NZEST SCHOLARSHIP EXAMINATION

1996 EXAMINER'S REPORT AND SOLUTIONS

PHYSICS

New Zealand Education and Scholarships Trust

1996 PHYSICS EXAMINER'S REPORT

STATISTICS

There were 595 candidates.
The top score was 86, the upper quartile was 53, the median 42 and the lower quartile 30.
The lowest mark was 3.

GENERAL COMMENTS

The questions were chosen or conceived within the real world of sunsets, lifts, Coke cans, ink-jet printers, cycling, trampolines, boating, solar cells, microwave ovens and power points. This, to match the current focus on situations from 'life'. As most physics teachers appreciate, real-world situations are usually complicated or blurred by multiple effects and what is seemingly obvious or taken for granted is not quite so obvious, nor quickly explained, especially in words. But some situations are and a selection is here.

Again the exam stressed concepts, ignored errors and - for lack of space - omitted modern physics. Hand-drawn pictures and diagrams were used - if only to remind us that physics is first and foremost a human endeavour and the exam was set not by a computer but by a human being (I think), moderated by humans, for humans. Physics is an experience, whether in the lab, or out in the world, and that viewpoint underpins this paper. The exam was designed as an opportunity for a student with a curiosity about the physical world, a passion for physics and a good understanding of the concepts to display those attributes. To do this it was necessary to demonstrate mathematical competence and the ability to construct a meaningful sentence.

The ten compulsory questions were broken into numerous parts with the early parts intended to be easier than the later parts. To score well, candidates needed to demonstrate.competence in algebraic manipulation - that is, to use mathematics confidently and quickly, as the need arose.

The results indicate that the exam and the candidate cohort were mismatched by about 10%, the median mark being lower than desired. Markers comments indicate that the exam was probably too long rather than too hard.

The remarks that follow are a fusion of two contributions: one, an explanatory comment by the examiner and the second from the marking panel based on their experiences.

COMMENTS ON QUESTIONS AND ANSWERS

Question 1 (535 attempts: mean 8.1 out of 17marks)

Part (a) is the opener for chap.1 of Halliday and Resnick's *Fundamentals of Physics* , 4th edition, (Wiley). Its appeal (to the examiner) was the simplicity of the concept and the astronomical result - literally - all in a few lines of understanding. Fairly well done. Some (candidates) reversed the calculation in a(ii) and showed that the given result fitted the equation. This was accepted. In (b)(i) the velocity was usually calculated first, followed by the period. The extensions, parts (ii) and (iii) proved difficult, as was intended.

Question 2 (529 attempts: mean 5.9 out of 14)

Surprisingly, the least popular question. The 'scales in the lift' graph is a cleaned-up version of real data taken with a Pasco strain-gauge force transducer and a battery-powered data logger. (Lifts are notoriously short on power points.) Much confusion in the answers between mass, weight and force. Perhaps the time to clear these ideas up is with the young, aged say 8 or 9 years. Also, a visit to the weights/pulleys section of a gymnasium, with some bathroom scales and a spring balance, might help here. Most candidates did not distinguish between 'moving up' and 'accelerating up'. The graphs presented a few problems and quite a few could not calculate the area under a graph.
In (b) most candidates stated that the acceleration was g in a vacuum and then added that, since the the drag was the same for both cans (same shape), the cans hit together. They don't, of course, and the difference is easily seen; from a four storey building the full can will hit with the empty can a floor behind.

Question 3 (549 attempts: mean 7.0 out of 21)

This is a fairly full package of SHM concepts combined with those of gravitational and elastic potential energy. The analysis applies to both bungy jumping and leaping onto floating buoys; in these contexts the question has appeared in previous scholarship papers. Because of the quadratic equation delivered up by the analysis one needs a certain amount of mathematical confidence to see the problem through. In a(iii) the failure to include Δx was a serious omission and there was a tendency to involve the KE rather than recognise that, at the start and the finish, the KE was zero - so just GPE and·EPE were involved. About 20 or so students managed the 'time-of-flight' calculations and got near-full marks. Most students, relying on intuition, picked up the easier marks at the end without quite clarifying why it was so.

Question 4 (544 attempts: mean 9.6 out of 18)

A question on the mechanics of cycling - which produced the highest mean mark. Part a(i) was well done although many could not state why the contribution to I from the axle was negligible (if r is small then r^2 is even smaller). In (ii) torque was confused with tension. Part (iii) was often misunderstood with many answering 20 x 2 = 40 instead of $\left(\frac{0+20}{2}\right).2 = 20$. In b(ii), the rotational KE found in a(iv) was often left out. Overall, candidates showed familiarity with the equations but were a little unsure of their application.

Question 5 (530 attempts: mean 5.8 out of 16)

This question on the ubiqitous ink-jet printer wasn't popular and had a low mean mark. What was done was done quite well but much wasn't attempted. Cracks in the arguments appeared around b(ii) where many candidates insisted on using $v = \omega r$ and got into strife. In (iii) (predictably) half the candidates drew the circular path the wrong way and many placed the circle centre within the field. The extension at the end was too subtle for all.

Question 6 (593 attempts: mean 6.2 out of 13)

The most popular question. Part (a) is based on a graph of the Doppler shift of an aircraft passing overhead; the plot appeared on the cover of *The Australian and New Zealand Physcist* a couple of years ago. When the height is zero the Doppler graph is squared up, as shown. The directive 'not to use maths' was to steer candidates away from the somewhat involved calculation of an intuitive result. A suitable, related and simpler calculation appears in (ii). Most coped with (a) while, with (b), either the mass, or the wavelength, or both, were incorrectly calculated so that the frequency was in error. Most candidates did not recognise the standing wave character of the lumps in the microwave oven while, of those that did, 3 'lumps' in the oven was a common answer, instead of 6. Most candidates had a vague awareness of how the heat was produced. A question for the curious.

Question 7 (550 attempts: mean 4.8 out of 15)

Most students found this question very difficult and the mean mark was accordingly low. It was included as a high level discriminator. A clear understanding of the induction laws is required to solve it. Unhappily, after sorting out (a) reasonably well, many candidates could not get out b(i), which is mechanics. Part (ii) was understood but part (iii) proved difficult. It comes out quickly with $\varepsilon = Blv$ although the flux method of part (a) is also quick and, in this instance, preferred. The $\cos(\theta)$ term was a puzzle to most while, in b(v), few realised that the zero-force condition implies constant velocity. Incidentally, in the examiner's opinion, the induction laws are 1) few, 2) simple and 3) powerful.

Question 8 (582 attempts: mean 6.8 out of 16)

Parts (a) and (b) are from Barber and Osborne's *Advanced Senior Physics*, a rich source of schol-level questions. The stumbling block in (a) was part (ii) where few could manage a complete answer. Part (ii) of (b) requires the candidate to visualise the travelling blobs of beats. Strangely, many got (i) and (ii) out but not (iii). Perhaps the answer provided was a distractor. Part (c) was open-ended, providing the markers with plenty of work. A few candidates believed the wave really mimicked a wire wave; it is easy to identify a mass but the tension is probably more emotional than mechanical.

Question 9 (554 attempts: mean 6.3 out of 13)

Quite well done although some would have electrocuted themselves - or blown a fuse. Not many mentioned the interchangeability of A and B to 2 and 3. About half attempted the 28.3V calculation and half the candidates got the time scale correct, some preferring 60Hz. The peak value of the 'mains' was often assumed to be 240V which, coupled with the time scale/frequency confusion, is reason enough to ask this same question - on essential knowledge - next year. The answers to (iii) showed the behaviour of a diode is well understood. The power calculation was very poorly done, even allowing for the factor of one-half which most missed. In (b) many candidates offered wave diagrams instead of phasor diagrams but the 90° phase angle was quite well known. The markers had the impression that candidates were not analyzing the problem but trying to remember a diagram they had once seen. The question was generously marked.

Question 10 (551 attempts: mean 8.6 out of 17)

This solar cell experiment is easy to set up, quick to perform, reveals some interesting principles and offers the bonus of a social revelation, namely, that society should not place its hopes on solar power, in this form, just yet. Some of the marks were easy, were the graph correctly read. In (a)(iii) the ghost of the Maximum Power theorem lurks; it is too hard to ask directly at this level, but it's there. Only part (vii) proved difficult; it requires an awareness that the battery will hold the potential down to 12V by drawing current from the source and dropping volts through the source's internal resistance. Most took the two marks for (viii). Incidentally, the diode is not necessary to stop reverse current because a solar cell is inherently reverse-biased anyway. The mean mark was second-highest for this question.

COMMENTS ON TEACHER EVALUATIONS

After penning the notes above the examiner received evaluations from twenty one teachers. The evaluations were a rather nice Christmas offering, with the exam being warmly received by each and every one. Coming from the nation's top physics teachers as they did, these comments were very reassuring.

Almost all evaluations noted the lack of a modern physics component and that is acknowledged with an apology. The difficulty with modern physics is that it seems a pretty bare cupboard for real-life problems and nothing with any character came to mind, or was uncovered. However, there are undoubtedly questions there, and this will be corrected in 1997, probably at the expense of mechanics. Other than that, the exam was very well received apart from two comments which passed over my shoulder, and kept going: "personally, I thought it was great mathematical physics" and another: "not enough real-life situations".

I'd like to reply to the query on the meaning of the words 'argue' or 'comment' in the questions. 'Argue' means, lay down a small path of reasoning, using physics concepts, which leads to the conclusion suggested. 'Comment' means that the answer/conclusion you have just reached seems unusual and a clarification is required.

Many thought the exam on the easy side although many recognized that some of the questions, like good wine, had an after taste, possibly vinegary. Others, including the marking panel, thought the exam too long while the 'evaluations' thought the length just right. Thus did opinion oscillate.

The comments being as positive as they were leaves the examiner between a rock and a hard place, because the candidates found it a tad hard. So if next year's exam is easier, to satisfy the perceived need of the candidates, it will not meet with teacher approval, nor even mine. This we have to accept because, in the end, it's the candidates who matter most - and they have the numbers.

Finally, my thanks to the NZEST Office for the splendid organisation, to the moderators for the wisdom and moderation of their criticism and to the marking panel for their strength and dedication. And, if you get the opportunity, push a couple of Coke tins off the science building.

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PHYSICS MARK SCHEME

NZEST 1996

QUESTION 1

(a) (i) 24 hours = 24 x 60 x 60 $\equiv 360°$

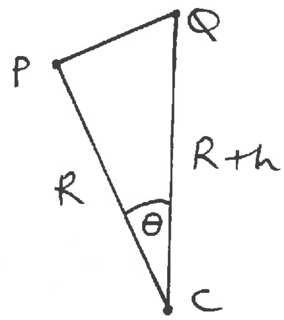
$$\Rightarrow 11.1 \text{ s} \equiv \frac{11.1}{24 \times 60 \times 60} \times 360°$$

$=0.0463°$

[2 marks]

(ii) In the triangle CPQ, QC = $R+h$ and PC = h.

$$\therefore \cos\theta = \frac{R}{R+h}$$



[1 mark]

(iii) If $\cos\theta = \dfrac{R}{R+h}$ then $\sec\theta = 1 + \dfrac{h}{R}$ = 1.000 000 327 (calculator)

$$\therefore \frac{h}{R} = 3.27\ 10^{-7}$$

$$\therefore R = 2.07 / 3.27\ 10^{-7} = 6.34\ 10^{6} \text{ m}$$

[4 marks]

(b)(i) A person at the equator is in circular motion around the Earth's centre. Circular motion requires a force to the centre of the circle. This small force, currently, is provided by a small fraction of the person's weight. However, if the Earth rotated faster a greater force would be required and, at the limit, this force will be the person's weight. The person is then 'weightless' since, when placed upon scales, the reading would be zero there being no force 'left over' to accelerate to Earth

$$\therefore mg = \frac{mv^2}{R} \Rightarrow v^2 = Rg$$

$$\therefore v^2 = 6.34\ 10^{6} \text{ x } 9.8$$

$$\therefore v = 7.88\ 10^{3} \text{ m/s}$$

$$\therefore T = \frac{2\pi R}{v} = 5.05\ 10^{3} \text{ s}$$

$= 1.40$ h

[5 marks]

(ii) From part (i) we can write:

$$mv^2 / r = m\omega^2 r = \text{constant} \times \text{r} .$$

This tells us that the force for circular motion tends to zero at the poles since the effective radius $r \to 0$. Or one could argue that, at the poles, there is no requirement of a centripetal force since there is no circle. The result is that, full weight force is available at the poles for any rotation speed of the Earth.

[2 marks]

(iii) An atmosphere could not exist at the equator at this rotation speed since there is no attractive force left to hold it on the surface; neither would an atmosphere exist at the poles because gas molecules, although held to the Earth by their full weight at the poles, would spread (diffuse) from the polar region toward the equator and, in the process, be lost, as they slowly acquired rotational speed. [3 marks]

QUESTION 2

(a)(i) Up. The scales measure the reaction force between the lift and the person. At rest, the reaction (up) equals the person's weight (down): $R = mg$. To accelerate upwards, the reaction must exceed the weight which, as the graph shows, it does at the start for a brief period. When the lift has reached a constant speed the reaction again equals the person's weight. Similarly, at the finish when stopping, the reaction is less than the weight.

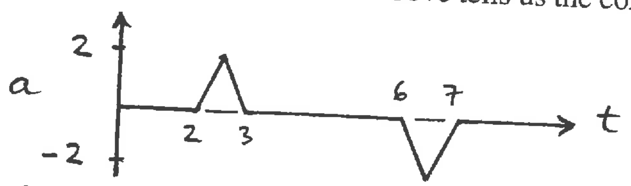
[2marks]

(ii) The effective weight has increased by about one fifth due to the upward acceleration; it is as though g has increased, reaching a maximum value a fifth larger than usual. Hence a is ~ 9.8/5 ~ 2 m/s^2.

Alternatively, $R - mg = ma$, where a is the upward acceleration. Noting that R_{max} = 59 x 9.8 Newtons and mg = 49 x 9.8 we calculate $a = (R - mg)/m$ = 98/49 = 2 m/s^2.

[2 marks]

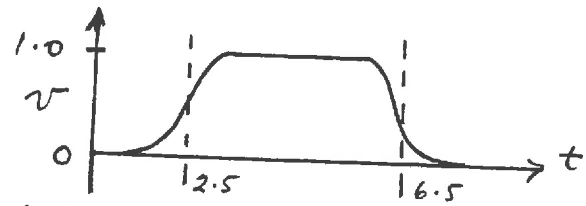
(iii) The acceleration / time graph can be drawn from the 'reaction' graph; it consists of two triangular shapes. The calculation above tells us the correct scale.



[2 marks]

(iv) The area of a triangle in the a/t graph gives the velocity change during that period of acceleration. The area of a triangle is 0.5 (base x height), hence the steady velocity of the moving lift is 0.5 x 2 x 1 = 1 m/s.

The velocity time graph is the integral of the a/t graph and it can now be sketched and scaled correctly. For an estimate, the curved parts at the start and finish do not need detailed consideration.



The area under the v/t graph gives the displacement and we can approximate this by a rectangle lasting from 2.5 s to 6.5 s and with height 1 m/s. Hence the displacement between stops is (6.5 - 2.5) x 1 = 4 m.

[4 marks]

(b)(i) In the absence of air resistance the cans will hit together, accelerating with g throughout the fall. In the presence of air resistance the heavier can lands first because the resistance is less significant with the heavier can than with the lighter can and the acceleration is, therefore, closer to g.

This can be presented symbolically: Let R be the resistance to motion. Then the force down is $F_L = mg - R$, for the light can, and $F_H = (m+M)g - R$, for the heavy can, M being the weight of liquid. So the accelerations are:

$$a_L = \frac{F_L}{m} = g - \frac{R}{m}$$

$$\text{and } a_H = \frac{F_H}{(m+M)} = g - \frac{R}{(m+M)}$$

Because of the second term, $a_H > a_L$, always. Hence the heavy can will outrun the light can.

[4 marks]

QUESTION 3

(a)(i) The spring constant, k, is determined by the numbers given:

$k = F/x$ = (70 x 9.8) / 0.33 = 2080 N/m

[1 mark]

(ii) The period T is then given by:

$$T = 2\pi\sqrt{m/k} = 2\pi\sqrt{70/2080} = 1.15\,s$$

[1 mark]

(iii) Energy conservation applies here: the loss of GPE by the gymnast equals the EPE taken up by the stretched mat. Thus, if the depression of the mat is called Δx we can write:

$$mg\,(h + \Delta x) = \tfrac{1}{2}\,k\,\Delta x^2$$

or

$$70 \times 9.8\,(1.5 + \Delta x) = \tfrac{1}{2}\,2080\,\Delta x^2$$

whence

$$1040\,\Delta x^2 - 686\,\Delta x - 1029 = 0$$

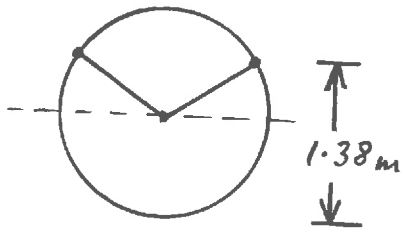
Thus

$$\Delta x = \frac{686 \pm \sqrt{686^2 + 4 \times 1040 \times 1029}}{2080}$$

for which the positive root is $\Delta x = 1.38\,\text{m}$

[4 marks]

(iv) The equilibrium position is where the mat settles when stood upon by the gymnast. Hence $H_o = 0.33\,m$, as noted at the start of the question.



$$H_0 + R = 1.38$$

$$\Rightarrow R = 1.38 - 0.33$$

$$= 1.05\,m$$

[3 marks]

(v)

$$\alpha = 180 + 2 \times \sin^{-1}\left(\frac{0.33}{1.05}\right)$$

$$= 217°$$

[2 marks]

And the time in the air = 2 x t_{fall} where $t_{fall} = \sqrt{2h/a} = 0.5533$ s.

Therefore, the time in the air is 1.106 s.

Thus, total time = 1.107 + 0.693 = 1.800 s. [4 marks]

(vii)(1) It increases.

The greater E_p at the top $\Rightarrow$ greater E_k at the bottom $\Rightarrow$ greater mat displacement.

(2) No change. [2 marks]
Unless the gymnast gains or loses energy in the bounce, energy conservation requires that the height remains unchanged.

(3) It increases. [2 marks]
The time above the mat is the same but the time in contact with the mat is increased due to the increased depression and, as well, the period of this motion is larger since it is proportional to $\sqrt{m}$. [2 marks]

QUESTION 4

(a)(i) $I = mr^2 = 10 \text{ x } 0.4^2 = 1.6 \text{ kg m}^2$.

The value of r^2 for the axle is 0.0025 and this, plus the small axle mass, means the contribution to the rotational inertia is negligible.

[3 marks]

(ii) $Fr = I\alpha = I\dfrac{\Delta\omega}{\Delta t} \Rightarrow F = \dfrac{I\,\Delta\omega}{r\,\Delta t} = \dfrac{1.6\times 20}{0.05\times 2} = 320 \text{ N}$ [3 marks]

(iii) $\theta = \frac{1}{2}(\omega_f - \omega_i)\,t = \varpi\, t = 20 \text{ rad}$

[1 mark]

(iv)

$$E_k = \tfrac{1}{2}I\omega^2 = \tfrac{1}{2}\times 1.6\times 20^2 = 320 \text{ J}$$

$$L = I\omega = 1.6\times 20 = 32 \text{ kg m}^2 \text{ rad / s}$$

[2 marks]

(b)(i) $v = r\omega = 0.420\times 20 = 8.4 \text{ m / s}$

[2 marks]

(ii)

$$E_k(tot) = E_k(trans) + E_k(rot)$$

$$\therefore E_k(tot) = \tfrac{1}{2}mv^2 + \tfrac{1}{2}I\omega^2$$

$$= \tfrac{1}{2}\times 200\times 8.4^2 + \tfrac{1}{2}\times 1.6\times 20^2\times 2$$

$$= 7056 + 640 = 7696 \text{ J}$$

[2 marks]

(iii)

$$\omega = \tau\theta$$

$$\therefore 7696 = 320\times 0.05\times \theta$$

$$\Rightarrow \theta = 481 \text{ rad}$$

(iv)

[2 marks]

$$\omega^2 = \omega_0{}^2 + 2\alpha\theta$$

$$\therefore \alpha = \frac{20^2}{2\times 481} = 0.416 \text{ rad / s}^2$$

and

$$\omega = \omega_0 + \alpha t$$

$$\Rightarrow t = \frac{20}{0.416} = 48.1\text{s}$$

[3 marks]

QUESTION 5

(a)(i) Ignore gravitational effects. Since $F=Eq$ and $a=F/m$ we have $a = Eq/m$.

[1 mark]

(ii) Since there is no acceleration in the x direction, the time to pass through the plates is $t = s/v = L/v_x$.

In the y direction we have:

$$s = ut + \tfrac{1}{2}at^2 \quad \text{and } u = 0$$

$$\text{hence } y = \tfrac{1}{2}\frac{Eq}{m}\frac{L^2}{{v_x}^2}$$

[3 marks]

(iii) $y = \dfrac{1.2\times10^{-13}}{2\times10^{-10}}\dfrac{14000}{0.01}\dfrac{0.016^2}{18^2} = 0.664 \text{ mm}$

[3 marks]

(iv) $n = \dfrac{q}{e} = \dfrac{1.2\times10^{-13}}{1.6\times10^{-19}} = 750\,000$

[1 mark]

(b)(i) The force, F, on a moving charged particle in a magnetic field is perpendicular to the velocity vector $\boldsymbol{v}$ (and to $\boldsymbol{B}$) and, if B is constant, then the magnitude of F is constant; these are the necessary two conditions for the particle to execute a circular path (or part of it).

Use $F(magnetic) = Bqv$, which equals $F(circular) = mv^2/r$, to get $r = mv/Bq$.

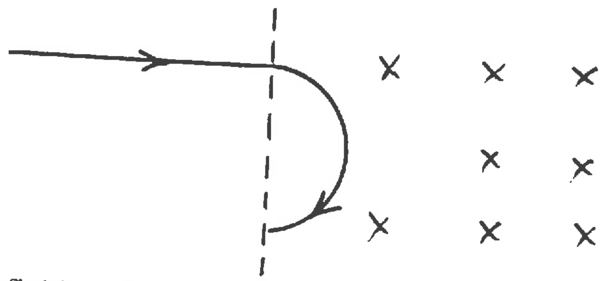
[2 marks]

(ii) Time for drop to execute a semicircle is $t = \pi r/v$, but $v = rBq/m$ (above) , therefore $t = \pi m/Bq$.

[2 marks]

(iii) The particles are negatively charged since electrons have been added to neutral drops. Accordingly, using the 'right hand slap rule' or similar, the path is a semicircle 'downwards'.

[2 marks]



(iv) The definition of work is $W = \boldsymbol{F}.\,\boldsymbol{ds}$. In the magnetic case the force vector on the particle ($\boldsymbol{F}$) is always at right angles to the velocity vector ($\boldsymbol{v}$). But $\boldsymbol{v} = \boldsymbol{ds}/dt$ so $\boldsymbol{F}$ is at right angles to $\boldsymbol{ds}$. Hence no change in the KE, and therefore no change in the magnitude of v because no work is done - although v changes direction.

[2 marks]

QUESTION 6

(a)(i) $f' = (480 + 430) / 2 = 455$ Hz

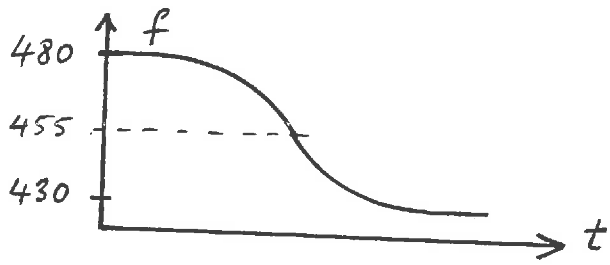
[1 mark]

(ii) $f' = cf/(c-v)$ where the negative sign applies because the boat approaches.

Thus $v = -\frac{cf}{f'} + c = 330 - 330 \times \frac{455}{480} = 17.2\ \text{m/s}$

[2 marks]

(iii)



[2 marks]

(b)(i)

$f_o = v/\lambda$ and $\lambda = 2L = 12$ m

$\Rightarrow f_o = \frac{1}{12}\sqrt{\frac{9000}{0.05}} = 35.4$ Hz

[2 marks]

(ii) Other frequencies are $2f_0, 3f_0$, etc ie 70.8 Hz, 106.2 Hz etc., all of which are associated with faster vibration of the wire than with f_0. The damping increases with velocity so the higher frequencies in the vibrating wire suffer stronger damping and tend to die away quicker leaving the more persistent f_0.

[2 marks]

(c)(i) $\lambda = \frac{c}{f} = \frac{3\times10^8}{2.25\times10^9} = 0.133$ m

0.4 m is 3λ so standing waves are produced in the metal box (the fields have nodes at the walls). There are six 'field lumps' - antinodes - across the box.

Maximum heating occurs where the fields are largest - which is at the standing wave antinodes.

[2 marks]

(ii) The distribution of positive (nuclear) and negative (electron) charge of a water molecule is not 'balanced', one end of the molecule being more positive than the other. Thus the molecule is the electrical equivalent of a magnetic compass needle. The oscillating electric (microwave) field in the oven chamber causes the 'dipole' molecule to vibrate / rotate at the field frequency - or try to. This is substantially prevented by the molecule 'rubbing' against neighbouring molecules, thereby generating heat.

[2 marks]

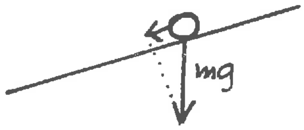
QUESTION 7

(a)(i) $\mathcal{E}$ is the induced emf, or induced voltage [1 mark]

(ii) ϕ is the magnetic flux linking the circuit (flux = $B.A$) [1 mark]

(iii) the induced emf opposes the change that produced it; the negative sign mathematically accounts for this. [1 mark]

(b)(i) The unbalanced force down the slope is $mg\ sin\theta$.
Hence $a = g\ sin\theta$.



[2 marks]

(ii) $v = u + at \Rightarrow v = gt\sin\theta$

[1 mark]

(iii)

$$\mathcal{E} = B_{\perp}.v.l \Rightarrow B\cos\theta.gt.\sin\theta.b$$
$$= Bbgt\sin\theta.\cos\theta$$

[2 marks]

(iv) A current will flow, generated by this emf. The direction of current is such as to 'oppose the change' ie the force on the current carrying wire acts up the slope, reducing the wire's speed.

[2 marks]

(v) At equilibrium, $F_{grav} = F_{em}$, and F_{em} on a current carrying wire is $B\,I\,l$. This force is perpendicular to B and I. In maths this becomes:

$mg\sin\theta = BIl \Rightarrow mg\sin\theta = B\cos\theta.\frac{\mathcal{E}}{R}.b$ where the last $\cos\theta$ takes account of the magnetic force being tilted at angle θ to the plane of the slope.

If the terminal velocity is v then $\mathcal{E} = B_{\perp}.v.l = B\cos\theta.v.b$

$$mg\sin\theta = B\cos\theta.vbB.\cos\theta.\frac{1}{R}.b$$
$$\Rightarrow mg\sin\theta = \frac{B^2b^2v\cos^2\theta}{R}$$
$$\Rightarrow v = \frac{mgR\sin\theta}{B^2b^2\cos^2\theta}$$

[3 marks]

(vi) A thick bar will enable eddy currents of appreciable magnitude to be established. In themselves, they can be large enough to oppose the slide. [2 marks]

QUESTION 8

(i)

$$c_{solid} = c_{vacuo} / n = 2.26 \times 10^8 \text{ m / s}$$
$$\lambda_{\text{solid}} = \lambda_{vacuo} / n = 541 \text{ nm}$$

[2 marks]

(ii) The 'built in' half-wavelength phase shift between the two reflected beams - by virtue of the different nature of the reflections - means that destructive interference of the reflected beams will obtain provided the path difference is 0, 1, 2,... wavelengths.

Thus the film thickness should be 0,1/2,2/2,.... wavelengths.

For red light, that means thicknesses of 270, 541,812nm etc
For blue light that means thicknesses of 180,360,540,720nm, etc

The (first) common thickness is 540 nm.

'Probably', because a thickness of 1080 nm would work too; any multiple of 540 nm in fact. However destructive interference will also occur for other colours as the thickness increases (eg 576 nm).

[4 marks]

(iii) Since white light has been robbed of red and blue the remaining colour will be that of the middle of the spectrum, 'greenish'.

[1 mark]

(iv) Yes, they would be. The red and blue beams constructively interfere for transmission. So, just as these colours are depleted from the reflected light they are enhanced in the transmitted light. (The transmittion effect is, however, slight because only a fraction of the intensity (say 5%) is reflected and, therefore, subject to the interference conditions; most of the beam passes straight through.)

(b)(i) Beat frequency $= f_1 - f_2 = 11$ Hz [1 mark]

[1 mark]

(ii) Distance between peaks of sound intensity = 330 / 11 = 30 m [1 mark]

(iii) The velocity of the peaks is the velocity of sound. When the sound is weakest at A it is also weak 30 m from A - toward B. But B is 50 m from A; therefore there is 20 m for the minimum to travel. That takes time $t = s / v = 20 / 330 = 0.061$ s.

[2 marks]

(c)(i) The 'wave' is transverse, as for a wire, and neighbouring masses are coupled - if only visually. However, unlike a wire wave, the masses can only move to one side (up) of the equilibrium position (seated) so only one-sided 'pulse' propagation is possible.

[2 marks]

(ii) Maybe yes, maybe no. Depends upon the legs. If all people had similar legs (same force) the answer is 'yes' because more massive individuals would take longer to stand. However, larger legs tend to go with more mass, so the answer is probably closer to 'no'.

[1 mark]

(iii) No. It is hard to imagine an spectator standing twice their height when two, similar, counter - propagating pulses pass through. [1 mark]

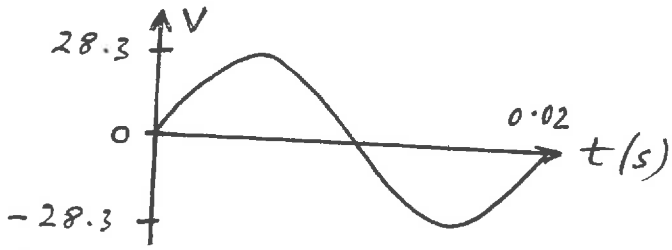
QUESTION 9

(a)(i) #1→C

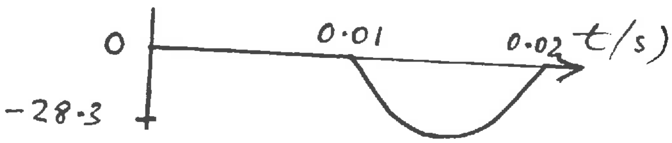
#2→B (A)
#3→A (B)

(ii) $V_{secondary} = \frac{100}{1200}.240 = 20\ V_{RMS}$ $\therefore V_{secondary}(peak) = 20.\sqrt{2} = 28.3$ V [2 marks]

Also T = 1 / f = 1 / 50 = 0.02 s.



(iii) [3 marks]

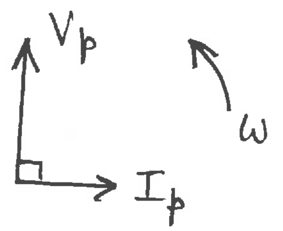


(iv) The power dissipated in the resistor is, for a complete cycle: [2 marks]

$\frac{V_{RMS}^2}{R} = \frac{20^2}{150} = 2.67$ W

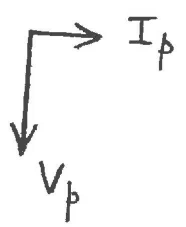
The diode cuts out half the cycle so that only half this power is dissipated in R :
$\therefore$ P_R = 2.67 / 2 = 1.33 W.

(b)(i) [2 marks]



$I_P = V_P / \omega L$

(ii) [2 marks]



$I_P = V_P \omega C$

[2 marks]

QUESTION 10

(a)(i)

$$E = IAt = 1.2\times10^3 \times 4\times 60\times 60$$
$$= 1.728\ 10^7\ \text{J}$$

[2 marks]

(ii)

$$E_{photon} = h\nu = 6.63\times10^{-34} \times \frac{3\times10^8}{5.5\times10^{-7}}$$
$$= 3.62\times10^{-19}\text{J}$$

$$\therefore n = \frac{E_{total}}{E_{photon}} = \frac{1.73\times10^7}{3.62\times10^{-19}} = 4.78\times10^{25}$$

[3 marks]

(iii) (1) $V = 0 \quad \therefore\ P = 0$

(2) $I = 0 \quad \therefore\ P = 0$

(3) $V = 1$ and $I = 2.4$ A $\therefore\ P = 2.4$ W

[3 marks]

(iv) $P_{max} = VI \approx 2.2 \text{ x } 11 \approx 24$ W

$\therefore R = V/I \approx 11 / 2.2 \approx 5\ \Omega$

[2 marks]

(v) Percent lost relative to the total energy incident on the cell = $\frac{1200-24}{1200}.100$ %

≈ 98 %

[1 mark]

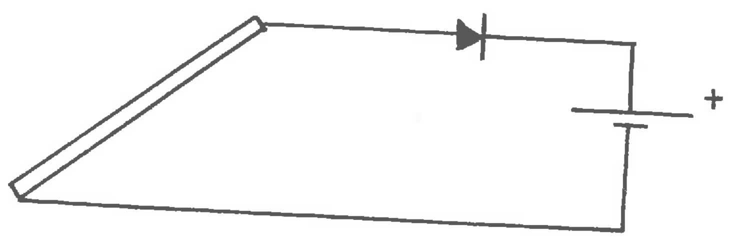
(vi) When the load resistance equals the internal resistance one half of the generated energy is lost within the cell, the other half appearing in the load. That is, 50% is lost in the cell (in this case 24 W). The energy appears as heat.

[2 marks]

(vii) At 12 V output the solar cell, according to the graph, can deliver 1.75 A. That is the current the solar cell will initially establish in the battery. (This gradually decreases as the battery charges and its emf rises above 12 V.)

[2 marks]

(viii)



[2 marks]

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