NZEST SCHOLARSHIP EXAMINATION

1995 EXAMINER'S REPORT AND SOLUTIONS

PHYSICS

New Zealand Education and Scholarships Trust

1995 PHYSICS EXAMINERS REPORT

STATISTICS

There were 481 candidates.
The top score was 99, the upper quartile was 80, the median 53 and the lower quartile 38.
The lowest mark was 4.

GENERAL COMMENTS

A change of examiner brings with it a change in style and emphasis even if the format of the exam was unchanged from 1994. The ten compulsory questions, of roughly similar length, were generally conceptual in style and broken into numerous parts. The early parts were intended to be easier than the later parts and, at some stage, pure theory was applied to a real world situation. The questions were sprinkled with diagrams, figures and photos that candidates might quickly come to terms with the concepts and geometry involved. To score well, candidates needed to demonstrate competence in algebraic manipulation and to display written explanatory skills.

The best students were well identified by the exam and the median was substantially raised above last year's result by the easier paper and more pictorial style. Nevertheless, those with less ability did not achieve quite as high a mark as was hoped.

The remarks on each question that follow are a fusion of two comments; one from the examiner with some thoughts on the question and another from the marking panel summarising their experience.

COMMENTS ON QUESTIONS AND ANSWERS

Question 1 (406 attempts: mean 4.3 out of 11marks)

The low mean indicates that students have trouble applying concepts and techniques in mechanics, about 20% showing understanding in (a) with a higher but similar figure in (b). The difficulty in (a) which is a three force statics problem seemed to be the two unknown forces. Many candidates chose to ignore the parachute force. Those who used components were less succesful than those who chose a vector triangle. The able students drew the force triangle and solved it in two lines. In (ii), the cos23 factor was (predictably) often omitted. Part (b) seemed to be easier but frequently the equation appeared with little explanation. The ability to create, and step through, a chain of reasoning with little problems like these is the hallmark of understanding.

Question 2 (460 attempts: mean 6.0 out of 10)

Generally well done and probably a confidence boost for the rest of the paper. The first part is standard stuff and was reasonably done. The formula in (a)(ii) was left visible for later use in (b) which was also well done - some lengthy but successful calculations notwithstanding. The analysis in (b) was made difficult by the reluctance of candidates to discard their SHM ideas and go back to first principles. Which is understandable. One small, courageous step is required. Incidentally, the impact oscillator in (b) is rich in 'oscillatory character', some harmonic, some chaotic.

Question 3 (402 attempts: mean 7.9 out of 12)

Candidates were generally confident with this circular motion / satellite question. Two early weaknesses revealed were a fuzzy idea of centrifugal force and the difficulty of communicating the ideas behind the geosynchronous orbit. Words often seem harder to use than the equations. Careful use of language is sure sign of ability. The same difficulty with verbal explanation was revealed later in Q5. The latitude 'puzzle' at the end was beyond most. The satellites here are for communication. The GPS satellites are closer to Earth with their 12h orbit; they could be discussed and demonstrated simultaneously (if a student has a boatie-parent?).

Question 4 (437 attempts: mean 5.0 out of 15)

The concepts here are basic and few: conservation of linear momentum in (a) and conservation of angular momentum in (b). In (a) there was a tendency to confuse total momentum with the change in momentum. Often the outcome of this confusion was zero momentum, always. The algebraic manipulation in (b), though short in length, requires a cool head to see it through. Generally the concepts were addressed correctly even though the algebra and arithmetic occasionally developed cracks. In (b)(iv) a number of candidates neglected the fact that L is constant, which leads to a quick solution, and substituted for the I and the L and slogged on to a conclusion. The work done by the children was correctly noted in (v).

Question 5   (336 attempts: mean 2.65 out of 10)

Candidates found this unattractive, attempted it last and for relatively low reward. The first part raises 'spiritual' matters in its appeal to symmetry and space. Thoughts like these, at higher and deeper levels of subtlety, pervade fundamental physics and the nature of 'interaction' and 'fields' and help to shape the mathematical form of these concepts. If the first part was aimed at the 'free thinker' the second part was designed as standard stuff. But it clearly wasn't, and the examiner is surprised. Perhaps the order of parts should have been reversed although that would have been illogical.

Question 6   (432 attempts: mean 5.6 out of 12)

The question runs through the double-slit interference pattern ideas before applying it to a real life situation. An improved version of this technique is actually used - it is known as the ILS (instrument landing system) - and a little thought tells us that such a 'beam' generating system must be used. Such is the refinement that the occasional landing in NZ, 747's included, is totally 'hands-off'. (Not advertised). A second set of aerials gives the descent beam. Candidates were familiar with the equations if not clear about the ideas in (a). Only half the candidates got the wavelength correct in (b)(i); a problem with the unit MHz? Some used the speed of sound. Some were not sure of $v = f\lambda$. Most offered something sensible for the other parts in (b); in particular, there were a number of imaginative suggestions involving Doppler, wind speed, landing from the opposite direction etc for (b) (iii). On the whole, it touched a nerve and generated a response.

Question 7   (417 attempts: mean 4.9 out of 12)

A question on magnetic effects which tests not only the clarity of understanding but the ability to express it in writing. Unfortunately, written answers take time, a little too much in the present case. Parts (a) and (b) concern induction. The details in (a) tended to be omitted or glossed over while (b) was well done. There is a disturbing apparent symmetry in (b) which suggests that the force that gives the initial lift as the field builds in the coil, also acts to pull the vehicle down when the field starts to collapse. Worth thinking about. In (c), few candidates recognised that the boat throws the water forward and therefore suffers the reaction force to that action. Newton's laws again. The Japanese have built such a boat - a photo is in Tipler's 'Physics', 3rd edit., pg 1317. There are two 'super' properties of a superconductor: (1) the dc resistance is absolutely zero (ac resistance is finite, but very small) (2) the magnetic field is excluded from the material (Meissner effect); this enables a magnet to float above a sample.

Question 8   (420 attempts: mean 5.2 out of 11)

The question has three straightforward sections which probably explains why many candidates chose to answer it first - not necessarily with success. All candidates could do one or more sections competently. In (b), the energy formulae were sometimes not recalled correctly - the examiner is not against a formula sheet to avoid this. Part (b)(ii) proved the most difficult, and here, a written explanation could have been sought as well. Problems with (c) were often associated with the candidate incorrectly reading the question, throwing in $\sqrt{2}$, not simplifying the resonance condition, etc.

Question 9 (445 attempts: mean 7.5 out of 12)

A popular question well done. Some uncertainty about the meaning of β^- was revealed but generally marks were lost for small lapses, such as leaving out the 4π in $4\pi r^2$, using 1360J for the sun's energy loss per second, repeatedly rounding off to 3SF in the decay equation rather than evaluating the equation directly, or writing down the answer to 9SF. (The calculator virus is alive and well!) The neutron technique for bone monitoring has been superseded by an X-ray method. Skeletal depletion is a serious price paid by astronauts; bone, which is piezoelectric, is considered superfluous in the absence of gravity and the body resorbs it.

Question 10 (424 attempts: mean 5.1 out of 15)

Part (a) is basic material and was well done apart from the common omission of 'max' in Emax. In (a)(ii), the work function was sometimes omitted from the equation, which leads to problems, but a pleasing number gave the correct derivation. In (b)(i) there were a few correct explanations of LASER while in (b)(ii) <u>no</u> candidate knew that laser wavefronts are flat and can therefore be sharply focused. A 'fringe' point at this level. Perhaps mentioning this in conjunction with CD manufacturing would make it memorable. Part (c) is not in the syllabus and it showed. In the subsequent lottery that was c(ii), half got the mark. Part (d) was an easy mark, generally taken.

Dr Scott Whineray
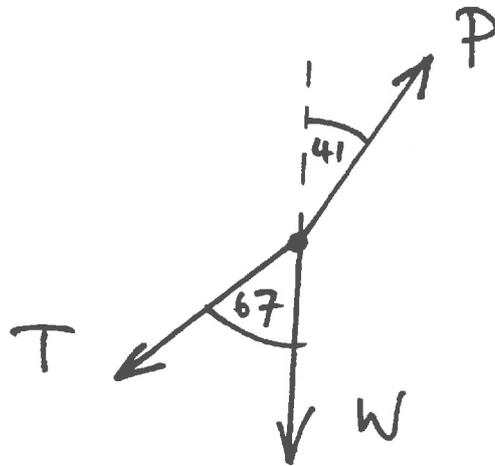Physics Department
Massey University
Albany Campus
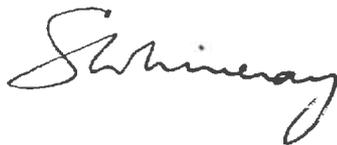
21 Nov 1995

PHYSICS SOLUTIONS

NZEST 1995

QUESTION 1

(a)　(i)　　　　　$W + T\cos 67 = P\cos 41$　　　　　　　　　　[1]
　　　　　　　　　　$T\cos 23 = P\cos 49$　　　　　　　　　　　[1]

　　　　∴　　$W + T\cos 67 = \cos 41 \cdot T \cdot \dfrac{\cos 23}{\cos 49}$　　　　[1]

　　or　　$W + 0.390T = 1.058T$
　　∴　　$W = 0.668T$　　　　　　　　　　　　　　　　　[1]

　　∴　　$T = \dfrac{55 \times 9.8}{0.668} = 806.8\ \text{N}$

(ii)　　　　$P = Fv$
　　　　　　　$= 806.8 \times \cos 23 \times 12$
　　　　　　　$= 8910\ \text{W}$　　　　　　　　　　　　　　　[2]

(b)　Time to corner $= 2 \times$ 'time up' $= \dfrac{l}{v}$　　　　　　[2]

　　'time up' given by　$h = \dfrac{1}{2}gt^2$

　　∴　　time up $= \sqrt{\dfrac{2h}{g}}$　　　　　　　　　　　[2]

　　∴　　$2\sqrt{\dfrac{2h}{g}} = \dfrac{l}{v}$

2

or $\qquad h = \dfrac{gl^2}{8v^2}$ [1]

QUESTION 2

(a)   (i)   Generally true that $F = ma$
Here, the force on m is position dependent:
$$F = -kx$$
Negative sign indicates that F is in opposite sense to x.
$$\therefore \qquad ma = -kx$$ [2]
is the governing equation.

(ii)   If one assumes $a = -\omega^2 x$ for SHM then, by comparison,
$$\omega^2 = \dfrac{k}{m}$$ [2]

$$\therefore \qquad \omega = \sqrt{\dfrac{k}{m}} \quad \text{and} \quad T = \dfrac{2\pi}{\omega} = 2\pi\sqrt{\dfrac{m}{k}}$$

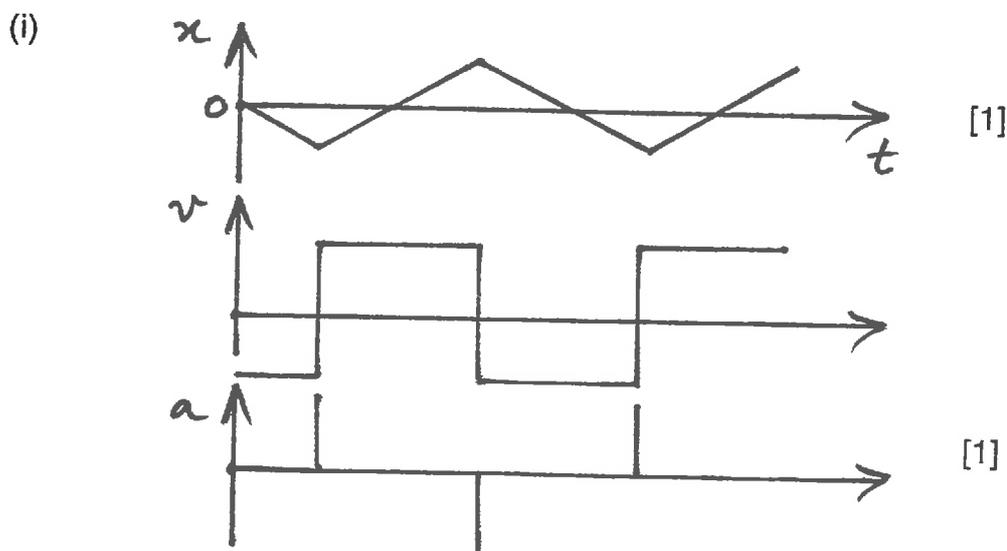Or one can start with $x = A\cos(\omega t + \phi)$ and differentiate twice to get
$$a = -\omega^2 x.$$

(b) $$\dfrac{T_1^2}{T_2^2} = \dfrac{m_1}{m_2}$$ [1]

$$\therefore \dfrac{2.5^2}{2.51705^2} = \dfrac{m}{m+1}$$ [1]

$$0.9864982 = \dfrac{m}{m+1}$$ [1]

$$\therefore m = 73.0 kg$$

(i)

[1]

[1]

3

(ii)   distance covered in one cycle = 4A
speed = v

$$\therefore\ T = \frac{4A}{v}$$ [1]

QUESTION 3

(a)   <u>Centripetal Force</u>
This is the force required to make mass m execute a circular path.
The force must be constant in magnitude and always directed ⊥ to **v**
[1]

<u>Centrifugal Force</u>
A fictitious force caused by a motion being measured in a non-inertial (circularly rotating) reference frame.

[1]

(b)   The force must be directed toward the centre of the orbit for sustained circular motion.
Orbit 1 is not stable since the force is out of the plane of the orbit;
But orbits 2 and 3 are stable.
[2]

(c)   (i)   The orbiting particle on earth's surface must move
in the <u>same plane</u> as the orbiting satellite.   [1]

Any particle on earth's surface moves in a circular orbit about the N/S axis. Of these orbits, only the equatorial one has its centre at the centre of the earth - and that, therefore, is the only one possible.
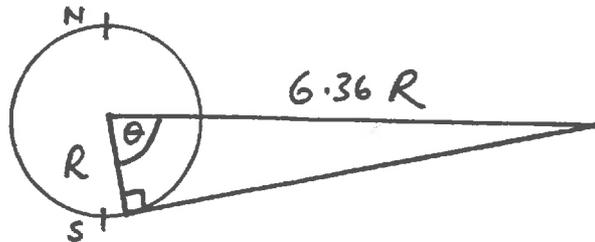[1]

(ii) $F_c = \dfrac{mv^2}{r} = m\omega^2 r = \text{force to centre} = \dfrac{GMm}{r^2}$ [1]

(iii)   Satellite must revolve once in one day
$\therefore \omega = 360^0/24$ hr

$$= \frac{2\pi}{24 \times 60 \times 60}$$

$= 7.27\ 10^{-5}\ \text{s}^{-1}$ [1]

4

(iv)

$$r^3 = \frac{GM}{\omega^2} = \frac{6.67 \; 10^{-11} \; 5.98 \; 10^{24}}{\left(7.27 \; 10^{-5}\right)^2}$$

$$\therefore \quad r = 42.2 \; 10^6 \; m \qquad \qquad [2]$$

$$\cos \theta = \frac{R}{6.36R} = \frac{1}{6.36}$$

$$\theta = 80.9° \qquad \qquad [2]$$

QUESTION 4

(a) (i)   For one mass: $\qquad F_{12} = \dfrac{\Delta p_1}{\Delta t}$

For other mass: $\qquad F_{12} = \dfrac{\Delta p_2}{\Delta t} \qquad \qquad [1]$

But $\qquad \qquad F_{12} = -F_{21}$

$$\therefore \qquad \frac{\Delta p_1}{\Delta t} = -\frac{\Delta p_2}{\Delta t} \qquad \qquad [1]$$

$$\therefore \qquad \frac{\Delta p_1}{\Delta t} + \frac{\Delta p_2}{\Delta t} = \frac{\Delta}{\Delta t}(p_1 + p_2) = 0 \qquad \qquad [1]$$

$$\therefore \qquad p_1 + p_2 = const$$

(ii)

$$m_a \, v_a = m_s \, v_s$$
$$\therefore 80 \, v_a = 0.5 \times 20 \qquad \qquad [3]$$
$$\text{or} \quad v_a = 0.125 \; m/s$$

(b) (i)

$$2M\left(\frac{l}{2}\right)^2 + \frac{Ml^2}{12} = I_{combined}$$

$$= Ml^2 \left(\frac{1}{2} + \frac{1}{12}\right) = \frac{7}{12} Ml^2 \qquad \qquad [1]$$

(ii) $$L_{init} = I\,\omega_0 = \frac{7}{12}\,Ml^2\,\omega_0$$ [1]

(iii) $$L_{final} = I'\,\omega'$$ [1]

where $$I' = 2M\left(\frac{l}{4}\right)^2 + \frac{Ml^2}{12}$$ [1]

$$= Ml^2\left(\frac{1}{8} + \frac{1}{12}\right)$$

$$= \frac{5Ml^2}{24}$$

$$\therefore\ \omega' = \frac{I\omega_0}{I'} = \frac{\dfrac{7Ml^2}{12}\cdot\omega_0}{\dfrac{5Ml^2}{24}}$$

$$\therefore\ \omega' = \frac{14}{5}\cdot\omega_0$$ [2]

(iv) $KE = L^2 / 2I$ where L^2 is constant.

∴ If I reduces, as it does, the KE increases. [2]

(v) Children do work pulling themselves into the centre. They provide the centripetal force - which is in the same direction as their displacement. That is $\Delta W = \mathbf{F}\cdot\Delta s$ is positive. [1]

QUESTION 5

(a) (i) The point charge looks the same from any direction you view it. So the field lines will have to point radially out (or in) to conform to this symmetry.
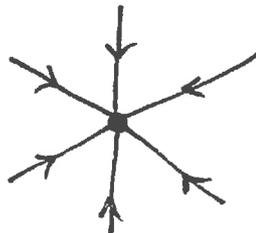
[1]

Any inclination of the lines to these radial directions leads to a contradiction - if you turned the charge around half a turn the inclination would reverse but it shouldn't.

An extreme case is to draw circles around the charge: Then the charge, when viewed from above, is the same physical situation as when viewed from below - but the field pattern would be different. Hence a contradiction.
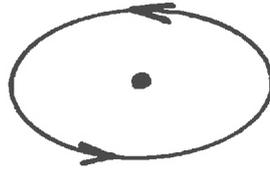
[1]

(ii) As the 'influence' spreads out into space the effect must be weaker because it is spreading out over an ever-expanding sphere.

What is constant is the strength of the source at the centre. So we reasonably assume that the ('influence' x area covered) is a constant, a constant related to the source strength.
i.e. Force field strength x area occupied = const.

ie. $F . 4\pi R^2 = const$

[2]

or $F \propto \dfrac{1}{R^2}$

For three-D space this is the force law is expected.

(b) (i) The fields have a different direction on the RHS of the system - hence a cancellation is here possible if the distance is adjusted so the field strengths are the same. We check this:

$$\therefore \frac{10 \times 10^{-6}}{4\pi\varepsilon_0 (0.809)^2} = \frac{50 \times 10^{-6}}{4\pi\varepsilon_0 (1.809)^2}$$
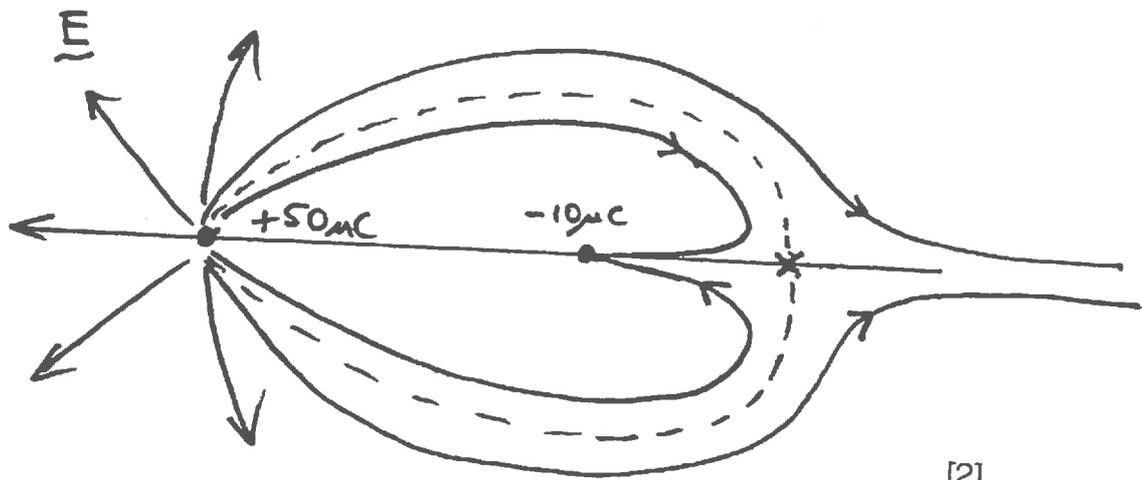
$$15.27 = 15.27$$

[2]

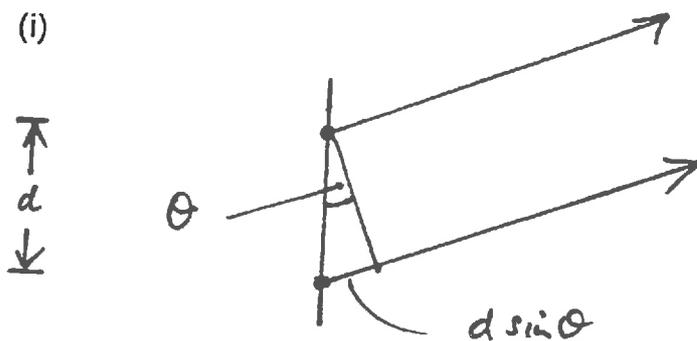It checks.

(ii) 20

[1]

(iii) At infinity, where the (complementary) negative charge resides.

[1]

[2]

QUESTION 6

(a) (i)

$d \sin \theta =$ path difference   [1]

For maximum intensity path diff. $= 0, \lambda, 2\lambda, \dots$ etc

But, for small angles $\sin \theta \approx \tan \theta \approx \dfrac{y_{max}}{L}$ [1]

$$\therefore d \sin \theta = d \frac{y_{max}}{L} = \lambda$$

$$\therefore y_{max} = \frac{\lambda L}{d}$$ [1]

(ii) If the path diff. $= 2\lambda, 3\lambda, \dots$ etc we also get a max. That is:

$$\pm 2y_{max} \Rightarrow p.d. = \pm 2\lambda$$
$$\pm 3y_{max} \Rightarrow p.d. = \pm 3\lambda$$ [1]

(iii) Down the middle line unless the λ's are integrally related.   [1]

(b) (i) $\lambda = \dfrac{c}{f} = \dfrac{3 \times 10^8}{30 \times 10^6} = 10\,m$ [1]

8

(ii)   By following the max. intensity down the centre line.   [1]

(iii)   Aircraft flies down a max. but it is not the central one.   [1]

(iv)   Only the central line has max. for both freq. - or the 11th line out.   [1]

(v)   Else you get a double max. on the same line close in.   [1]

(vi)   The maxima are sharpened and intensified.   [2]

QUESTION 7

(a)   (i)   Faraday: Induced emf in loop is proportional to the rate of change of magnetic flux threading it.

Lenz: The direction of the induced current is to oppose the change, i.e. maintain the status quo.   [1]

The loop is pulled in the direction of the magnet, the induced current is in such a direction as to try and maintain the field at the initaial level. Initially the field emerged from the North Pole so the current direction must be:

[1]

This current in the field of the magnet causes the loop to be pulled to the magnet's movement. The effective current in the North Pole of the magnet flows in the same direction - like currents attract - hence the movement.   [1]

(b)   (i)   The field in the coil is initially zero and the induced current tries to maintain it at zero, i.e. the induced current creates a field cancelling the briefly imposed one.. The result is repulsion - the train is lifted.

Speed matters b/c the induced current is x to the <u>rate</u> of change of flux. No 'rate'no, current.   [3]

(ii)   Yes, there is drag - the current is induced before the magnet is over the coil; it is induced as the magnet approaches, hence there is repulsion acting to prevent the magnet passing overhead, and to prevent it leaving.   [1]

(c) (i) $F = q\,\mathbf{v} \times \mathbf{b}$ where q is the charge, **v** the velocity vector and **B** the magnetic induction.

[1]

Charge is forced in one direction by the field; charge is 'in' the water, hence water forced in that direction too. This is the action force. Boat experiences the opposite (reaction) force.
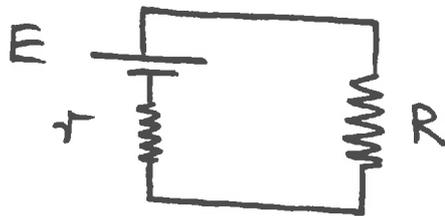
[1]

(ii)   For the directions shown the water is forced to the front, so the boat will move 'backwards'.

[1]

(iii) $F = BIL \Rightarrow 5000 = 2.3 \times I \times 2$

$\therefore I = 1086A$

[1]

(d)   Two effects are unique: (i)   zero resistance (to dc)
    (ii)   the expulsion of magnetic field from the body of the material (causes magnets to float)

[1]

QUESTION 8

(a)

$E = 0.5\,(r + R)$ [1]

$E = 0.25\,(r + 11)$

$\therefore 0.5\,(r + 5) = 0.25\,(r + 11)$

$2r + 10 = r + 11$ [1]

$\therefore r = 1\Omega$ and $E = 3V$

[1]

(b) $\dfrac{1}{2}CV^2 = \dfrac{1}{2}\,5 \times 10^{-6} \times 30^2 = 2.25 \times 10^{-3}J$ [2]

$\dfrac{1}{2}Li^2 = 2.25 \times 10^{-3}J$

$\therefore i = 0.671A$

[2]

(c) (i) $I_p = \dfrac{V_p}{R}$

[1]

10

(ii) $$P_{peak} = I_p^2 R = \frac{V_p^2}{R}$$ [1]

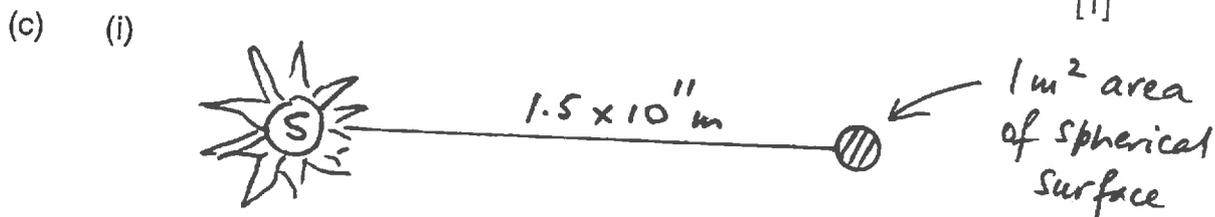(iii) $$V_{Lp} = I_p \cdot \omega L = \frac{V_p \cdot \omega L}{R}$$ [2]

QUESTION 9

(a) (i) $$\frac{1}{12}$$ [1]

(ii) $$500 \cdot \left(\frac{11}{12}\right)^7 \text{ lost} \Rightarrow 272 \text{ remain}$$ [2]

(Note: $N = N_0 e^{-\lambda t}$ gives $500 \, e^{-\frac{7}{12}} = 279$. The dice and the decay are not exactly equivalent).

(b) (i) $$^1_0 n + ^{31}_{15}P \rightarrow ^{32}_{15}P \rightarrow ^4_2\alpha + ^{28}_{13}Al$$
$$^{28}_{13}Al \rightarrow ^{28}_{14}Si + ^0_{-1}\beta + ^0_0\gamma$$ [2] + [2]
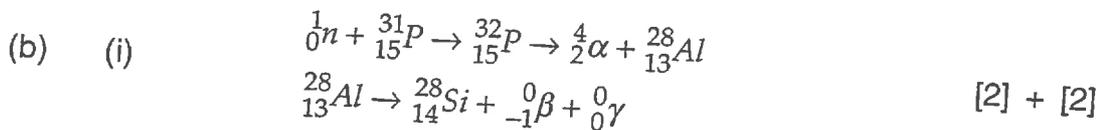
(ii) Because the neutron is relatively massive and uncharged it is stopped only by nuclear contact. [1]

(c) (i)

Total J/s emitted is: $1360 \times 4\pi \times \left(1.5 \times 10^{11}\right)^2$
$$= 3.846 \times 10^{26} \, W$$ [2]

(ii) $$E = mc^2 \Rightarrow 3.486 \times 10^{26} = m \times 9 \times 10^{16}$$

$$\therefore m = 0.426 \times 10^{10} \, kg/s$$ [2]

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QUESTION 10

(a)   (i)
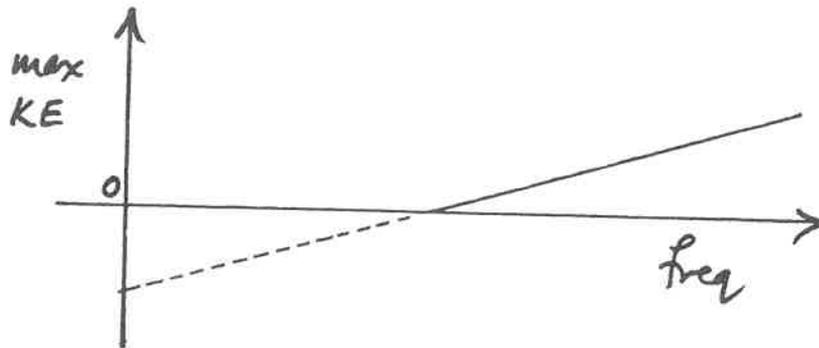
[3]

(ii)

$$eV_s = hf - \phi$$

[1]

$$\text{or} \quad V_s = \frac{hf}{e} - \frac{\phi}{e}$$

$$= \frac{hc}{e\lambda} - \frac{\phi}{e}$$

$$\therefore \quad V_3 = \frac{hc}{e\lambda_3} - \frac{\phi}{e}$$

[1]

$$\text{and} \quad V_6 = \frac{hc}{e\lambda_6} - \frac{\phi}{e}$$

[1]

$$\therefore V_3 - V_6 = \frac{hc}{e}\left(\frac{1}{\lambda_3} - \frac{1}{\lambda_6}\right)$$

$$\therefore 2 = \frac{h \times 3 \times 10^8}{1.6\,10^{-19}} \cdot \frac{1}{10^{-19}} \cdot \left(\frac{600 - 300}{600 \times 300}\right)$$

$$\therefore h = 6.4 \times 10^{-34} \text{ Js}$$

[1]

(iii)   There is no dependence upon the light intensity.   [1]

(b)   (i)   Light Amplification by Stimulated Emission of Radiation.   [1]

(ii)   Flat wavefronts (from lasers) give exceptionally good point foci, i.e. a lot of energy is dumped, per second, on a tiny spot of the retina. Result, burnt tissue.

[1]

(c)   (i)

p	n
$-$	$+$

$\longleftarrow$

$\underline{E}$ in gap

[2]

(ii)

(a)
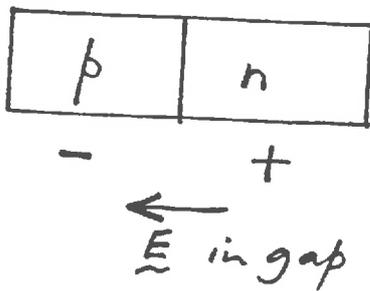
This configuration tends to cancel the junction field and this lowering causes enhanced current - whereas with the reverse arrangement the barrier is 'enlarged' and the current reduced.

[2]

(d)   Velocity of light.

[1]

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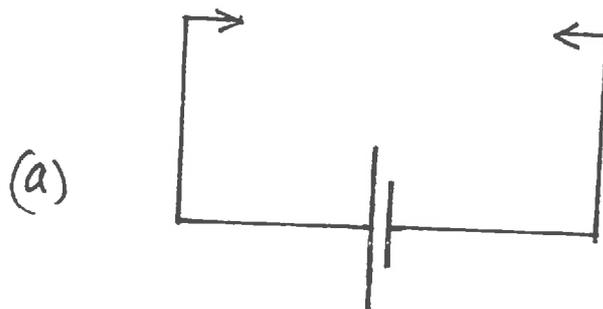### ACADEMIC ACHIEVEMENT BY CHOICE

NZEST Grading System

Using the 1995 subject marks, tabled below, you will see that the NZEST Grading System provides parity between subjects: ie, candidates who sat Chemistry ,which had a low mean, did not suffer as the lowest Grade A+ mark of 60 receives 9 scholarship points compared with the lowest Grade A+ mark of 90 in Maths with Calculus which also receives 9 scholarship points.

Grade	Scholarship Points		Grade	Scholarship Points		Grade	Scholarship Points
A+	9		B+	6		C+	3
A	8		B	5		C	2
A-	7		B-	4		C-	1
						D	0

1995: Subject	No sitting	Mean mark	Top mark	A+	A	A-	B+	B	B-	C+	C	C-
Accounting	204	42	80	69	66	61	59	53	49	45	41	38
Biology	416	56	83	75	72	68	64	60	56	52	49	46
Chemistry	519	36	86	60	57	53	49	45	41	37	33	30
Classical Studies	125	61	91	85	81	76	71	66	60	56	51	47
Economics	220	40	67	57	55	52	49	46	43	40	37	35
English	358	54	91	75	71	67	63	59	55	51	47	40
French	103	64	92	83	80	76	72	68	64	60	55	50
Geography	110	51	99	87	81	75	69	64	58	52	46	42
German	39	76	95	85	82	78	74	70	66	60	55	50
History	161	56	91	80	75	70	65	61	56	51	46	40
History of Art	60	59	80	75	72	69	66	63	60	58	55	51
Japanese	119	65	95	90	85	80	74	70	64	58	52	46
Latin	11	69	85	85	81	-	72	69	60	57	-	-
Maori	6	45	72	-	-	-	72	-	64	-	50	42
Maths/Calculus	628	53	100	90	83	76	69	62	55	48	41	34
Maths/Statistics	588	49	95	80	74	68	62	56	50	44	38	32
Physics	481	51	99	88	82	75	69	62	55	48	41	32

Note re low Chemistry mean:
The NZEST Academic Committee would like to advise that it is very concerned about the continuing low mean in Chemistry. A new examination team has been appointed for 1996 and they are quietly confident that the mean can be lifted to a reasonable level without in any way dropping the scholarship standard.