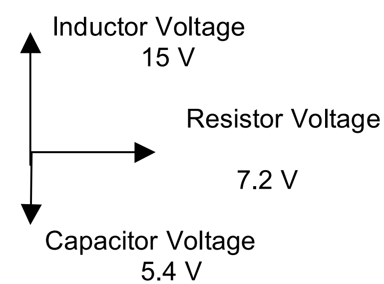
NEW ZEALAND SCHOLARSHIP 2004

ASSESSMENT SCHEDULE FOR PHYSICS

SECTION A: SHORT QUESTIONS

Question	Type 1 (explanatory) or Type 2 (problem)	B Evidence	A Evidence
1(i)	2	${}^{210}_{84}\mathrm{Po} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{206}_{82}\mathrm{Pb}$ Initial mass m_i = 209.983 amu Final mass m_f = 209.977 amu Candidates do not successfully convert amu to kg but do use E= $(m_i - m_f)\ c^2$ to calculate a final energy. E=5.4 x 10^{14} joules	${}^{210}_{84}\mathrm{Po} \rightarrow {}^{4}_{2}\mathrm{He} + {}^{206}_{82}\mathrm{Pb}$ Initial mass m_i = 209.983 amu Final mass m_f = 209.977 amu Candidates successfully convert amu to kg Energy E = $(m_i - m_f)\ c^2$ = 8.969 x 10^{-13} joules
1(ii)	2		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 $v_\alpha = \frac{m_{pb}}{m_\alpha} v_{pb}$ $\frac{1}{2} m_\alpha v_\alpha^2 = \frac{E}{1 + \frac{m_\alpha}{m_{pb}}}$ The most efficient pathway is to solve the problem algebraically however 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 fraction of the original energy *E*.

Question	Type 1 (explanatory) or Type 2 (problem)	B Evidence	A Evidence
			kinetic energy of alpha particle = 0.98 E
2	1	Candidates must include the following: • 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. **Experimental example of wave behaviour:** Candidates will use choose at least one wave behaviour and explain it but will tend to introduce irrelevancies in relation to the description. **Experimental example of particle behaviour:** Candidates will state at least one particle behaviour from the photoelectric effect. Candidates will tend to introduce irrelevancies in relation to the description.	Candidates must include the following: • 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	Type 1 (explanatory) or Type 2 (problem)	B Evidence	A Evidence
3	1	Candidates need to identify that the voltmeter is not faulty and back this up by a clear explanation. Candidates explanation will not include a numerical check. Their explanation must include: • 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 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.	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.

Question	Type 1 (explanatory) or Type 2 (problem)	B Evidence	A Evidence
			$V_s = \sqrt{(15-5.4)^2 + 7.2^2} = 12\text{ V}$ 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)	1		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)	1		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).
5(i)	1	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 $I_f\omega_f = I_i\omega_i$ But with extended arms $I_f > I_i$ therefore $\omega_f < \omega_i$ ie the angular velocity of the person and platform is less.	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.

Question	Type 1 (explanatory) or Type 2 (problem)	B Evidence	A Evidence
5(ii)	1		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 $L = I\omega_\mathrm{i}$ Finally $L - m\omega_\mathrm{i}\mathrm{r}^2 = (I - mr^2)\omega_\mathrm{f}$ $\therefore \omega_\mathrm{i} = \omega_\mathrm{f}$ or an argument based on the lack of an external torque.
6(i)	2	Place the origin at M_1. Then take moments about M_1; this gives $(M_1 + M_2)r = M_2D$	
6(ii)	2		$\frac{\mathrm{G}M_1M_2}{D^2} = M_1\omega_1^2\mathrm{r}$ $= M_1\omega_1^2\frac{\mathrm{D}M_2}{(M_1+M_2)}$ $\therefore \omega_1^2 = \frac{4\pi^2}{T^2} = \frac{\mathrm{G}(M_1+M_2)}{D^3}$ $\Leftrightarrow \frac{T^2}{D^3} = \frac{4\pi^2}{\mathrm{G}(M_1+M_2)}$

SECTION B: LONG QUESTIONS

Question	Type 1 (explanatory) or Type 2 (problem)	B Evidence	A Evidence
1(i)	2	$R = \frac{V}{I} = \frac{0.2}{0.40} = 0.5\,\Omega$ Straight line, with gradient representing *R* = 0.5 Ω, passing through (0,0), (0.2,0.4) should be drawn on the graph.	
1(ii)	2		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.)
1(iii)	1		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

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<tr><th>Question</th><th>Type 1 (explanatory) or Type 2 (problem)</th><th>B Evidence</th><th>A Evidence</th></tr>
<tr><td></td><td></td><td></td><td>– 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></tr>
<tr><td>1(iv)</td><td>1</td><td>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.</td><td></td></tr>
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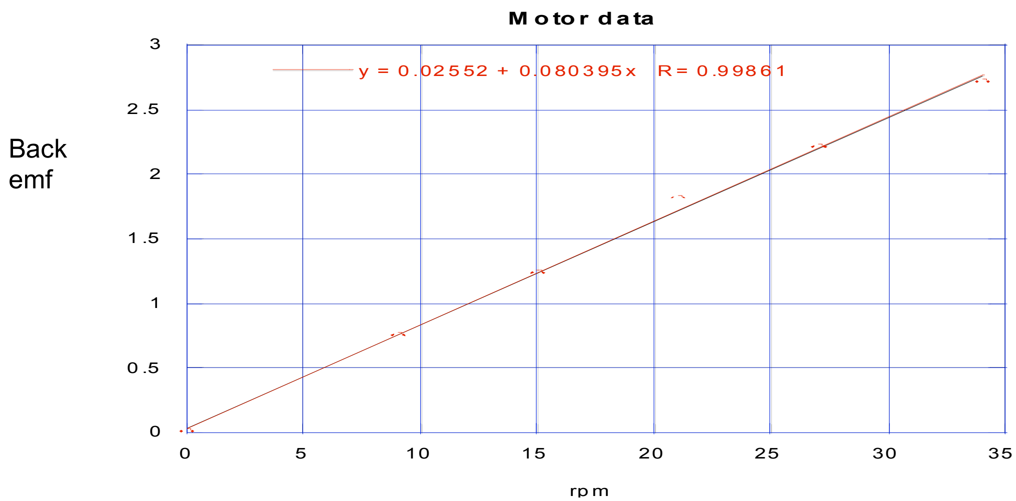
<tr><td colspan="4">
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<tr><td>2(i)</td><td>1</td><td>The frequency of the reflected wave would be greater than the frequency of the incident wave.
This is because as the blood moves towards the detector the reflected wavefronts will become closer together.</td><td>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.</td></tr>
<tr><td>2(ii)</td><td>2</td><td></td><td>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.</td></tr>
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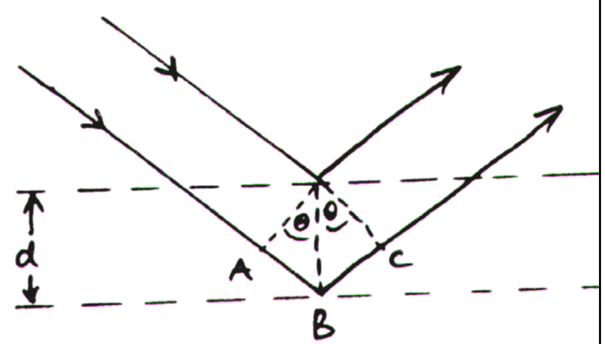
Question	Type 1 (explanatory) or Type 2 (problem)	B Evidence	A Evidence
			This equation would cause the effect to be the opposite way round.
2(iii)	2	$v = \frac{\Delta fc}{2f\cos\theta} = \frac{3100 \times 1.5 \times 10^3}{2 \times 5 \times 10^6 \cos 30^\circ} = 54\,\text{cm s}^{-1}$ Candidates who 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)	1		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.
3(i)	1	The sources must have: 1) the same wavelength 2) fixed phase difference or coherent	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

Question	Type 1 (explanatory) or Type 2 (problem)	B Evidence	A Evidence
3(ii)	2		 The extra path difference for the lower ray relative to the upper ray is AB + BC =2AB but AB/d = sinθ Therefore for a maximum in the reflected intensity at angle θ the path difference must be an integral number of wavelengths $m\lambda = 2d\sin\theta \quad m = 1, 2, 3, ...$
3(iii)	2		$3\text{rd order} \Rightarrow m = 3$ $\theta = \frac{29.2°}{2} = 14.6°$ $\lambda = 1.27 \times 10^{-10}\ \text{m}$ $d = \frac{m\lambda}{2\sin\theta} = \frac{3 \times 1.27 \times 10^{-10}}{2 \times \sin 14.6°}$ $= 7.56 \times 10^{-10}\ \text{m}$

Question	Type 1 (explanatory) or Type 2 (problem)	B Evidence	A Evidence
3(iv)	1	Candidates recognised that the wavelength of light was too large for interference.	Visible light has a wavelength of about 5000×10^{-10} m, which is too large for interference to be observed from adjacent planes. Mention will be made of diffraction and the necessary condition that wavelength should approximately be of the order of the plane spacing.
4(i)	1		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)	1	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. The side nearest the long wire experiences a force away from the long wire.	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)	2		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: $F_1 = BI_1 l = \frac{\mu_0 I_1 I_2 b}{2\pi d}$

Question	Type 1 (explanatory) or Type 2 (problem)	B Evidence	A Evidence
			Force F_2 on side of loop farthest from wire: $F_2 = BI_1 l = \dfrac{\mu_0 I_1 I_2 b}{2\pi(d+a)}$ Resultant force F: $F = \dfrac{\mu_0 I_2 I_1 b}{2\pi d} - \dfrac{\mu_0 I_1 I_2 b}{2\pi(d+a)}$ $F = \dfrac{\mu_0 I_1 I_2 b}{2\pi}\left[\dfrac{1}{d} - \dfrac{1}{a+d}\right]$
4(iv)	2	**Either:** When a<<d: $F \approx \dfrac{\mu_0 I_1 I_2 b}{2\pi}\left[\dfrac{1}{d} - \dfrac{1}{d}\right] = 0$ ie the forces on the two sides of the loop are approximately equal in magnitude and cancel each other out. **or:** When d<<a: $F \approx \dfrac{\mu_0 I_1 I_2 b}{2\pi}\left[\dfrac{1}{d}\right]$ ie this is the maximum possible force as the force on the side of the loop farthest from the wire is negligible.	When a<<d: $F \approx \dfrac{\mu_0 I_1 I_2 b}{2\pi}\left[\dfrac{1}{d} - \dfrac{1}{d}\right] = 0$ ie the forces on the two sides of the loop are approximately equal in magnitude and cancel each other out. When d<<a: $F \approx \dfrac{\mu_0 I_1 I_2 b}{2\pi}\left[\dfrac{1}{d}\right]$ ie this is the maximum possible force as the force on the side of the loop farthest from the wire is negligible.
4(v)	2	$d = \dfrac{\mu_0 N I_1 I_2 b}{2\pi F} = \dfrac{1.26\times10^{-6}\times5000\times100\times100\times20}{2\pi\times20000\times9.8} = 1.0\times10^{-3}\,m$	

Question	Type 1 (explanatory) or Type 2 (problem)	B Evidence	A Evidence
4(vi)	2		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
4(vii)	1	Discussion of 1 advantage and 1 disadvantage required for credit. The discussion must involve the physics eg forces, energy, power etc. Some minor misconceptions or irrelevancies will be apparent. **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. **Disadvantages:** There is a high current in the wires (I=100A) 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.	Discussion of 1 advantage and 1 disadvantage required for credit. The discussion must involve the physics eg forces, energy, power etc. Response should not include any irrelevancies or misconceptions. **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=100A) 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.