# University Entrance, Bursaries and Scholarships Examination
# PHYSICS 2003

**Marking Schedule and Examination Commentary**

## General Comments

The 2003 paper was similar in style to recent years but was slightly more challenging than the 2002 paper. As usual, the paper was based on contextual algebraic and descriptive questions. The paper had more emphasis on descriptive questions than in previous years. This clearly increased the difficulty of the paper. Most questions had the more challenging parts towards the end. Only the most able candidates were able to successfully answer these parts, and to score more than 125 marks. It appeared that nearly all the candidates finished the paper in the allocated time.

'Show that' questions continue to be well answered. Units were handled well by most candidates this year. A considerable number gained full marks. The only unit consistently poorly done was that of angular momentum. This was also the case in last year's paper. Significant figures were also handled well this year. Candidates are clearly well instructed in the use of significant figures and units.

As in previous years, candidates showed a high level of proficiency at using formulae and solving straight-forward problems. This is clearly demonstrated in candidates' responses to Questions Four and Nine. These questions were almost entirely computational. Candidate performance in these questions was very good. It is clear that most candidates are well prepared in this aspect of physics. However, candidates' ability to explain physics concepts and phenomena is extremely poor. In all questions, apart from Questions Four and Nine, a significant proportion of the question required a non-computational response. Candidates' performance in these questions was well below a satisfactory level. As this is the last year of norm-referenced examinations at this level, teachers should spend more time with candidates on 'explain-type' questions to prepare them for NCEA Level 3 physics. Candidates need a considerable amount of practice at answering this type of question. They need to read the question very carefully and use simple, clear English to communicate their physics concepts.

Most candidates were generally well prepared to answer questions from all four sections of the prescription. It is clear that a large number of candidates have been well taught. It also appears that a significant number of candidates are totally unaware of the requirements and demands of physics at this level. It was very saddening to see a large number of almost empty answer booklets.

While the performance of candidates across the four sections of the prescription was consistent, candidates found the following areas of the prescription challenging.

- Basic definitions of terms such as longitudinal waves and fundamental frequency.
- The phenomenon of interference.
- The Doppler effect.
- The physics of banked curves.
- Conservation of energy.
- Simple applications of Newton's laws of motion.
- The concept of the spring constant.
- Kirchhoff's Laws.
- The concepts of electrical current and voltage.
- Rectification.
- The physics of the photoelectric effect.
- The wave/particle duality of light.
- Momentum conservation in nuclear reactions.

The general presentation of candidate responses was very good. Some candidates still need to be reminded that they should be trying to produce a clear, tidy answer booklet that is easy to read. The use of pencil and/or correction fluid was greatly reduced this year, to the delight of the marking panel.

## Comments on Specific Questions

Note: the mean mark in each case has been obtained from a sample of papers and is unscaled.

**Question One: Henry the Harpsichord Player** (mean 4.4/11)

As in earlier years, Question One was supposed to be reasonably straightforward in order to settle candidates into the examination. Unfortunately, candidates found this question harder than expected.

(a) Poorly done by a large number of candidates. Many provided responses such as standing or transverse wave.

(b) Generally well done.

(c) Poorly done by most candidates. Very few gained full marks. A large number simply stated that the fundamental frequency was the same as the first harmonic.

(d) Generally well done.

(e) Poorly done by most candidates. Most stated that the velocity depended on frequency and wavelength.

(f) Poorly done by most candidates. It appeared few candidates had any practical experience of common musical instruments. A major misconception was that the string would expand and this would result in a longer wavelength.

**Question Two: Interference and the Doppler Effect** (mean 6.1/17)

(a) Generally poorly done by most candidates. There appears to be a lack of understanding about the nature of longitudinal waves.

(b) Poorly done by many candidates. Many could identify the phenomenon – interference (which was given in the title of the question). A large number could not adequately explain this phenomenon.

(c) Very poorly done by nearly all candidates. This was a challenging question.

(d) Extremely poorly done. A very challenging problem. Only the most able students gained any marks.

(e) Generally reasonably well done. Few candidates stated that the velocity of the sound wave remained constant. It was disappointing to see few students using labelled diagrams.

(f) Well done by most candidates. Candidates demonstrated good algebraic skills in this question.

(g) Well done.

**Question Three: Banked Curves** (mean 5.2/11)

(a) Well done by most candidates.

(b) Poorly done by nearly all candidates. Most candidates realised that a centripetal force must act inwards but very few were able to explain the origin of this force.

(c) Generally well done.

(d) Poorly done. A large number of candidates did not state clearly that the car would move away from the centre of the road.

(e) Poorly done by many candidates. Very few candidates started with a force diagram. This was very disappointing. Far too often the $\tan\theta$ term mysteriously appeared without any indication of its origin.

**Question Four: The Roundabout** (mean 8.6/15)

(a) Well done.

(b) Well done.

(c) Well done. Many candidates could not give their final answer to the correct number of significant figures. Many candidates were unaware of the correct unit for angular momentum.

(d) Reasonably well done. Most candidates did not state that angular momentum was conserved.

(e) Generally well done. A common mistake by candidates was to disregard Jennifer's new position in their calculation of the new moment of inertia.

(f) Well done. Not squaring the angular velocity was a common error.

(g) Very poorly done by nearly all candidates. Very few candidates realised that the energy gained by the system must have actually come from somewhere. The concept of energy conservation is poorly understood.

**Question Five: A Space Odyssey** (mean 6.2/14)

(a) Well done. Many candidates could not give their final answer to the correct number of significant figures.

(b) Reasonably well done.

(c) Very poorly done by nearly all candidates. Most candidates incorrectly assumed that the linear velocity was constant for the two situations. A large number assumed that the situation involved angular acceleration.

(d) Well done. A considerable number of candidates gave a unit for their ratio.

(e) Well done.

(f) Poorly done by most candidates. Few candidates attempted to quantify the effect of reduced velocity on the artificial gravity.

(g) Very poorly done by most candidates. A challenging problem that appeared to be well beyond the ability of most candidates.

**Question Six: Bungy Jumping** (mean 5.2/16)

(a) Well done.

(b) Well done. A number incorrectly stated that the energy went into kinetic energy.

(c) Poorly done by many candidates. Most identified the correct formula but could not calculate the correct extension. A large number could not correctly state an appropriate unit for the spring constant.

(d) Very poorly done by most candidates. Very few candidates could explain this simple application of Newton's second law. This was most disappointing.

(e) Very poorly done by nearly every candidate. Only the most able candidates realised that elastic potential energy needed to be included.

(f) Generally well done. Too many candidates attempted to apply standard SHM statements to this situation.

(g) Very poorly done by nearly every candidate. A challenging problem which was well beyond most candidates.

**Question Seven: Kirchhoff's Laws** (mean 4.3/12)

(a) Reasonably well done. A number of candidates struggled to express themselves clearly in this question.

(b) Very poorly done by most candidates. Most were unaware of the fundamental principles underpinning Kirchhoff's laws.

(c) Reasonably well done. A considerable number of candidates mentioned the flow of energy, a rather disturbing response.

(d) Very poorly done by nearly all candidates. A large number of candidates stated that opposing currents from each battery cancelled out. Some stated that the resistance was too high for current to flow. These responses indicated that a significant group of students had some serious misconceptions of this principle.

(e) Reasonably well done. Candidates familiar with Kirchhoff's laws had no problem dealing with this simple situation. Many candidates could not give their final answer to the correct number of significant figures.

**Question Eight: Rectification** (mean 5.6/14)

(a) Well done.

(b) Generally well done. Many incorrectly substituted the rms value for the primary voltage.

(c) Very poorly done by nearly all candidates. Only the most able candidates realised that the diode arrangement was the critical point. A significant number of candidates stated that the voltage flowed to point A.

(d) Generally well done. Most candidates were able to gain three marks. Only the most able candidates realised that the centre-tapped transformer caused the output voltage to equal 6 V.

(e) Poorly done by most candidates. The role of the capacitor in this type of circuit was poorly understood.

(f) Generally well done.

**Question Nine: AC Resonance** (mean 9.0/18)

Many candidates scored full marks for this question but a large group scored zero, often by omitting the entire question.

(a) Well done.

(b) Well done.

(c) Generally well done by most candidates. Clear setting out of working would ensure greater success in similar questions.

(d) Well done. Many candidates could not give their final answer to the correct number of significant figures.

(e) Well done.

(f) Reasonably well done by most candidates. Many candidates could not give their final answer to the correct number of significant figures.

(g) Generally well done. Explanations were often not detailed enough to gain full marks.

(h) Well done. A large number of candidates had obviously memorised the correct formula.

**Question Ten: The Photoelectric Effect**
(mean 4.7/14)

This question was poorly done. Candidates' understanding of the photoelectric effect was extremely poor. A large number of candidates scored zero for this question.

(a) Generally well done. A considerable number wrote $E = hf$ or $E = mc^2$.

(b) Reasonably well done. A large number of candidates confused ionisation energy with the work function. Only a few candidates included 'minimum energy' in their definition.

(c) Very poorly done by nearly all candidates. It appeared that very few candidates were familiar with the method to calculate the maximum kinetic energy.

(d) Poorly done by most candidates. Few candidates could identify the correct model and even fewer could state a piece of supporting evidence.

(e) Generally well done.

(f) Generally well done.

(g) Very poorly done by nearly all candidates. Most candidates did not attempt this question. Very few realised that the key was to know that a watt is equivalent to a joule per second.

(h) Very poorly done by nearly all candidates. Most candidates did not attempt this question.

**Question Eleven: Nuclear Physics** (mean 5.4/10)

(a) Well done.

(b) Well done.

(c) Well done.

(d) Generally well done. Some candidates were clearly unaware of the meaning of the term 'recoil'.

(e) Generally well done. A significant group of candidates were not aware of the vector nature of momentum.

# MARKING SCHEDULE

## QUESTION 1: HENRY THE HARPSICHORD PLAYER (11 marks)

(a) Third Harmonic / second overtone (1 mark)

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(b)

$L = \frac{3\lambda}{2}$

$L = 0.750$ m (1 mark)

$\lambda = 0.500$ m

$v = f\lambda$ (1 mark)

$f = \frac{645}{0.500} = 1290 \text{ Hz} = 1.29 \times 10^3 \text{ Hz}$

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(c) The lowest frequency. (1 mark)

Standing wave (resonance) produced. (1 mark)

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(d)

$L = \frac{\lambda}{2}$

$L = 1.00$ m (1 mark)

$\lambda = 2.00$ m

$v = f\lambda$ (1 mark)

$v = 326 \times 2.00 = 652 \text{ m s}^{-1}$

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(e) Different material/mass per unit length /thickness/mass/weight. (1 mark)

Different tension. (1 mark)

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(f) Increased temperature will increase velocity of sound causing an increased frequency. (1 mark)

As the string increases in temperature it will expand causing decreased tension/velocity resulting in reduced frequency. (1 mark)

## QUESTION 2: INTERFERENCE AND THE DOPPLER EFFECT (17 marks)

(a) Medium/particles vibrate(s) parallel to the direction of propagation. (2 marks)

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(b) Interference (1 mark)

Areas of loudness – path difference integral multiples of the wavelength/ no phase difference (1 mark)

Areas of quietness – path difference half integral multiples of the wavelength/ 180 degree phase difference (1 mark)

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(c) Change/Alter the phase of one of the sound waves (1 mark)

so that when they meet they have a phase difference of half a cycle. (1 mark)

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(d) $\left(2 - \frac{1}{2}\right)\lambda_k = 2\lambda_u$ (2 marks)

$\Rightarrow \frac{3}{2} \times 577 \times 10^{-9} = 2\lambda_u$

$\lambda_u = 433 \times 10^{-9}$ m (1 mark)

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(e) As the car moves away, the same number of waves are fitted into longer distance, so the wavelength increases/apparent wavelength increases. (1 mark)

Speed of sound is constant in air, so the frequency decreases. (1 mark)

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(f) $\Delta f = f_{app} - f_{away}$

$= f\frac{v_w}{v_w - v_s} - f\frac{v_w}{v_w + v_s}$ (1 mark)

$= fv_w\left[\frac{1}{v_w - v_s} - \frac{1}{v_w + v_s}\right]$ (1 mark)

$= fv_w\left[\frac{v_w + v_s - (v_w - v_s)}{(v_w - v_s)(v_w + v_s)}\right]$ (1 mark)

$= \frac{2fv_w v_s}{v_w^2 - v_s^2}$

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(g) Substituting

$= \frac{2 \times 4.00 \times 10^2 \times 27.8 \times 335}{335^2 - 27.8^2}$ (1 mark)

$= 66.8$ Hz (1 mark)

**QUESTION 3: BANKED CURVES** (11 marks)

(a)

$$35 \text{ km h}^{-1} = \frac{35 \times 1000}{3600}$$ (1 mark)

$= 9.72 \text{ m s}^{-1}$ (1 mark)

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(b) The component of the reaction force provides the necessary centripetal force (1 mark)

to create circular motion. (1 mark)

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(c)

$$\tan \theta = \frac{v^2}{rg}$$ (1 mark)

$$= \frac{9.72^2}{60.0 \times 9.80}$$ (1 mark)

$(\theta = 9.13223...^{\circ})$

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(d) Slide away from the centre of the track. (1 mark)

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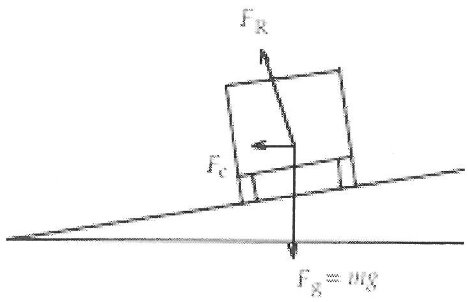
(e)




(1 mark) for force diagram $F_R$ and $F_g$ with correct orientation

By resolving reaction force into $F_c$ and $F_g$.

$$\tan \theta = \frac{F_c}{F_g}$$

$F_c = F_g \tan \theta$ (1 mark)

$$mg \tan \theta = \frac{mv^2}{r}$$ (1 mark)

$v^2 = rg \tan \theta$

$v = \sqrt{rg \tan \theta}$ (1 mark)

**QUESTION 4: THE ROUNDABOUT** (15 marks)

(a) $I_{TOTAL} = 600 + 40 \times 1.5^2 + 40 \times 3.0^2$ (2 marks)

$(=1050 \text{ kg m}^2)$

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(b) $\omega = \frac{2\pi}{T}$ (1 mark)

$= \frac{2\pi}{4}$ (1 mark)

$= 1.57 \text{ rad s}^{-1}$

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(c) $L = I\omega$ (1 mark)

$= (1050 + 360) \times 1.5707$

$= 2214.8$ (1 mark)

$= 2210 \text{ kg m}^2 \text{ s}^{-1}$

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(d) Angular momentum remains constant (assuming no external torques). (1 mark)

Jennifer, by moving towards the centre, reduces/changes the rotational inertia of the system therefore the angular velocity increases/changes. (1 mark)

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(e) $L_i = L_f$ (1 mark)

$L_f = (1050 + I_f)\omega_f$ (1 mark)

$I_f = 0.25 I_i = 90$

$2214.8228 = (1050 + 90)\omega_f$ (1 mark)

$\omega_f = 1.94 \text{ rad s}^{-1}$

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(f) $E_{Ki} = \frac{1}{2}(1050 + 360) \times 1.5708^2 = 1739.5 \text{ J} \ (1737.5 \text{ J})$ (1 mark)

$E_{Kf} = \frac{1}{2}(1050 + 90) \times 1.942827^2 = 2151.5 \text{ J} \ (2145.2 \text{ J})$ (1 mark)

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(g) Jennifer provides the energy (1 mark)

from internal/chemical/muscular energy. (1 mark)

**QUESTION 5: A SPACE ODYSSEY** (14 marks)

(a) $= \frac{2.00 \times 2\pi}{60}$ (1 mark)

$= 0.209$ (1 mark)

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(b)

$a_c = 9.80 = \frac{v^2}{r}$ (1 mark)

$= \frac{r^2 \omega^2}{r}$

$r = \frac{9.80}{\omega^2}$ (1 mark)

$r = \frac{9.80}{0.20944^2}$

$(r = 223.413\ \text{m})$

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(c) $a_c(\text{head}) = (r - h)\omega^2$ (1 mark)

$a_c(\text{foot}) = r\omega^2$ (1 mark)

$\frac{a_c(h)}{a_c(f)} = \frac{(r - h)}{r}$

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(d) $= \frac{(r - h)}{r} = \frac{223 - 2}{233}$ (1 mark)

$= 0.991$ (1 mark)

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(e) $v = r\omega$ (1 mark)

$= 223.4 \times 0.2094$ (1 mark)

$(= 46.8\ \text{m s}^{-1}$ or $46.7)$

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(f)

$v_{true}(\text{astronaut}) = v_s - v_a = \frac{3}{4} v_s$ (1 mark)

therefore the artificial gravity will be reduced to 9/16 of the previous value (making him feel lighter). (1 mark)

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(g) To minimise the effect $v_s$ must be much greater than $v_a$. (1 mark)

$v_s = \sqrt{9.80r}$ by making $r$ much larger it increases $v$, but also makes the angular velocity less. (1 mark)

**QUESTION 6: BUNGY JUMPING** (16 marks)

(a)

$E_p = mgh$ (1 mark)

$= 85 \times 9.80 \times 70$ (1 mark)

(= 58310 J)

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(b) Elastic/potential energy in the bungy. (1 mark)

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(c)

$E_p = \frac{1}{2}kx^2$ (1 mark)

$\Rightarrow 58310 = 0.5k(70.0 - 25.0)^2$ (1 mark)

$k = 57.6 \text{ N m}^{-1}$ (1 mark)

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(d) $mg = kx$, (so the acceleration is zero). (1 mark)

At this point the net force is zero. (1 mark)

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(e)

$\frac{1}{2}mv^2 = mgh - \frac{1}{2}kx^2$ (2 marks)

$= 85 \times 9.8 \times 39.5 - \frac{1}{2} \times 57.58 \times (14.5)^2$

$= 26850.4 \text{ J}$ (1 mark)

$v = \sqrt{\frac{2 \times 26850.4}{85}}$

$v = 25.1 \text{ m s}^{-1}$ (1 mark)

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(f) Maximum upward force occurs (1 mark)

when the bungy is at maximum extension (at the water surface). (1 mark)

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(g) k is doubled. (1 mark)

If the length is halved, the extension caused by a particular force is halved.

$F = k_L x_L = k_s \frac{x_L}{2}$ (1 mark)

$\Rightarrow k_s = 2k_L$

**QUESTION 7: KIRCHHOFF'S LAWS** (12 marks)

(a) Law 1: The sum of the currents at a junction is zero. (1 mark)

Law 2: The sum of the voltage drops around a closed loop is zero. (1 mark)

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(b) Law 1: Conservation of charge. (1 mark)

Law 2: Conservation of energy. (1 mark)

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(c) Amount of charge (in coulombs) (1 mark)

flowing past a point in one second. (1 mark)

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(d) By applying Kirchhoff's Law 2: (2 marks)
$+10 - 10I - 20I - 10 = 0$ therefore $I = 0$ A,

**or** because the two batteries are opposing each other, their respective electric fields cancel creating a net voltage of zero leading to zero current.

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(e) $10.0 - I_1 \times 10.0 - 10.0 \times 0.600 = 0$ (1 mark)
Therefore $I_1 = 0.400$ A (1 mark)

$I_1 + I_2 = I_3 = 0.600$ or $(10.0 - I_1 \times 20.0 - 10.0 \times 0.600 = 0)$ (1 mark)

Therefore $I_2 = 0.200$ A (1 mark)

## QUESTION 8: RECTIFICATION (14 marks)

(a) $V_P = \sqrt{2} \times V_{rms}$ (1 mark)

$= \sqrt{2} \times 235$ (1 mark)

(= 332 V)

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(b) $N_S = \dfrac{V_S}{V_P} N_P$ (1 mark)

$= 8000 \times \dfrac{12.0}{332.340}$ (1 mark)

$= 289$

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(c) Regardless of the direction of the secondary voltage, the diode arrangement means current always flows from A to B. (2 marks)

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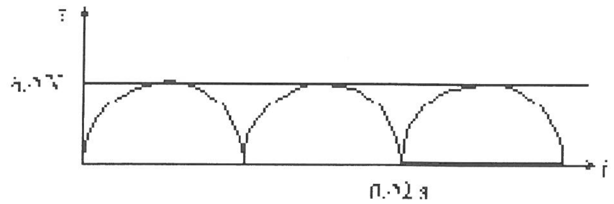
(d)



(2 marks) for correct shape

(1 mark) for correct period value

(1 mark) for correct peak value of voltage – 6V

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(e) The capacitor acts as a reservoir of charge (1 mark)

and so when the current starts to drop (due to reducing voltage) the capacitor is able to supply charge to the resistor to boost the rate of flow of charge. (1 mark)

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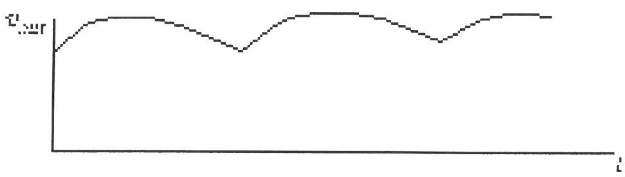
(f)



(2 marks) for correct shape

**QUESTION 9: AC RESONANCE** (18 marks)

(a) $\omega = 2\pi f$ (1 mark)

$= 2\pi \times 50$ (1 mark)

$(= 314 \text{ rad s}^{-1})$

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(b) $X_C = \dfrac{1}{\omega C}$ (1 mark)

$= \dfrac{1}{2\pi \times 50 \times 2.00 \times 10^{-6}}$ (1 mark)

$(= 1590\ \Omega)$

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(c) $X_C = 1591.549\,\Omega$ (1 mark)

$X_L = \omega L = 2\pi \times 50 \times 2.00 = 628.3\ \Omega$ (1 mark)

$Z = \sqrt{R^2 + (X_C - X_L)^2}$ (1 mark)

$= \sqrt{200^2 + (1591.549 - 628.4)^2}$

$(= 984\ \Omega)$

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(d) $V = IZ$

$I = \dfrac{V}{Z} = \dfrac{10.0}{984}$ (1 mark)

$= 0.0102\ \text{A}$ (1 mark)

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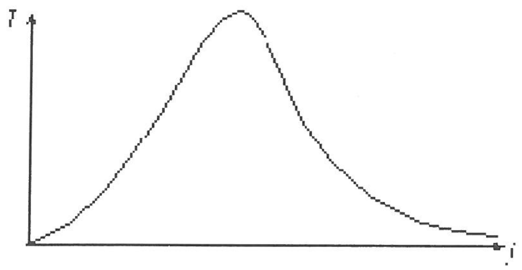
(e) 

(2 marks) for correct shape

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(f) $V = IR,\ I = V/R,\ \therefore\ I = 10/200$ (1 mark)

$= 0.0500\ \text{A}$ (1 mark)

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(g) When $X_L = X_C$ the impedance is a minimum because they cancel each other out. (1 mark)

The current is a maximum when the impedance is a minimum. (1 mark)

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(h) At resonance $X_L = X_C$

$\Rightarrow 2\pi f L = \dfrac{1}{2\pi f C}$ (1 mark)

$\Rightarrow f = \dfrac{1}{2\pi}\sqrt{\dfrac{1}{LC}}$ (1 mark)

$f = \dfrac{1}{2\pi}\sqrt{\dfrac{1}{2 \times 2 \times 10^{-6}}}$ (1 mark)

$f = 79.6\ \text{Hz}$

**QUESTION 10: THE PHOTOELECTRIC EFFECT** (14 marks)

| | | |
|---|---|---|
| (a) | Conservation of energy. | (1 mark) |
| (b) | Minimum energy needed to release an electron. | (1 mark) |
| (c) | Stopping (blocking) voltage from the power supply. | (1 mark) |
| | When $eV = E_K$ then current zero. | (1 mark) |
| (d) | Particle model. | (1 mark) |
| | Brighter light contains more photons so more electrons are released or time delay would be expected if wave model applied before release. | (1 mark) |
| (e) | $E = hf = \frac{hv}{\lambda}$ | (1 mark) |
| | $= \frac{6.63 \times 10^{-34} \times 3.00 \times 10^{8}}{4.75 \times 10^{-7}}$ | (1 mark) |
| | $(= 4.19 \times 10^{-19}\ \text{J})$ | |
| (f) | $E_K = hf - \phi$ | (1 mark) |
| | $= 4.19 \times 10^{-19} - 3.10 \times 10^{-19}$ | |
| | $= 1.09 \times 10^{-19}$ J | (1 mark) |
| (g) | Number of photons $= \frac{5.10 \times 10^{-6}}{4.187 \times 10^{-19}}$ | (1 mark) |
| | $= 1.22 \times 10^{13}$ | (1 mark) |
| (h) | $n = \frac{1.217948 \times 10^{13} \times 4.00 \times 10^{-4}}{2000}$ | (1 mark) |
| | $= 2.43 \times 10^{6}$ (or $2.44 \times 10^{6}$) | (1 mark) |

**QUESTION 11: NUCLEAR PHYSICS** (10 marks)

(a) a = 14 (1 mark)

b = 7 (1 mark)

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(b) β decay (1 mark)

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(c) $p = mv$ (1 mark)

$= 5.00 \times 10^{6} \times 9.10 \times 10^{-31}$ (1 mark)
$(= 4.55 \times 10^{-24}\ \text{kg m s}^{-1})$

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(d) Momentum is conserved (as there are no external forces acting). (1 mark)

As the momentum before is zero the momentum after must be as well. (1 mark)

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(e) $p = \sqrt{p_{\text{neutrino}}^2 + p_{\text{electron}}^2}$ (1 mark)

$= \sqrt{(4.55 \times 10^{-24})^2 + (4.55 \times 10^{-24})^2}$ (1 mark)

$= 6.435 \times 10^{-24}$

$v = \frac{p}{m} = \frac{6.435 \times 10^{-24}}{2.32 \times 10^{-26}}$

$= 277\ \text{m s}^{-1}$ (1 mark)