NEW ZEALAND QUALIFICATIONS AUTHORITY
MANA TOHU MĀTAURANGA O AOTEAROA

Scholarship, 2004

Physics (93103)

National Statistics

Assessment Report

Assessment Schedule

Physics, Scholarship, 2004

General Comments

Over 1 000 candidates presented themselves for assessment against the Scholarship standard for physics. The top candidates clearly were very well prepared and had an excellent grasp of the physics taught at this level. However, many candidates were not well prepared for this type of examination.

Candidates' mathematical ability was satisfactory for this level. Candidates who failed to gain the scholarship standard typically used the formulae sheet as the basis of their answers to all types of questions. Scholarship physics does not rely on appropriate formulae selection. Candidates should expect to be examined in terms of their ability to write explanatory answers based on a good physical understanding of a particular situation. It appears that many students believe that physics is about substituting numbers into formulae. When preparing for Scholarship, candidates need to be encouraged to extend themselves by attempting challenging problems supported with appropriate stimulus material, which requires a demonstration of their understanding of physics.

Successful candidates appeared to have a good conceptual understanding of the following aspects:
- mass-deficit calculations
- wave-particle duality
- use of phasors in AC circuits
- simple angular momentum descriptions.

Candidates struggled with the following aspects:
- applications of Newton's Laws
- applying the Doppler effect in a less familiar context
- the conditions for interference and applications of interference and diffraction
- interaction of magnetostatic and time changing magnetic fields (eg back emf).

National Statistics

Number of Results	Percentage		
	Not Achieved	Scholarship	Outstanding
1,012	96.1%	3.1%	0.8%

Assessment Report

Scholarship Performance Commentary:

Clear, coherent and logical working is required for all problems. Candidate working needs to show clear evidence of relevant physics relationships required for the solution. For example, in Section B Question Four (iii), candidates who reached the scholarship standard were able to show structured working throughout this complex problem. They presented a logical solution pathway defining all relevant terms, and presented their final solution in a concise manner. Another good example of candidates being able to show performance at the scholarship standard was in Section B Question Three (ii). This type of problem provided the candidate with the opportunity to derive a given relationship. The scholarship standard requires the student to abstract the relevant concept or principle from the physical situation. In this problem the relevant concept was that of path difference. Candidates performing at the scholarship standard were able to clearly show, typically by use of a diagram, the path difference existing in this situation.

Candidates performing at scholarship level were also aware of the appropriate size of answers as evidenced in Section B Question Two (iii) where candidates performing below scholarship level often presented answers that were in excess of a million metres per second for the speed of blood in a human.

Scholarship candidates are required to provide concise explanations or analyses that show clear understanding of physical phenomena. Candidates performing at the scholarship level were able to demonstrate their understanding of physical phenomena by providing clear coherent statements, based upon sound physical understanding. Scholarship candidates also need to demonstrate an ability to write concise, compact and correct answers in the time and space provided. Candidates performing at the scholarship standard were able to present their ideas succinctly in a form that provided assessors with clear evidence of scholarship level performance. For example in Section B Question Four (ii), candidates were asked to discuss the force arising from the interaction of the magnetic fields (and the resulting force produced). Candidates performing at the scholarship standard were able to analyse this situation in terms of the relevant material presented at the beginning of the question, and to present a coherent organised answer that included a clear description of the interaction of the magnetic fields. Candidates at this level typically presented a well-labelled diagram to help explain the situation. Candidates performing below the scholarship standard typically discussed only part of the interaction, choosing to ignore a number of relevant aspects.

Another good example of candidates being able to show performance at the scholarship standard was in Section B Question Four (vii). This question asked for candidates to discuss advantages and disadvantages in terms of underlying physical concepts. Candidates performing at the scholarship standard were able to demonstrate coherent physical understanding without relying on non-physical references such as safety aspects or financial considerations to fill out their responses.

Scholarship performance is not demonstrated by the amount of material presented. The quality of response is what is judged against the standard. Candidates disadvantaged themselves by presenting information that is irrelevant or erroneous.

Outstanding Scholarship Performance Commentary

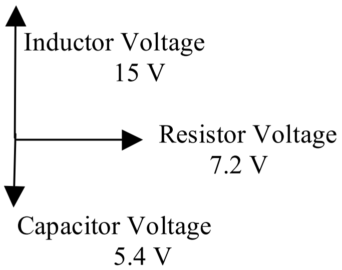
Candidates at the outstanding performance level were required to consistently reflect clear thinking along with a depth and breadth of conceptual understanding. Candidates at this level consistently performed across the entire paper and demonstrated exceptional conceptual understanding. For example, Section A Question One (ii) provided an opportunity for candidates to present an efficient and elegant algebraic solution to this problem. Candidates showing outstanding performance were able to abstract the relevant information and provide an insightful solution. Candidates performing at scholarship level in this question typically inserted the data directly and used a more brute-force method to solve the problem. Another good example of candidates demonstrating outstanding performance was in Section B Question One. Only outstanding candidates could analyse the physics involved in this question to a level that produced a relevant conclusion. Candidates performing at this level had superior conceptual understanding of the role of the back emf in the circuit to allow them to solve the problem. Candidates below this level looked for patterns in the data rather than focusing on the relevant physics.

Assessment Schedule

Scholarship Physics (93103)

Evidence Statement

Question	Evidence for Scholarship	Evidence for Scholarship Criteria 1	Evidence for Scholarship Criteria 2
	SECTION A : SHORT QUESTIONS		
1(i)	${}^{210}_{84}\text{Po} \rightarrow {}^{4}_{2}\text{He} + {}^{206}_{82}\text{Pb}$ Initial mass m_i = 209.983 amu Final mass m_f = 209.977 amu Energy E = $(m_i - m_f)\, c^2 = 8.969 \times 10^{-13}$ joule		✓
1(ii)	Momentum is conserved Initial momentum = 0, Final momentum = $m_{pb}\, v_{pb} - m_\alpha\, v_\alpha = 0$ $\frac{v_\alpha}{v_{pb}} = \frac{206}{4} = 51.5$ or ratio $v_\alpha : v_{pb} = 51.5 : 1$ The energy released is equal to the gain in kinetic energy of the two particles. The initial kinetic energy is zero so the total kinetic energy equals the energy released. $\frac{1}{2} m_{pb} v_{pb}^2 + \frac{1}{2} m_\alpha v_\alpha^2 = E$ Substitute $v_\alpha = 51.5 v_{pb}$ or $v_\alpha = \frac{m_{pb}}{m_\alpha} v_{pb}$ Can rearrange algebraically to find kinetic energy of alpha particle for outstanding performance. $\frac{1}{2} m_\alpha v_\alpha^2 = \frac{E}{1 + \frac{m_\alpha}{m_{pb}}}$ For ordinary scholarship standard, candidates can substitute in values for *E* and the masses to find the velocities and calculate the kinetic energy. This should then be expressed as a percentage of the original energy *E*. kinetic energy of alpha particle = 0.98 *E*		✓
2	Candidates must include the following to be awarded credit: • explanation of wave–particle duality • experimental example of wave behaviour • experimental example of particle behaviour. **Explanation of wave–particle duality:** Candidates need to demonstrate an understanding that the behaviour of light in some experiments can only be understood in terms of waves, and in other experiments it can only be explained by particles. This has lead to the idea that light has to be thought of as both a wave and a particle, implying that these apparently different concepts are in fact closely related. This dual nature is known as wave–particle duality. **Experimental example of wave behaviour:** Candidates could use diffraction, interference, refraction* or polarisation* as examples of this. They need to describe the phenomena chosen and briefly explain it in terms of waves. (*not on NCEA level 3 syllabus) **Experimental example of particle behaviour:** Candidates have studied the photoelectric effect so will probably use this as an example. They need to describe the photoelectric effect and briefly explain it in terms of particles.	✓	

Question	Evidence for Scholarship	Evidence for Scholarship Criteria 1	Evidence for Scholarship Criteria 2
3	Candidates need to identify that the voltmeter is not faulty and back this up by a clear explanation. Their explanation must include: • a numerical check that the component voltages do add up to the supply voltage, if added as phasors • a clear explanation of why the voltages should be added as phasors rather than scalars. Their explanation could include some of the following points: The voltages are varying sinusoidally with time and the measured values indicate average (rms) values not instantaneous values. At any instant in time some of the voltages would be positive and some negative. This needs to be taken into account when adding the voltages together. The voltages are not in phase so they need to be added using a phasor diagram.  The supply voltage should be equal to the vector sum of the voltages across the components. $V_s = \sqrt{(15-5.4)^2 + 7.2^2} = 12$ V This is the same as the voltmeter reading. The inductor voltage can be bigger than the supply voltage because it is always π out of phase with the capacitor voltage. However the **difference** between the inductor and capacitor voltage cannot exceed the supply voltage.	✓	
4(i)	The force exerted by the wire on the ball must include a vertical component (equal and opposite to the weight of the ball).	✓	
4(ii)	If the speed is to increase then the wire must provide a tangential force component. To produce this the hammer thrower must move their hands (ie the end of the wire) from the centre of the circle (ie it is no longer acting along a radius).	✓	

Question	Evidence for Scholarship	Evidence for Scholarship Criteria 1	Evidence for Scholarship Criteria 2
5 (i)	Because no external torques act on the system of person + platform (p+p), the angular momentum remains the same. $\therefore L_{\text{final}} = L_{\text{initial}}$ or $I_f\omega_f = I_i\omega_i$ During the uncrossing of arms, the angular velocity will increase since the rotational inertia has decreased slightly since. $I_f < I_i$ therefore $\omega_f > \omega_i$ ie the angular velocity of the person and platform has increased. But with extended arms $I_f > I_i$ therefore $\omega_f < \omega_i$ ie the angular velocity of the person and platform is less.	✓	
5 (ii)	Look at the system from above and imagine the path of the dropped weight. The dropped weight follows the tangent line. The removal of the centripetal force on the weight by the hand allows it to move tangentially. The angular momentum of this weight about the axis is unchanged and by the same token the angular momentum of p+p is reduced. So is the rotational inertia of p+p. Both effects lead to the angular velocity of p+p remaining the same. Mathematically Initially $L = I\omega_i$ Finally $L - m\omega_i r^2 = (I - mr^2)\omega_f$ $\therefore \omega_i = \omega_f$ or an argument based on the lack of an external torque.	✓	
6(i)	Place the origin at M_1. Then take moments about M_1; this gives $(M_1 + M_2)r = M_2D$	(not considered to be sufficient on its own to be a scholarship opportunity)	
6(ii)	$\frac{GM_1M_2}{D^2} = M_1\omega_1^2 r$ $= M_1\omega_1^2\frac{DM_2}{(M_1+M_2)}$ $\therefore \omega_1^2 = \frac{4\pi^2}{T^2} = \frac{G(M_1+M_2)}{D^3}$ $\Leftrightarrow \frac{T^2}{D^3} = \frac{4\pi^2}{G(M_1+M_2)}$		✓

<table>
<tr><th>Question</th><th>Evidence for Scholarship</th><th>Evidence for Scholarship Criteria 1</th><th>Evidence for Scholarship Criteria 2</th></tr>
<tr><td></td><td>SECTION B: LONG QUESTIONS</td><td></td><td></td></tr>
<tr><td>1</td><td>Electric Motor</td><td></td><td></td></tr>
<tr><td>1(i)</td><td>$R = \frac{V}{I} = \frac{0.2}{0.40} = 0.5\ \Omega$

Straight line with gradient representing $R = 0.5\ \Omega$, (passing through (0,0), (0.2,0.4) should be drawn on the graph.</td><td></td><td>✓</td></tr>
<tr><td>1(ii)</td><td>Candidates need to refer to the back emf suggested in the theory to explain the results.

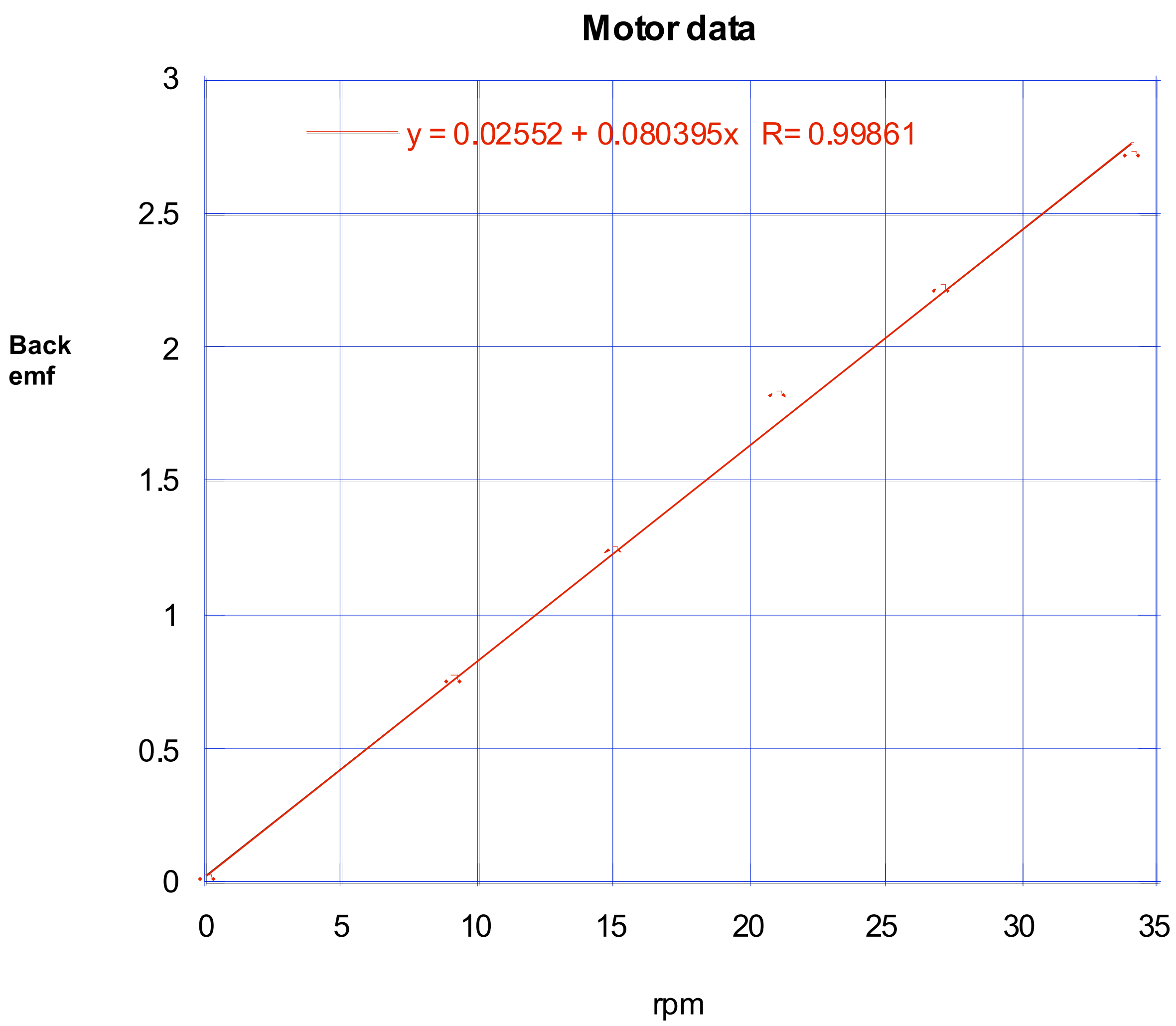
Key points:
• The induced emf would oppose the motion of the coil, making it harder to turn.
• The voltage supply would need to produce a larger voltage to overcome the induced emf whilst turning the coil. This is why a smaller than expected current is measured for a given applied voltage.

No Credit given for an explanation based on a change in the resistance of the wire. (The resistance would need to increase from 0.5 Ω to approx 40 Ω, which is unrealistic even with some heating of the wire.)</td><td>✓</td><td></td></tr>
<tr><td>1(iii)</td><td>Key points:
• Faraday's Law states that the magnitude of an induced emf is determined by the rate of change of flux. For the motor the induced emf should be proportional to the rotation rate. (Rotation rate is proportional to the rate of change of flux).
• The induced emf can be calculated from the difference between the measured voltage and the expected voltage in the wire when it's not rotating. (ie – the difference between the two lines on the graph).

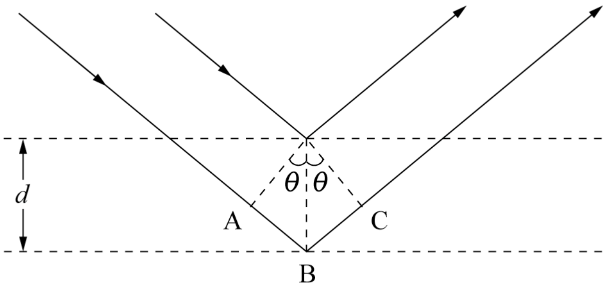
Students must:
• Calculate the back emf (back emf = $V - I \times 0.5$), or determine this emf from the distance between the two lines on their previous graph.
• Plot the back emf against rotation rate (labelled axes, sensible scales, points correctly plotted and straight line of best fit).

Back EMF   Rotation Rate
0   0
0.74   9
1.22   15
1.71   15
2.205   27
2.7   34</td><td></td><td>✓</td></tr>
</table>

Question	Evidence for Scholarship	Evidence for Scholarship Criteria 1	Evidence for Scholarship Criteria 2
1(iv)	Conclusion should include the following: • A summary of the findings – eg Voltage is non-linearly related to current. The back emf is proportional to rotation rate. • Reference to the hypothesis – eg the motor generates a back emf proportional to the rate of change of flux as suggested in the hypothesis.	✓	



Question	Evidence for Scholarship	Evidence for Scholarship Criteria 1	Evidence for Scholarship Criteria 2
2	**Doppler and Blood Flow**		
2(i)	The frequency of the reflected wave would be greater than the frequency of the incident wave. This is because as the blood moves towards the detector the reflected wavefronts will become closer together. The velocity of the ultrasound is unchanged so it will have a higher frequency.	✓	
2(ii)	Student 1 has derived the correct equation. Student 2 is incorrect because as the blood velocity tends to zero the Doppler shift tends to infinity, or as the blood velocity increases the Doppler shift decreases. Student 3 is incorrect because we would expect maximum Doppler shift when the blood is moving towards or away from the detector and zero shift when the blood is moving perpendicularly to the sound wave. This equation would cause the effect to be the opposite way round.		✓
2(iii)	$v = \dfrac{\Delta fc}{2f\cos\theta} = \dfrac{3100 \times 1.5 \times 10^3}{2 \times 5 \times 10^6 \cos 30^\circ} = 54 \text{ cm s}^{-1}$ Candidates who have selected student 2's equation as correct will obtain a huge velocity. They should realise that this is unrealistic and correct their error by using one of the other equations. Candidates who have selected Student 3's equation will obtain a similar (but incorrect) answer. Their mistake is not obvious, so award credit for continuity.		✓
2(iv)	Explanation must include the key points below: This method measures the magnitude of the **change** in frequency. There is no indication of whether the change in frequency is positive or negative so therefore there is no indication of whether the blood is flowing towards or away from the detector. Another possible answer could include a discussion of effective scattering volumes overlapping each other.	✓	

Question	Evidence for Scholarship	Evidence for Scholarship Criteria 1	Evidence for Scholarship Criteria 2
3	**Bragg's law**		
3(i)	The sources must have: 1) the same wavelength 2) fixed phase difference or coherent 3) a separation (d) greater than the wavelength 4) comparable amplitudes	✓	
3(ii)	 The extra path difference for the lower ray relative to the upper ray is AB + BC = 2AB but AB/d = $\sin\theta$ Therefore for a maximum in the reflected intensity at angle θ the path difference must be an integral number of wavelengths $m\lambda = 2d\sin\theta \quad m = 1, 2, 3, \ldots.$		✓
3(iii)	3rd order $\Rightarrow m = 3$ $\theta = \frac{29.2°}{2} = 14.6°$ $\lambda = 1.27 \times 10^{-10}$ m $d = \frac{m\lambda}{2\sin\theta} = \frac{3 \times 1.27 \times 10^{-10}}{2 \times \sin 14.6°}$ $= 7.56 \times 10^{-10}$ m		✓
3(iv)	Visible light has a wavelength of about 5000 × 10^{-10} m, which is too large for interference to be observed from adjacent planes. Mention could be made of diffraction by the better candidates.	✓	

Question	Evidence for Scholarship	Evidence for Scholarship Criteria 1	Evidence for Scholarship Criteria 2
4	**A Maglev Train**		
4(i)	The current in the wire generates a magnetic field. The loop of wire carries a current and is in this magnetic field. These interact to produce a force.	✓	
4(ii)	The direction of the magnetic field is into the paper (right-hand grip rule). The direction of the force on the loop is given by the right-hand rule. Each side of the loop experiences a force towards the centre of the loop. The magnitude of the force on the sides of the loop is given by $F = BIl$, where B is the magnetic field produced by the wire ($B \propto \frac{1}{r}$). The forces at the top and bottom of the loop cancel as B is the same, so the forces are equal and opposite. The force is greater along the side of the loop nearest the wire than the opposite side, so the net force will be acting away from the wire.	✓	
4(iii)	Magnetic field produced by wire: $B = \frac{\mu_0 I_2}{2\pi r}$ where r is distance from wire. Force F_1 on side of loop nearest the wire: $F_1 = BI_1 l = \frac{\mu_0 I_1 I_2 b}{2\pi d}$ Force F_2 on side of loop farthest from wire: $F_2 = BI_1 l = \frac{\mu_0 I_1 I_2 b}{2\pi(d+a)}$ Resultant force F: $F = \frac{\mu_0 I_2 I_1 b}{2\pi d} - \frac{\mu_0 I_1 I_2 b}{2\pi(d+a)}$ $F = \frac{\mu_0 I_1 I_2 b}{2\pi}\left[\frac{1}{d} - \frac{1}{a+d}\right]$		✓
4(iv)	When $a<<d$: $F \approx \frac{\mu_0 I_1 I_2 b}{2\pi}\left[\frac{1}{d} - \frac{1}{d}\right] = 0$ ie the forces on the two sides of the loop are approximately equal in magnitude and cancel each other out. When $d<<a$: $F \approx \frac{\mu_0 I_1 I_2 b}{2\pi}\left[\frac{1}{d}\right]$ ie this is the maximum possible force as the force on the side of the loop farthest from the wire is negligible.		✓
4(v)	$d = \frac{\mu_0 N I_1 I_2 b}{2\pi F} = \frac{1.26\times10^{-6}\times5000\times100\times100\times20}{2\pi\times20\ 000\times9.8} = 1.0\times10^{-3}\,\text{m}$		✓
4(vi)	• Estimate the mass of an average person – say 70 kg (accept estimates between 50 and 100 kg) The total mass of a full carriage = 20 000 + (70 x 70) = 24 900 kg Calculate new value of d $d = 0.82$ mm		✓

Question	Evidence for Scholarship	Evidence for Scholarship Criteria 1	Evidence for Scholarship Criteria 2
4(vii)	• Discussion of 1 advantage and 1 disadvantage required for credit. Accept anything reasonable based on a discussion of the physics involved eg forces, energy, power etc. Possible answers may include: **Advantages:** Train can glide along the track without friction between the wheels and track, so less force is needed to accelerate/decelerate, maintain constant velocity etc. Very high speeds can be reached by levitating the train and using electromagnetic (or other) propulsion methods. This avoids the mechanical limitations of conventional motors and wheels where at high speeds there is a lot of friction, heating and stress on the mechanical components. **Disadvantages:** Friction between the wheels and track can be useful – eg when accelerating or braking. A different method of propulsion/braking could be used, or the train could rest on the track at times. There is a high current in the wires (I = 100 A) and these wires will be long (5,000 turn coil, kms of track). We would expect significant heating of these wires ($P = I^2R$) and therefore they will require a lot of power.	✓	

Judgement Statement

The following is a guide to the standard required for each grade in the two criteria.

Criterion 1: Total Number of Opportunities: 15	**Criterion 2: Total Number of Opportunities: 13**
Minimum Levels of performance: • Scholarship Performance is demonstrated if the student gives concise explanations or analyses in terms of phenomena, concepts, principles and/or relationships that show clear understanding in no fewer than SEVEN situations. • Outstanding Performance is demonstrated if the student gives concise explanations or analyses in terms of phenomena, concepts, principles and/or relationships that show clear understanding in no fewer than NINE situations.	**Minimum Levels of performance:** • Scholarship Performance is demonstrated if the student has been able to abstract the relevant concepts and/or principles from physical situations and integrate these in the solution of no fewer than SEVEN complex problems. • Outstanding Performance is demonstrated if the student has been able to abstract the relevant concepts and/or principles from physical situations and integrate these in the solution of no fewer than NINE complex problems.
Overall Sufficiency: **Scholarship:** In order to gain Scholarship Physics, a candidate must meet the minimum requirements as set out above AND have no fewer than SEVENTEEN scholarship opportunities identified throughout there paper. For example a candidate may have seven criterion 1 opportunities but must have at least ten criterion 2 opportunities to gain Scholarship Physics. **Outstanding Performance:** In order to gain Outstanding Performance in Scholarship Physics, a candidate must meet the minimum requirements as set out above AND have no fewer than TWENTY-ONE scholarship opportunities identified throughout their paper. For example a candidate may have nine criterion 1 opportunities but must have at least 12 criterion 2 opportunities to gain Outstanding Performance in Scholarship Physics.	