for most students. See the general comment above.

(b) Generally well done.

5(a) Generally well done. A common error was taking 1.4 m as the radius of the path.

(b) Generally well done but some students gave incorrect units.
Most students were able to give the general shape of the graph.

6 Confusion of higher frequency with higher current was very common in part (c)(i).
There was confusion with Bohr theory in part (c)(ii).
For part (d) many students simply stated what happened. Only a few showed understanding that the photoelectric effect was crucial in establishing the need for a quantum theory of light.

Assoc. Professor C.T. Tindle
University of Auckland
Examiner 1992

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NEW ZEALAND EDUCATION & SCHOLARSHIP TRUST

PHYSICS

SCHOLARSHIP EXAMINATION 1992

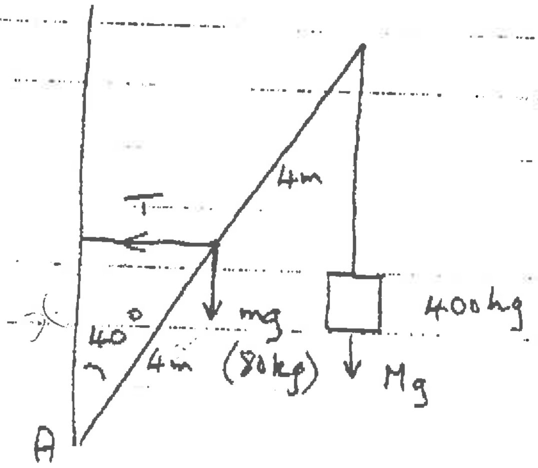
Candidate Code Number..

Circle the letter that you believe to represent the correct answer.
To change your choice, cross out and recircle: A ~~B~~ **C** D E

1)	A	**B**	C	D	E
2)	A	B	**C**	D	E
3)	A	B	**C**	D	E
4)	A	B	C	D	**E**
5)	**A**	B	C	D	E
6)	**A**	B	C	D	E
7)	A	**B**	C	D	E
8)	**A**	B	C	D	E
9)	A	B	**C**	D	E
10)	A	B	C	**D**	E
11)	A	B	C	D	**E**
12)	**A**	B	C	D	E
13)	A	**B**	C	D	E
14)	A	B	C	D	**E**
15)	A	B	C	**D**	E
16)	A	**B**	C	D	E
17)	A	B	**C**	D	E
18)	A	B	C	**D**	E
19)	A	B	C	**D**	E
20)	A	B	C	D	**E**

1.

(a)

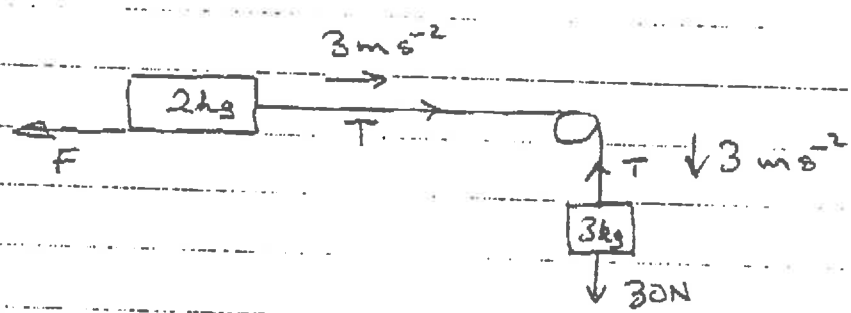


Take moments about A

$$T \times 4\cos 40° = 80 \times 10 \times 4\sin 40° + 400 \times 10 \times 8\sin 40°$$
$$= 4 \times (800 + 8000)\sin 40°$$
$$T = 8800\tan 40°$$
$$= 7384$$

∴ Tension = 7384 N.

(b)



(i) For 3kg block $\Sigma F = ma$ (vertically)

$$30 - T = 3 \times 3$$
$$T = 30 - 9 = 21\text{ N}$$

For 2kg block $\Sigma F = ma$ (horizontally)

$$T - F = 2 \times 3$$
$$F = T - 6$$
$$= 21 - 6 = 15\text{ N}$$

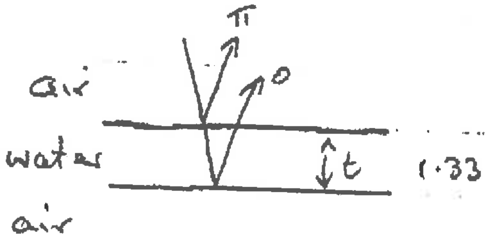
Frictional force = 15 N.

(ii) For constant speed need $T = 15$ N

therefore replace 3kg block with a 1.5 kg block

2.

(a)



$\lambda = 560$ nm.

There is phase change π at first reflection and no phase change at second interface.

For reinforcement we need path difference $= \frac{\lambda}{2}$

$\therefore \quad 2t = \frac{\lambda}{2}$

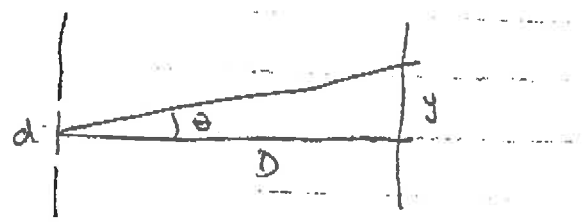
$t = \frac{560 \text{ nm}/1.33}{4}$ Needs $\frac{\lambda}{n}$?

$= $ ~~140 nm~~ 105 nm

$\therefore$ Minimum thickness $=$ ~~140 nm~~ 1.05×10^{-7} m

(b) Maxima $m\lambda = d \sin\theta$

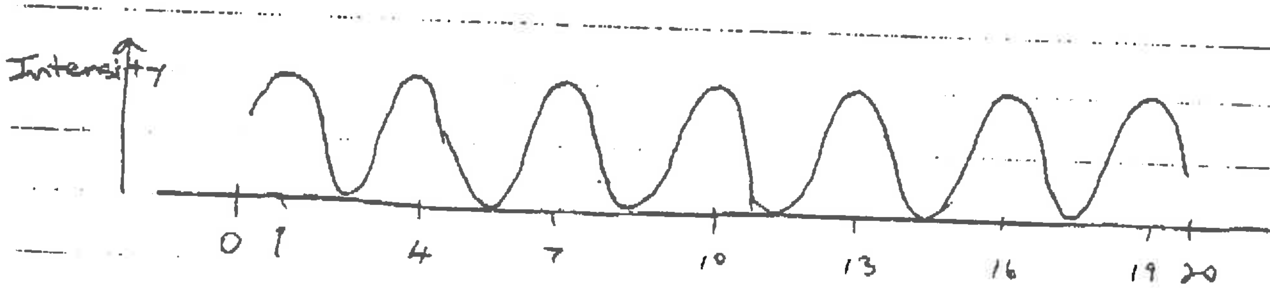
(i) $\approx d \frac{y}{D}$



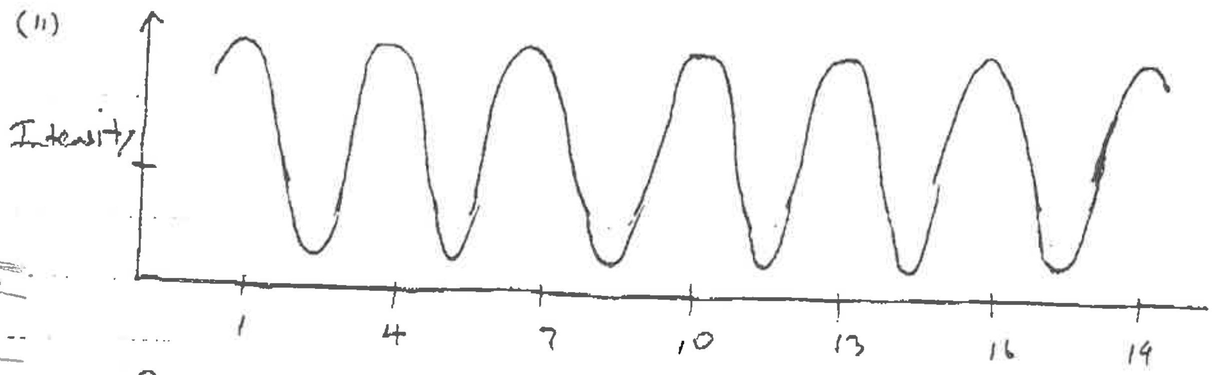
$\therefore \quad y = m\lambda \frac{D}{d}$

$= m \frac{\lambda \cdot 1.2}{40\lambda}$

$= m \times 3$ cm.



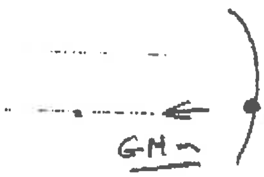
(ii)



BONUS MARK FOR RATIO MAXIMA : MINIMA = 9 : 1

3.

(a)



For satellite "$\Sigma F = ma$"

$$\frac{GMm}{(R+h)^2} = m\omega^2(R+h)$$

$$\therefore (R+h)^3 = \frac{GM}{\omega^2}$$

$$= GM\left(\frac{T}{2\pi}\right)^2$$

$$= 6.67\times10^{-11} \times 5.97\times10^{24} \times \left(\frac{2\times60\times60}{2\pi}\right)^2$$

$$= 5.228 \times 10^{20}$$

$$= 522.8 \times 10^{18}$$

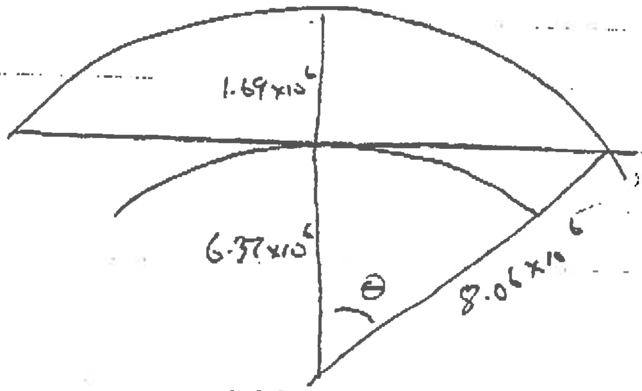
$$R+h = 8.056 \times 10^6$$

$$h = (8.06 - 6.37) \times 10^6$$

$$= 1.69 \times 10^6$$

$\therefore$ height = **1690 km**

(b).



$$\cos\theta = \frac{6.37}{8.06}$$

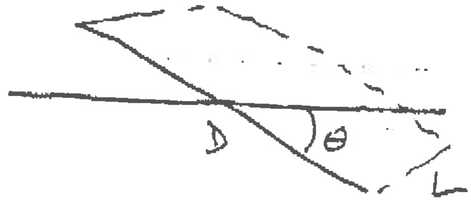
$$\theta = 37.8^\circ$$

$\therefore$ Time for horizon to horizon $= \frac{2\times37.8}{360} \times 2$ hours.

$= $ **25.2 minutes**.

4.

(a)



Flux through loop at angle θ = $B\, D \sin\theta\, L$

Change in flux in time Δt = $BDL \sin(\theta + \Delta\theta) - BDL\sin\theta$

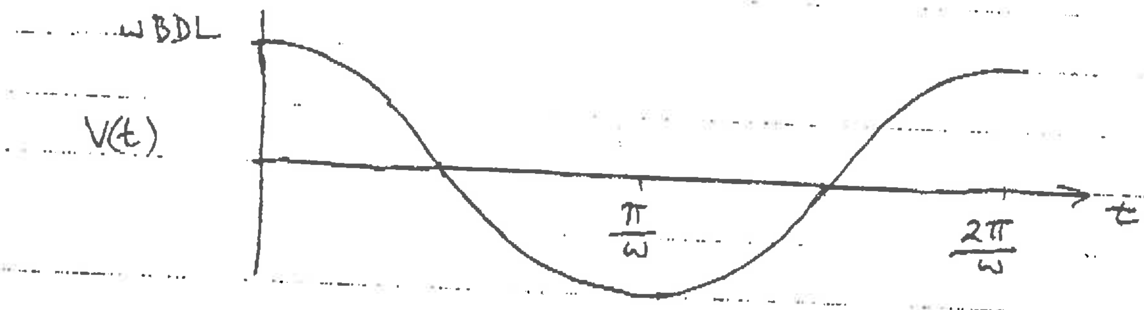
$= BDL\left[\sin\theta\cos\Delta\theta + \cos\theta\sin\Delta\theta - \sin\theta\right]$

$= \mp\ BDL\cos\theta . \Delta\theta .$

Voltage generated = $\dfrac{\mp BDL\cos\theta . \Delta\theta}{\Delta t}$

(b)

$V(t) = -BDL\cos\theta . \omega$



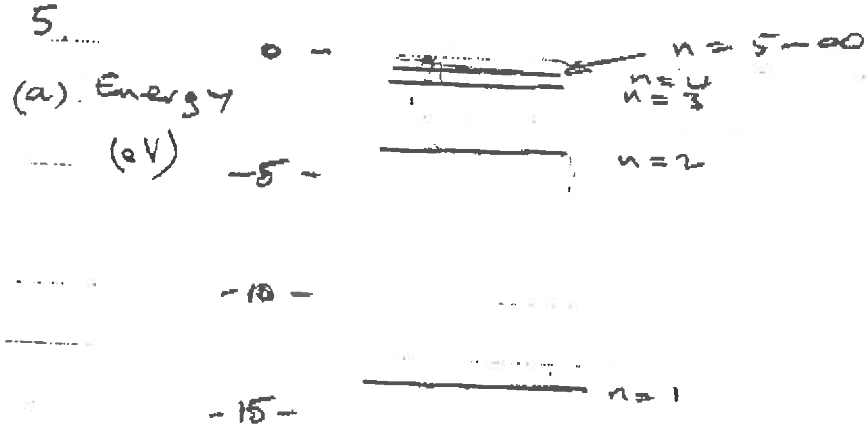
(c) Only the outer (valence) electrons in metal atoms are free to move and they flow along the wire as electric current.

The positively charged nuclei and the closed shells of electrons do not move.

Electrons move back and forth in SHM

5.

(a)



When an atom of hydrogen is excited in a collision the electron can be knocked into a higher energy level. The electron soon drops down into lower energy levels and emits light of a wavelength which corresponds to the energy difference of the levels.
The spectrum therefore has a series of well defined sharp lines.

(b) Electron jumps to level n = 1 give light of high energy and short wavelength which is not part of the visible spectrum.

(c) Longest wavelength is for n = 3 → n = 2

$$h\nu = \left(\frac{1}{2^2} - \frac{1}{3^2}\right) 13.6 \times 1.6 \times 10^{-19}$$

$$h\frac{c}{\lambda} = 3.02 \times 10^{-19}$$

$$\lambda = \frac{hc}{3.02 \times 10^{-19}}$$

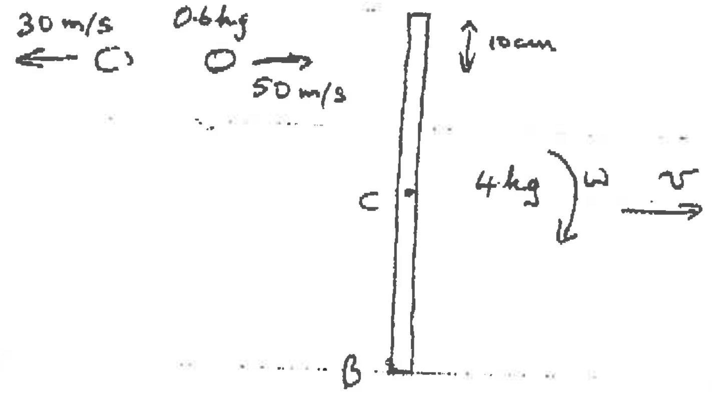
$$= \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{3.02 \times 10^{-19}}$$

$$= 656 \text{ nm}$$

1\.

(a)

(i)



$I = 0.24\ kg\ m^2$

$\Delta p = p_f - p_i = -30 \times 0.6 - 50 \times 0.6$

Change in momentum $= -$ <u>48 kg. m. s^{-1}</u>

(ii) Angular momentum of ball about C before collision

$= p.\ r$

$= 0.6 \times 50 \times 0.2 = $ <u>6 kg. m^2. s^{-1}</u>

(b)(i) Using conservation of momentum

momentum before = momentum after

$0.6 \times 50 = -0.6 \times 30 + 4 \times v$

$4v = 0.6 \times 80$

$v =$ <u>12 m.s^{-1}</u> Velocity of Centre of M

(ii) Using conservation of angular momentum about point C

angular momentum before = angular momentum after

$0.6 \times 50 \times 0.2 = -0.6 \times 30 \times 0.2 + 0.24\ \omega$

$9.6 = 0.24\omega$

$\omega = 40$ rad/sec

Angular velocity = <u>40 rad/sec.</u>

(iii) Linear motion gives B a velocity of $12\,ms^{-1}$ to right.

Rotation gives B a velocity ωr to left

where $\omega r = 40 \times 0.3$

$= 12\ m\ s^{-1}$

Hence initial velocity of B is <u>zero.</u>

(c). Energy loss = Initial KE − Final KE(ball + rod) − Final RE of rota

$= \frac{1}{2} \times 0.6 \times (50)^2 - \frac{1}{2} \times 0.6 \times (30)^2$

$- \frac{1}{2} \times 4 \times (12)^2 - \frac{1}{2} \times 0.24 \times (40)^2$

$= 750 - 270 - 288 - 192$

$= 0 \text{ J}$

No energy lost in collision.

2(a)(i) The magnitude of the upthrust force on the floating object is equal to the weight force on the liquid displaced.

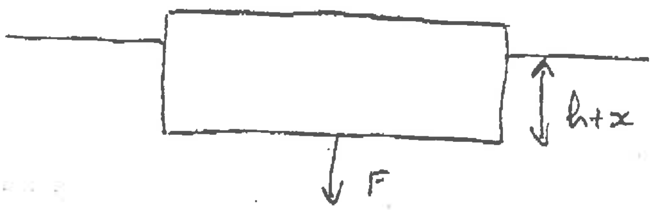
(ii) Apply $\Sigma F = ma$ to block vertically

Gravity force down − upthrust = 0

$\rho_w H A g - \rho_f h A g = 0$

$\therefore \quad h = \frac{\rho_w}{\rho_f} H$ ——— (1)

(b)



Apply $\Sigma F = ma$ to block vertically

F + gravity force down − upthrust = 0

$F + \rho_w H A g - \rho_f (h+x) A g = 0$

$\therefore \quad F = \rho_f A g x + \underbrace{\rho_f h A g - \rho_w H A g}_{\text{cancel using (1)}}$

$\therefore \quad F = \rho_f A g x$

(c)(i) When the string is cut the force $\rho_f A g x$ is not balanced and is a restoring force on the block. Since the restoring force is proportional to the displacement the motion will be SHM.

(ii) Acceleration of block $= \dfrac{\rho_f A g x}{\text{mass}}$

$$= \frac{\rho_f A g x}{\rho_W A H}$$

$$= \frac{\rho_f g}{\rho_W H} x$$

$$= \frac{g}{h} x \qquad \text{using (1)}$$

Standard SHM equation has
acceleration $= -\omega^2 \times$ displacement
where $\omega = \dfrac{2\pi}{T}$ and T is the period.

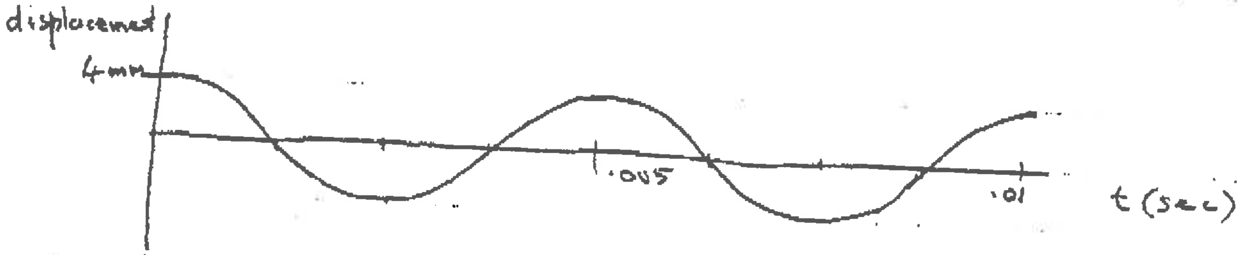
$$\frac{g}{h} = \left(\frac{2\pi}{T}\right)^2$$

$$T = 2\pi \sqrt{\frac{h}{g}} \qquad \text{or } T = 2\pi \sqrt{\frac{\rho_W H}{\rho_f g}} \checkmark$$

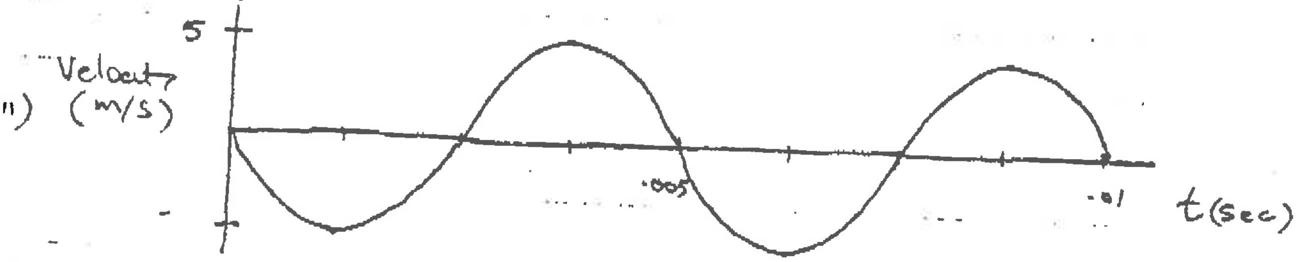
(d) Mass moving in SHM is now increased but restoring forces remain the same.
Hence acceleration is reduced
hence period is increased.

3 (a) 200 Hz $\quad T = \frac{1}{200} = .005$ sec

(i)



(ii)

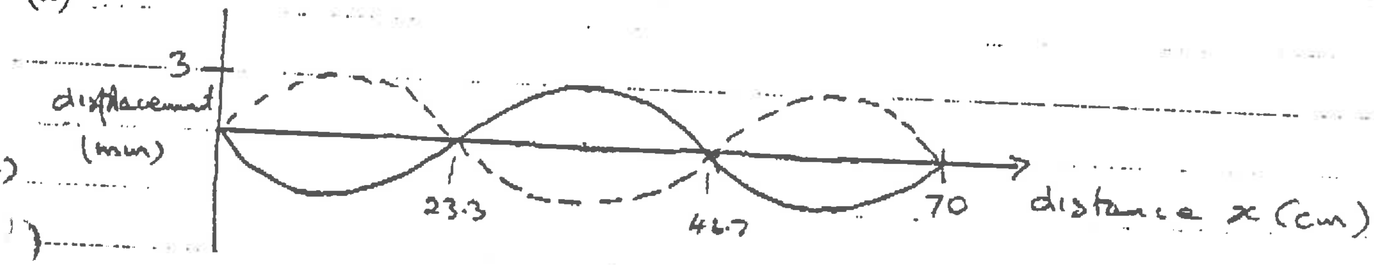


$V_{max} = \omega A = \frac{2\pi}{.005} \times .004 = 5.03$ m/s

b (i) Frequency of 3rd harmonic = 600 Hz

Period $= \frac{1}{600} = 1.667$ ms.

(ii)



(iii) 0.83 ms is half the period.

(iv) Maximum acceleration $= \omega^2 A$

$= (2\pi \times 600)^2 \times .003$

$= 42.6 \times 10^3$ m.s^{-2}

(c) In fundamental the string length is $\frac{\lambda}{2}$

$\therefore \frac{\lambda}{2} = 70$ cm.

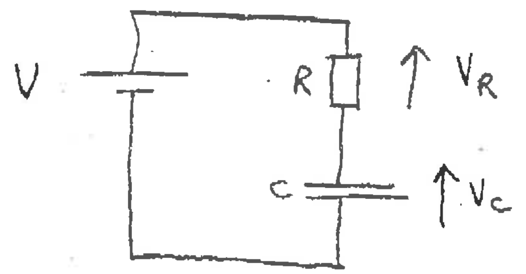
$\lambda = 1.4$ m.

$v = f\lambda = 1.4 \times 200 = 280$

$\therefore$ velocity = 280 m.s^{-1}

4(a)(i) Initially there is no charge on the capacitor and no voltage across it.
When the switch is closed the charge builds up on the capacitor and the voltage increases.
This reduces the voltage across the resistor and so the current changes with time.
Current flow stops when the capacitor has the same voltage as the batte

(ii)



$$V_R = i(t)\,R$$
$$= i_0 e^{-\alpha t} R$$

$$V_c = V - V_R = \underline{V - i_0 e^{-\alpha t} R} \quad \text{——— (1)}$$

(iii) Charge on capacitor given by

$$q(t) = \int_0^t i(t)\,dt$$
$$= \int_0^t i_0 e^{-\alpha t}\,dt$$
$$= i_0 \left[\frac{-1}{\alpha} e^{-\alpha t}\right]_0^t$$
$$= \frac{i_0}{\alpha}\left[-e^{-\alpha t} + 1\right]$$

But "$Q = VC$"

$$\therefore \quad V_c = \frac{q(t)}{C} = \frac{i_0}{\alpha C}\left[1 - e^{-\alpha t}\right]$$

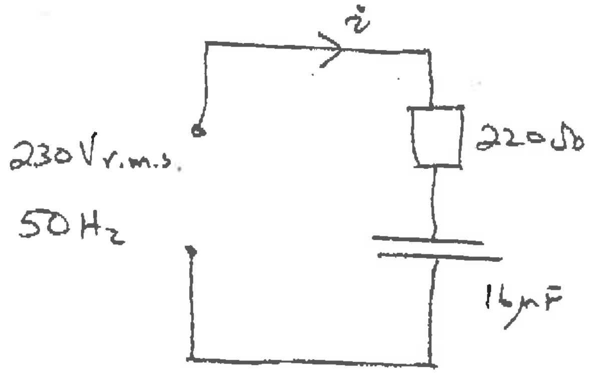
$\therefore$ Using (1) $$\frac{i_0}{\alpha C}\left[1 - e^{-\alpha t}\right] = V - i_0 e^{-\alpha t} R$$

These are equal if $\frac{i_0}{\alpha C} = V$ and $\frac{i_0}{\alpha C} = i_0 R$

Hence $\alpha = \frac{1}{RC}$

(b)

(i)



$V_R = i \times 220$

$V_c = \frac{i}{\omega C} = \frac{i}{2\pi \times 50 \times 16 \times 10^{-6}} = i \times 199$

$V_{TOTAL} = (V_R^2 + V_c^2)^{1/2}$

$230 = i\,(220^2 + 199^2)^{1/2}$

$i = 0.775$

∴ RMS Current is **0.775 amp.**

(ii) "Power $= i^2 r$"

$= (0.775)^2 \times 220$

∴ Power $=$ **132 W**

5.(a)(i) Energy = Work done = "$q \times V$"

$= 1.6 \times 10^{-19} \times 2000$

$= 3.2 \times 10^{-16}$ J

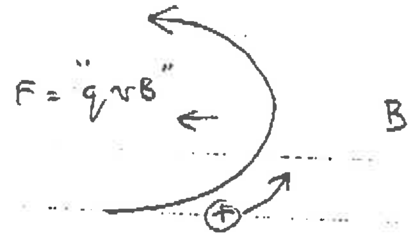
But Energy = "$\frac{1}{2} m v^2$"

$\therefore v = \left(\frac{2 \times 3.2 \times 10^{-16}}{1.98 \times 10^{-25}} \right)^{1/2}$

$= 5.685 \times 10^4$

$\therefore$ Speed = 5.68×10^4 m.s^{-1}

(ii)



Using "$\Sigma F = ma$"

$q v B = \frac{m v^2}{r}$

$\therefore B = \frac{m v}{r q}$

$= \frac{1.98 \times 10^{-25} \times 5.685 \times 10^4}{0.7 \times 1.6 \times 10^{-19}}$

$= 10.05 \times 10^{-2}$

$\therefore$ Magnetic field is 0.1005 Tesla

Direction into the page.

b (i) Flux = "B A"

$= 3 \times 1.2 \times 1.2$

$= \underline{4.32 \text{ Weber}}$

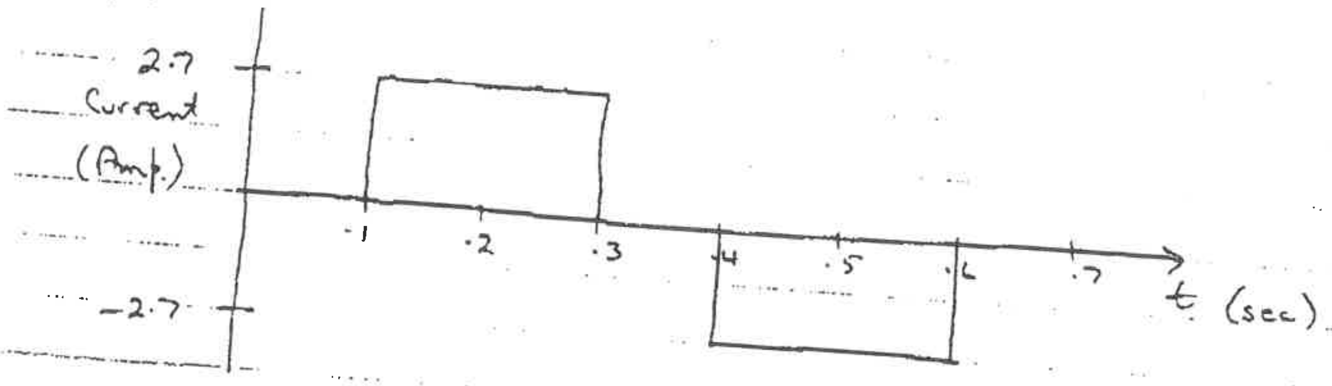
(ii) $\text{Voltage} = \dfrac{\Delta \phi}{\Delta t}$

$\Delta t = \dfrac{1.2}{6} = 0.2 \text{ sec}$

$\therefore \text{Voltage} = \dfrac{4.32}{0.2} = 21.6 \text{ V}$

$\text{Current} = \text{"}\dfrac{V}{R}\text{"} = \dfrac{21.6}{8} = \underline{2.7 \text{ Amp.}}$

(iii)



6 (a) Photons in the light give their energy to electrons in the metal. These photo electrons are emitted from the metal surface and can travel across to the plate P. This produces a current flow in the ammeter.

(b) When M is positive with respect to P the photo electrons experience an electric field which acts to decelerate them. Therefore only the most energetic photo electrons reach P and the current is reduced. When the voltage V is large enough no electrons reach P and the current drops to zero.

(c) (i) Since the energy of a photon is $h\nu$ where h is Planck's constant photons of higher frequency have higher energy and give photo electrons of higher energy. Hence a larger voltage V is required to reduce the current to zero.

(ii) Energy of photon = Energy of electron + Work required to escape from

$$h\nu = eV_c + \phi$$

ϕ is Work function i.e. minimum energy for an electron to escape from metal surface.

V_c is cutoff voltage corresponding to frequency ν

e is electron charge.

ANY <u>TWO</u> OF THESE

6(d) Photo electrons are emitted immediately the light is turned on even when the light intensity is very low. Wave theory would require time for energy to build up. Quantum theory says each photon has energy $h\nu$ whatever the light intensity.

The cutoff voltage would not exist in wave theory because an electron could always get more energy by absorbing for a longer time. Quantum theory says there is a maximum energy for the electron equal to $h\nu$ minus the work function.

If the frequency of the light is too low

i.e. $h\nu < \phi$

then no photo electrons are produced whatever the light intensity.

In wave theory some photo electrons would always be produced.