NEW ZEALAND SCHOLARSHIP 2004

PHYSICS

Sample of assessed candidate work: Outstanding Performance - Performance Descriptor 1 – Performance Category 1.

This candidate has gained 10 A1, and 8 A2, and 6 B level answers. A1 and B1 answers involve explanations and analysis, while A2 and B2 answers involve the solution of complex problems. Refer to the assessment schedule for marking codes.

SECTION ONE: SHORT QUESTIONS
QUESTION ONE
(i) Using the data supplied calculate the energy change associated with this decay.

$$209.983 - 205.974 - 4.003 = 6 \times 10^{-3}\,\text{amu}$$
$$= 9.966 \times 10^{-3}\,\text{kg}$$
$$E = mc^2$$
$$= 9.966 \times 10^{-3} \times (3 \times 10^8)^2$$
$$\approx 8.97 \times 10^{-13}\,\text{J}$$

A2 answer.

(ii) Assuming that the polonium atom was at rest before decaying, calculate what fraction of the energy available from the decay process is gained by the alpha particle.

$$M(Pb)v_1 = M(\alpha)v_2$$
$$51.455 = \frac{v_2}{v_1}$$
$$\text{Energy} = \frac{1}{2}m_1 v_1^2 + \frac{1}{2}m_2 v_2^2$$
$$= \frac{1}{2}51.455\frac{v_2^2}{51.455^2} + \frac{1}{2}mv_2^2$$
$$= \frac{v_2^2}{51.455} + v_2^2$$
$$\therefore \text{energy} = \frac{51.455}{52.455} = \frac{49}{50}$$

A2 answer.

QUESTION TWO

Explain what is meant by the term **wave-particle duality**, provide a description of experimental evidence supporting the wave nature of light, and a further description supporting the particle nature of light.

Light seem to travel like a wave while it exhibits interactions like that of a particle. This means light's existence can be modelled by both wave and particle theory.

Experiments that supports the wave model of light include the interference patterns exhibited when light is passed through a thin slit. This interference pattern can be attributed the diffraction of light as it passes through the opening which constitute that it is a wave. As waves bend when passing an object edge – it tends to bend around the object. Furthermore experiments such as thin film interference shows that light has a wavelength. Further support comes from refraction of light, another wave-like behaviour.

A1 answer.

On the other hand, the photoelectric equipment cannot be explained by the wave model for various reasons. First the emission of electron from photo-sensitive surfaces are dependant on frequency of light, not intensity. This can be explained by the particle model of light. As light comes in discrete packets or quanta (like particles) and on contact with electrons all the energy is transferred which explains the absence of a time delay after contact. (Energy of light is not continuous). Hence higher intensities offer more photon of the same energy.

This lead to the theory that all matter has wave and particle characteristics (De. Broglie's equation connects these two)

QUESTION THREE
Is the voltmeter faulty? Defend your point of view.

No it is not faulty. Since the voltage on the capacitor is 180° out of phase to that of the inductor, they cancel each other out to a degree – in which case the energy is transferred directly from electric potential to magnetic potential. This allows the voltage across the inductor to be greater than that of the source. The "additional voltage" is provided from the capacitor. This can be verified by the following:

$$V_s^2 = (V_L - V_c)^2 + V_R^2$$
$$= (15 - 5.4)^2 + 7.2^2$$
$$= 92.16 + 51.84 = 144$$
$$V_s = 12V$$

This is in concordance with the data given.

A1 answer.

QUESTION FOUR
(i) Assuming the ball is moving at a constant speed in a horizontal circle, explain why the wire from the thrower's hands to the ball cannot be parallel to the ground.

It is impossible for the wire to be parallel because of the constant weight force that applies to the ball. It can be seen that as a result of the weight force there is always a vertical component to the tension T. Hence there will always be an angle between the plane of rotation and horizontal. Unless centripetal force Fc is infinite, which is impossible.

A1 answer.

(ii) Explain how the hammer thrower is able to increase the speed of the ball as he winds up for the throw.

Since angular momentum is conserved, (L = I ϖ= constant) he only has to decrease rotational inertia in order to increase angular velocity. He can do this by reducing the radius of the swing by pulling his arms in towards himself (centre of rotation). Since I = mr^2 and ϖ =v/r, angular momentum L = mr^2 v/r = mvr. So as this is constant (Law of conservation of Momentum) a decrease in radius r will increase linear velocity V since mass of the system M is constant. So he should pull his arms in to reduce radius of rotation. As this will change the distribution of mass hence rotational inertia.

Candidate has failed to identify the key physics concepts. Evidence does not contribute towards any descriptor.

QUESTION FIVE
(i) Still holding the masses, the student extends her arms slowly.

This will change the distribution of mass of the system in that mass will be concentrated to the edges. Hence rotational inertia is increased. Since angular momentum L is conserved and L = I ϖ, rotational velocity ϖ will decrease so she will spin slower (period will increase).

B1 answer.

(ii) With her arms extended, the student drops one of the masses.

If the mass is dropped straight down this would decrease her rotational inertia and increase her angular velocity as angular momentum is conserved. However, it is more likely that she drops by just letting go of the mass, in which case the mass will travel at a tangent to the rotational motion: This means the angular momentum of the stool system decrease by mvr, (m mass of the dropped mass, v is velocity (linear and r is radius at which it is released) as the overall angular momentum is conserved while the rotational inertia of the stool will also decrease by mr^2. So there should be no changes to the angular velocity of the stool. As the decrease in angular momentum is that of the mass which has been excluded So the final angular momentum is in the same proportion.

A1 answer.

QUESTION SIX

(i) Express the distance, r, of the star of mass M_1 from the centre of mass in terms of M_1, M_2 and D.

$$\text{COM} = M_1r_1 = M_2r_2$$
$$r_2 + r_1 = D$$
$$M_1r_1 = M_2(D - r_1)$$
$$r_1 = \frac{M_2(D - r_1)}{M_1}$$
$$r = \frac{M_2D}{(M_1 + M_2)}$$

B2 answer.

(ii) By equating the gravitational force between the stars with the magnitude of the centripetal force on one of them, show that the orbital period of the binary system, T, is related to the distance between the starts, D, by the relationship.

$$\frac{GM_1M_2}{D^2} = \frac{M_1v^2}{r}$$
$$\frac{GM_2}{D^2} = \varpi^2 r = \frac{4\pi^2 r}{T^2}$$
$$\therefore \frac{GM_2}{D^2} = \frac{4\pi^2}{T^2}\left(\frac{M_1M_2D}{M_1(M_1 + M_2)}\right)$$
$$\frac{T^2}{D^3} = \frac{4\pi^2}{G(M_1 + M_2)}$$

A2 answer.

SECTION B: LONG QUESTIONS

QUESTION ONE: ELECTRIC MOTOR

(i) Calculate the resistance, *R*, of the coil when stationary and graph the relationship that normally exists between I and V for a conductor of resistance, *R*.

> *[Candidate's graph and table omitted.]*
>
> V=0.2
> A=0.4 = V/I = 0.2V/0.4A
> = 0.5 Ω
>
> Resistance = 0.5 Ω

B2 answer.

(ii) Give an explanation why the voltage and current measurements obtained for the motor are different from the results you would normally expect for a conductor of resistance, *R*.

> When the current is switched on there is a large change of the rate of flow of charge, this induces a large back emf in the motor acting as an inductor $\left(V = -L\frac{\Delta i}{\Delta t}\right)$. This results in a gradual increase in current and the voltage across the inductor gradually decrease as the back emf decreases (as rate of current change is reduced).
> This gradual increase in current can be modeled by the equation $\frac{1}{I_0} = 1 - e^{-t/\tau}$ where time constant τ is dependent of inductance and resistance. Whereas for a conductor the current immediately reaches maximum value ($I = I_o$). Reactance of inductor is dependant on frequency rotation, so it is not constant.
> Hence this results in the change in reactance of the inductor where as the resistance of conductors are constant.

Candidate has failed to identify the key physics concepts. Evidence does not contribute towards any descriptor.

(iii) Devise a graphical method that would verify your explanation in part (ii). (*Hint: Are there any variables you would expect to be linearly related?*) Your answer should include a drawn graph.

> The reactance of the inductor is proportional to the frequency or angular velocity of the change in current
>
> $X_L = \varpi L$ and L is constant
>
> $\frac{V}{I} = X_L = 2\pi f L$
>
> $\therefore \frac{V}{I} \propto f$
>
> So graph of V/I against f should be a straight line.
> This gradient shoud give 2πL.
>
> The intercept gives resistance of the circuit.
>
> $\frac{V}{I} = \sqrt{(\varpi L)^2 + R^2}$
>
> If this linear it will prove that the electric motor can act as an inductor showing reactance similar to an inductor.

Candidate has failed to identify the key physics concepts. Evidence does not contribute towards any descriptor.

[Candidate's graph omitted.]

(iv) Write a conclusion to summarise and explain your findings.

> Gradient = 0.1405 = 2πL L= 0.0224 H
> However this is assuming that the resistor is very insignificant hence
> $(\varpi L)^2 + R^2 \simeq (\varpi L)^2 = Z^2$
> $\varpi L = Z$
> However since the y intercept = 0.7 this is only applicable for values of f greater than about 25.
> $(2\pi \times 25 \times 0.0224)^2 + 0.7^2 \simeq (2\pi \times 25 \times 0.0224)^2$ Hence this shows the resistor has resistance of 0.7 ohm while has an inductance of about 0.02 H.

Candidate has failed to identify the key physics concepts. Evidence does not contribute towards any descriptor.

QUESTION TWO: DOPPLER AND BLOOD FLOW

(i) Does the reflected ultrasound have a lower, higher or the same frequency as the transmitted wave? Explain.

> It should have higher frequency. Because when the waves reach the blood moving towards the transmitter the frequency increase by $1+\frac{V_B}{V_T}$ where V_B is velocity of blood. And when this transmitted back to the receiver this is further increased by overall the frequency increase by $\frac{V_T + V_B}{V_T + V_B}$. This is because the waves reach the blood at closer intervals than the emitted wavelength as the blood is moving as apparent frequency increases as the wavelength decreases.

A1 answer.

(ii) Identify the correct equation, giving reason to justify your choice (a derivation of the correct equation is not required).

> Student 1 is correct. Student 3 is wrong because his model shows that when θ = 0, the change is maximum. This is false as the velocity component responsible for Doppler effect is not perpendicular to wave. Student 1 is correct as unlike student 2, her Δf is proportional to V of blood. This is plausible as the greater the V of observer / source the more distinct doppler effect is.

A2 answer.

(iii) Calculate the speed of the blood.

$$v = \frac{\Delta f c}{2f\cos\theta}$$
$$= \frac{3.1\times10^3 \times 1.5\times10^3}{2\times5\times10^6 \times \cos(30^\circ)}$$
$$= 0.537\,\mathrm{m\,s^{-1}} = 0.54\,\mathrm{m\,s^{-1}}\,(2\,\mathrm{sf})$$

B2 answer.

(iv) Suggest a difficulty in determining the direction of blood flow using the above technique.

Both cases the Δf calculated will be the same. This is because for the equation when V is negative (away from source) then the angle between wave and blood flow is 180 - θ. The cos θ is the negative equivalent of cos (180 - θ) ie. $\cos\theta = -\cos(180 - \theta)$. This means $V\cos\theta = -v\cos(180 - \theta)$.
So both direction will achieve the same result, thus it will be difficult to determine which direction it is.
.

A1 answer.

QUESTION THREE: BRAGG'S LAW

(i) State the necessary conditions for interference fringes to be produced by two sources of light at a distance of *d* apart.

Sources have to be coherent : in phase – constant, equal frequency
The light has to be monochromatic
D has to be very small (d <<L where L is distance to screen)
Sources have to be of similar intensity
Wavelength must be similar to distance between sources

B1 answer.

(ii) Using your knowledge of the necessary conditions for constructive interference of the rays, derive Bragg's Law.

For constructive interference path distance = $m\lambda$
PD= additional distance travelled = $2d\sin\theta$

$\therefore m\lambda$ = extra distance
$m\lambda = 2d\sin\theta$

Candidate has failed to identify the key physics concepts. Evidence does not contribute towards any descriptor.

(iii) Calculate the interplanar distance *d*.

$$((180 - 29.3)/2) + \theta = 90$$

$$\theta = 14.6^\circ$$

$$\frac{m\lambda}{2\sin\theta} = d$$

$$d = \frac{3 \times 1.27 \times 10^{-10}}{2\sin 14.6}$$

$$d = 7.56 \times 10^{-10}\,\text{m}$$

A2 answer.

(iv) Given the value of *d* calculated above, comment on why X-rays rather than visible light are used for diffraction experiments with crystals.

For interference to occur d ≈ λ. The λ of visible light is in the order of 450 – 650 mm. This is too large. Much larger than d. So X-rays are used as they have lower wavelength.

X rays have wavelengths similar to the d calculated as interference will be more effective.

A1 answer.

QUESTION FOUR: A MAGLEV TRAIN

(i) Explain why there is a force acting on the loop.

A1 answer.

The wire and loop are both carrying current hence both creates a magnetic field in the perpendicular plane. Since these are both in the same plane, the magnetic fields will interact with opposite field lines repelling one another and like fields attracting each other.

(ii) Explain why the force on the loop acts to move the loop away from I_2.

The calculation can be treated as follow : Since the sections of the loop perpendicular to the wire will not interact with the wire, the loop is treated as 2 separate parallel wires with current I, in opposite direction:
The interaction between the wire on the closer wire of the loop is $F = -\frac{kI_1I_2L}{d}$ and since the current is in opposite direction this is a repelling force. The other force is attractive : $F = \frac{kI_1I_2L}{d+a}$
Since d < (d+a) the attractive force is weaker than the repulsive force. So overall the wire experiences a repulsion force and similarly the loop experiences a repulsion force from the wire (Newton third law).

A1 answer.

(iii) Derive an expression for the magnitude of the force acting on the loop.

$$B = \frac{\mu_0 I_1}{2\pi d}$$

$$\therefore B = \frac{\mu_0 I_1}{2\pi d}$$

$$B = \frac{\mu_0 I_1}{2\pi(d+a)}$$

$$\therefore F_{TOTAL} =$$

$$= \frac{\mu_0 I_1}{2\pi d} \times I_2 \times b - \frac{\mu_0 I_1}{2\pi(d+a)} \times I_2 \times b$$

$$= \frac{\mu_0 I_1 I_2 b}{2\pi d}\left(\frac{1}{d} - \frac{1}{d+a}\right)$$

A2 answer.

(iv) From your explanation given above, it can be seen that the relative size of the variables *a* and *d* will have a strong influence on the size of the force. Discuss what would happen to the force in the limited cases where $a \ll d$ and $d \ll a$.

When a << d $\left(\frac{a}{d^2 + ad}\right) \approx 0$ so the force is 0. This is sensible as when the distance a between the two wires making up the loop (parallel to the I_2 wire) is almost non-existant, * then the attractive force between the wires travelling parallel will cancel the force of the wire in the opposite direct as the distance between these two and the wire of I_2 are almost equal so their interaction cancel out and F = 0 i.e radius making up the magnetic field B = $\frac{\mu}{2\pi}\frac{I}{r}$ is almost equal.

When d <<a $\frac{a}{d^2 + ad} \simeq \frac{a}{ad} = \frac{1}{d}$ So only the repelling force applies.
This is because the magnetic field at the wire closer to wire with I_2 is so much greater than the wire further from I_2 that the repulsion force is not affected by the attractive force of the second wire so F= $\frac{\mu_o I_2 I_1 b}{2\pi d}$ - only repulsion * relative to d

A2 answer.

(v) Calculate the distance d between the lower side of the coil and the cable.

$b = 20\text{m} \quad F = 200/d$

$F = 196000\text{N}$

$d = 200/196000$

$d = 1.0 \times 10^{-3}\text{m}$

B2 answer.

(vi) One of the designers is concerned that the distance *d* will change considerably when people get on the train. Estimate the value of *d* for a full carriage holding 70 people.

Mass of one person 70 kg
M=24900
F=244020 N
d=200/244020
d=8.2x10^{-4} m

A2 answer.

(vii) Discuss at least one advantage and at least one disadvantage with the design of this type of train. Your discussion should be relevant and linked to the physics of the situation.

Advantage : Since the train is supported by a force from magnetic field, there is no strain on the structure of the train itself so there is little need for repair.
Since there is no fuel used but electricity there is no pollution – noise or environmental.

Since friction is reduced dramatically by levitation, the train can travel much faster than conventional trains.

A1 answer.

Disadvantage:
The train will be expensive
The train require large electricity input, since the cable beneath the train will be long, there will likely be high resistance hence a large voltage needs to be applied (similar to power cables). This will be dangerous and power consuming
The train can only safely accommodate a certain amount of weight before the distance between coil and cable becomes to close and is likely to come in contact, the results will be disasterous.

Sample of assessed candidate work: Performance Descriptor 2 - Performance Category 3

This candidate has gained 8 A1, and 8 A2, and 6 B level answers. A1 and B1 answers involve explanations and analysis, while A2 and B2 answers involve the solution of complex problems. Refer to the assessment schedule for marking codes.

SECTION ONE: SHORT QUESTIONS
QUESTION ONE
(i) Using the data supplied calculate the energy change associated with this decay.

$$\Delta E = \Delta m \times c^2$$
$$= (m(Pb) + m({}^4_2\alpha) - m(Po) \times 1.661 \times 10^{-27} kg \times (3.00 \times 10^8 ms^{-1})^2$$
$$= (6 \times 10^{-3}) \times 1.661 \times 10^{-27} kg \times 9.00 \times 10^{16} m^2s^{-2}$$
$$= 8.9694 \times 10^{-13}\ J$$
$$= 8.97 \times 10^{-13} J \quad (3sf)$$
$$\text{Energy Change} = 8.97 \times 10^{-13} J$$

A2 answer.

(ii) Assuming that the polonium atom was at rest before decaying, calculate what fraction of the energy available from the decay process is gained by the alpha particle.

$$\text{Fraction} = \frac{4.003}{4.009} \quad - \quad 0.9985$$
$$\frac{m(He)}{m(Po) - m(Pb)}$$
$$= \frac{4003}{4009}$$

Candidate has failed to identify the key physics concepts involved. Evidence does not contribute towards any descriptor.

QUESTION TWO
Explain what is meant by the term **wave-particle duality**, provide a description of experimental evidence supporting the wave nature of light, and a further description supporting the particle nature of light.

The term wave-particle duality means that light displays properties of waves and also properties of particles. Light can be shown to act like a wave in certain experiments. Light has a measurable frequency and wavelength, like a wave. It will refract like a wave, but only a very small amount due to short wavelength. In a diffraction grating, light will interfere with itself by diffraction and cause an interference pattern.
Light also reflects and refracts in different optically dense materials, and slows down in more dense materials. The photo electric effect shows that light has particle properties. Energy is quantised in light, made of many individual photons with energy E=hf. To ionize metals, electrons must be removed and that requires a certain minimum energy. With light, the energy given to each electron depends only on the frequency, unlike with a wave where energy is dependent on the amplitude.

A1 answer.

QUESTION THREE

Is the voltmeter faulty? Defend your point of view.

The voltmeter is not faulty. In a AC circuit, the voltage is continually changing. AC circuit, the voltage is continually changing. Since capacitors and inductors store and release charge, out of sync with the voltage supply, their 'peak' voltage (Vrms = Vpeak/√2) can be higher than a simple addition would allow. In fact the equation is

$V_{sup} = \sqrt{(V_{ind} - V_{cap})^2 + V_R{}^2}$ which gives $12.0 = \sqrt{(15 - 5.4)^2 + 7.2^2}$ or

12V=12V which is correct. This equation works because the capacitor is 180° out of sync in the AC waveform compared to the inductor, and both of them are at 90° to the supply. This is why Pythogorian addition is used.

A1 answer.

QUESTION FOUR

(i) Assuming the ball is moving at a constant speed in a horizontal circle, explain why the wire from the thrower's hands to the ball cannot be parallel to the ground.

To stay in a horizontal circle, the gravitational force must be balanced on the ball. To do this the thrower must pull the ball upwards as well as in a circle. He cannot do this if his hands are parallel to the ball, as they could only pull horizontally.

A1 answer.

(ii) Explain how the hammer thrower is able to increase the speed of the ball as he winds up for the throw.

To increase the speed of the ball he pulls harder on the fixed wire. Through tension this leads to a greater force on the ball. Since $a = v^2/r$, increasing a but keeping the same r (the length of the wire) will increase v. Acceleration (a) = F/m so increasing force increases acceleration ∴ increasing speed.

Candidate has failed to identify the key physics concepts. Evidence does not contribute towards any descriptor.

QUESTION FIVE

(i) Still holding the masses, the student extends her arms slowly.

Her angular velocity will slowly decrease. Her rotational inertia (I) will increase as $I = \Sigma mr^2$, and r is increasing. Meanwhile L (angular momentum) will be conserved and not change. Since $L = I\varpi$, increasing I will decrease ϖ.

Candidate has identified some of the relevant physics of this situation.
B1 answer.

(ii) With her arms extended, the student drops one of the masses.

Her angular velocity will not change. Although her rotational inertia will decrease by roughly half, she will also lose the same proportion of angular momentum. Since $\varpi = L/I$, decreasing both angular momentum and inertia by half will not change the angular velocity. She will lose the angular momentum because it was "stored" in the ball she dropped.

Candidate has identified the key physics concepts but failed to apply them correctly to the generic situation. Evidence does not contribute towards any descriptor.

QUESTION SIX

(i) Express the distance, r, of the star of mass M1 from the centre of mass in terms of M1, M2 and D.

$$M_1 r = M_2(D - r)$$
$$M_1 r + M_2 r = M_2 D$$
$$r = \frac{M_2}{M_1 + M_2} \text{x} D$$

B2 answer.

(ii) By equating the gravitational force between the stars with the magnitude of the centripetal force on one of them, show that the orbital period of the binary system, *T*, is related to the distance between the stars, *D*, by the relationship.

$$F_1 = \frac{GM_1M_2}{D^2} \qquad T = \frac{2\pi}{\varpi} = \frac{r2\pi}{v}$$
$$a_1 = \frac{F_1}{m_1} \qquad v = \frac{2\pi r}{T} \quad v^2 = \frac{4\pi^2 r^2}{T^2}$$
$$F_g = \frac{GMm}{D^2}$$
$$\therefore a_1 = \frac{GM_2}{D^2}$$
$$\therefore \frac{v^2}{r} = \frac{GM_2}{D^2} \qquad a = \frac{v^2}{r}$$
$$\therefore \frac{4\pi^2 r^2}{rT^2} = \frac{GM_2}{D^2} \qquad r = D\,\frac{M_2}{M_1 + M_2}$$
$$\frac{4\pi^2 DM_2}{T^2(M_1 + M_2)} = \frac{GM_2}{D^2}$$
$$\frac{4\pi^2 M_2}{T^2(M_1 + M_2)} = \frac{GM_2}{D^3}$$
$$\frac{4\pi^2}{T^2(M_1 + M_2)} = \frac{G}{D^3}$$
$$\frac{4\pi^2}{G(M_1 + M_2)} = \frac{T^2}{D^3}$$

A2 answer.

SECTION B: LONG QUESTIONS

QUESTION ONE: ELECTRIC MOTOR

(i) Calculate the resistance, *R*, of the coil when stationary and graph the relationship that normally exists between I and V for a conductor of resistance, *R*.

[Candidate's graph and table omitted.]

R = V/I = 0.2V/0.4A
= 0.5 Ω

V at 0 rev s^{-1} = 0.2V
A at 0 rev s^{-1} = 0.4 A

Resistance = 0.5 Ω

B2 answer.

(ii) Give an explanation why the voltage and current measurements obtained for the motor are different from the results you would normally expect for a conductor of resistance, *R*.

When the motor rotates it induces an emf in the opposite direction to the voltage, as it acts as an inductor. This induced emf adds to the voltage used by the motor, however it does not produce a current. The size of the emf depends on the size of the change of flux, which is proportional to the rotational speed.

$$\therefore V_{recorded} = V_{supply} + \varepsilon_{emf}$$
$$= IR + \frac{\Delta\phi}{\Delta t}$$
$$= IR + k\varpi$$

A1 answers.

(iii) Devise a graphical method that would verify your explanation in part (ii). (*Hint: Are there any variables you would expect to be linearly related?*) Your answer should include a drawn graph.

$$\varepsilon = -\frac{\Delta\phi}{\Delta t} \qquad \Delta\phi \propto \varpi$$

$$V = IR + \varepsilon$$
$$\therefore V = IR + k\varpi$$

$$V - IR = k\varpi$$

I will assume that the V recorded would be V from IxR plus the emf ε. If I minus IR from every V value, then I should get a linear graph of (V-IR) vs ϖ with a gradient R, ie, $\varepsilon \propto \varpi$

[Candidate's graph omitted.]

A2 answers.

(iv) Write a conclusion to summarise and explain your findings.

> This graph shows that the emf is proportional to the angular velocity. Since $\varepsilon = -\frac{\Delta\phi}{\Delta t}$ this shows that how much the flux changes inside the motor is directly proportional to the rate at which the motor rotates. When using a motor in a DC electrical system one must calculate and adjust for the emf produced by the spinning motor.

B1 answer.

QUESTION TWO: DOPPLER AND BLOOD FLOW

(i) Does the reflected ultrasound have a lower, higher or the same frequency as the transmitted wave? Explain.

> It has a higher frequency, as the blood is moving towards the receiver. Although it is not moving directly towards the receiver, its amplitude of movement towards it used by the Doppler effect is proportional to the cos of the angle between the path of movement and the receiver.

Candidate has failed to identify the key physics concepts. Evidence does not contribute towards any descriptor.

(ii) Identify the correct equation, giving reason to justify your choice (a derivation of the correct equation is not required).

> Equation 1 is the correct equation.
> As $v \to 0$, $\Delta f \to 0$ (doppler effect does not occur when v=0). Also, it should be at its greatest at θ=0, and 0 at 90°. This occurs when multiplied by cosθ.

A2 answer.

(iii) Calculate the speed of the blood.

$$v = \frac{\Delta f c}{2f\cos\theta}$$
$$= \frac{3.1\times10^{3}\times1.5\times10^{3}}{2\times5\times10^{6}\times\cos(30^{\circ})}$$
$$= 0.537\,\text{m s}^{-1} = 0.54\,\text{m s}^{-1}\,(2\,\text{sf})$$

B2 answer.

(iv) Suggest a difficulty in determining the direction of blood flow using the above technique.

> It would be hard to get an accurate reading on the frequency. When using ultrasound to determine the frequency of reflected sound, some of the waves may reflect not off the target artery/vein but off an adjacent vessel with blood travelling in the opposite direction. This will cause a Doppler shift in the opposite direction, giving reflected sound a mixture of positive Δf and negative Δf.

Candidate has failed to identify the key physics concepts. Evidence does not contribute towards any descriptor.

QUESTION THREE: BRAGG'S LAW

(i) State the necessary conditions for interference fringes to be produced by two sources of light at a distance of *d* apart.

$n\lambda = d\sin\theta$
The light produced needs to be monochromatic, ie only one wavelength. It needs to be the same wavelength from both sources. The wavelength of the light also needs to be comparable in size to d. It is best if $0.1d<\lambda<0.5d$.

Candidate has failed to identify the key physics concepts. Evidence does not contribute towards any descriptor.

(ii) Using your knowledge of the necessary conditions for constructive interference of the rays, derive Bragg's Law.

Constructive interference occurs when Δdistance = $n\lambda$
Extra distance travelled = $d\sin\theta + d\sin\theta$
= $2d\sin\theta$

∴ the extra distance must occur when two peaks line up, ie $m\lambda$. M∈I

∴ $m\lambda$ = extra distance
$m\lambda = 2d\sin\theta$

A2 answer.

(iii) Calculate the interplanar distance *d*.

$m = 3 \quad d = \dfrac{m\lambda}{2\sin\theta}$

$\lambda = 1.27 \times 10^{-10}\,\text{m}$

$\sin\theta = \sin 29.2$

$d = \dfrac{3 \times 1.27 \times 10^{-10}\,\text{m}}{2\text{x}\sin(29.2^\circ)}$

$= 3.90 \times 10^{-10}\,\text{m (3sf)}$

Candidate has failed to identify the key physics concepts. Evidence does not contribute towards any descriptor.

(iv) Given the value of *d* calculated above, comment on why X-rays rather than visible light are used for diffraction experiments with crystals.

X-rays are used since their wavelengths are similar in size to the distance d. $\dfrac{m\lambda}{2d}$ should be smaller than 1 and greater than 0.1, which only occurs when $\lambda \approx 1/3$ d. The wavelength of visible light is outside the range needed, so cannot be used. Outside the range $\sin\theta$ is either >1, which is impossible and no refraction occurs, or $\sin\theta \approx 0$, which gives too small an angle.

A1 answer.

QUESTION FOUR: A MAGLEV TRAIN

(i) Explain why there is a force acting on the loop.

> The long wire produces a magnetic field. Since the loop is in the field and is carrying a current, a force is produced, $F = BI\ell$

A1 answer.

(ii) Explain why the force on the loop acts to move the loop away from I_2.

> A diagram on the magnetic field around I_2 will demonstrate this easier.
>
> *[Candidate's graph omitted.]*
> According to the right hand rule, the force on the LHS will be away from I2, while the force on the RHS will be towards. Since the strength of the field at LHS is stronger than the RHS ($B \propto 1/r$), the repelling force is greater than the attractive force. The loop is rigid so the entire loop is accelerated away with a force (F_1-F_2).

A1 answer.

(iii) Derive an expression for the magnitude of the force acting on the loop.

$$F = F_{LHS} - F_{RHS}$$

$$B = \frac{\mu_0 I_1}{2\pi d}$$

$$\therefore B_{at\,LHS} = \frac{\mu_0 I_1}{2\pi d}$$

$$B_{at\,RHS} = \frac{\mu_0 I_1}{2\pi(d+a)}$$

$$\therefore F_{TOTAL} = F_{LHS} - F_{RHS}$$

$$= \frac{\mu_0 I_1}{2\pi d} \times I_2 \times b - \frac{\mu_0 I_1}{2\pi(d+a)} \times I_2 \times b$$

$$= \frac{\mu_0 I_1 I_2 b}{2\pi d}\left(\frac{1}{d} - \frac{1}{d+a}\right)$$

A2 answer.

(iv) From your explanation given above, it can be seen that the relative size of the variables *a* and *d* will have a strong influence on the size of the force. Discuss what would happen to the force in the limited cases where *a*<<*d* and *d*<<*a*.

> If d>>a, then $\frac{1}{d} \approx \frac{1}{d+a}$ (for example 1/10000 ≈ 1/10001). This means the force ≈ k x (1/d - 1/ d) or 0. So when d is a lot larger than a, the force is effectively 0.
>
> If a>>d, then $\frac{1}{d+a} \approx 0$ that means the equation becomes ≈ k x 1/d , and the attractive force on the far side can be effectively ignored.
>
> $$k = \frac{\mu_0 I_1 I_2 b}{2\pi}$$

A2 answer.

(v) Calculate the distance *d* between the lower side of the coil and the cable.

$$d = \frac{\mu_0 N I_1 I_2 b}{2\pi F} = \frac{4\pi \times 5000 \times 100 \times 100 \times 20}{2\pi \times (2 \times 10^4 \times 9.8)}$$

$$= 1.020408163 \times 10^{-3}\,\text{m}$$

$$\approx 1 \times 10^{-3}\,\text{m}$$

B2 answer.

(vi) One of the designers is concerned that the distance *d* will change considerably when people get on the train. Estimate the value of *d* for a full carriage holding 70 people.

Estimated weight of average person – 80kg

∴ increase in weight = 80 x 70
= 5600kg

new total weight = 25600 kg

$$\therefore d = \frac{\mu_0 N I_1 I_2 b}{2\pi(mg)}$$

$$= 7.971938776 \times 10^{-4}\,\text{m}$$

$$\approx 0.8\text{mm}$$

I estimate d to be roughly 80% of the first d, or 0.8mm.

A2 answer.

(vii) Discuss at least one advantage and at least one disadvantage with the design of this type of train. Your discussion should be relevant and linked to the physics of the situation.

The main advantage of this type of design is the minimization of friction. Solid objects touching has a lot more friction than air touching objects, this is why planes can move a lot faster than cars. By levitating the train it does not touch solid objects as much as before and requires less propulsize force to overcome friction. The main disadvantage with this train is what happens when it leans over. As long as the coil is directly above the cable it is fine, as gravitational and magnet forces balance out. However if the train moves sideways or leans over (for example due to wind) there is a horizontal component to the magnetic force and the train would accelerate sideways. This could cause it to tip over and “derail”. This design also requires very large coils with a lot of current passing through them. This acts as a very strong inductor and could cause very large sparks if the coil came close to another conductor.

A1 answer.

Sample of assessed candidate work: Performance Descriptor 3 – Performance Category 6.

This candidate has gained 6 A1, and 5 A2, and 9 B level answers. A1 and B1 answers involve explanations and analysis, while A2 and B2 answers involve the solution of complex problems. Refer to the assessment schedule for marking codes.

SECTION ONE: SHORT QUESTIONS
QUESTION ONE

(i) Using the data supplied calculate the energy change associated with this decay.

$^{210}_{84}Po \rightarrow {}^{206}_{82}Pb + {}^{4}_{2}\alpha$

Initial mass = $(209.983 \times (1.661 \times 10^{-27})) = 3.487817 \times 10^{-25}$kg.

Final mass = $(205.974 \times 1.661 \times 10^{-27}) + (4.003 \times 1.661 \times 10^{-27})$

$= 3.4212281 \times 10^{-25} + 6.6489 \times 10^{-27} = 3.48771793 \times 10^{-25}$

Mass deficit = $(3.487817 \times 10^{-25}) - (3.4877 \times 10^{-25}) = 9.907 \times 10^{-30}$ kg

$E = \Delta mc^2 = (9.907 \times 10^{-30}) \times (3 \times 10^8)^2 = 8.9163 \times 10^{-13}$

Energy change = 8.916×10^{-13}J

> A mathematical error has occurred during the process. B2 answer.

(ii) Assuming that the polonium atom was at rest before decaying, calculate what fraction of the energy available from the decay process is gained by the alpha particle.

Δ in energy $= 8.916 \times 10^{-13}$J

Fraction gaied by $\alpha = \frac{4.003}{205.974}$J

> Candidate has failed to identify the key physics concepts involved. Evidence does not contribute towards any descriptor.

QUESTION TWO

Explain what is meant by the term **wave-particle duality**, provide a description of experimental evidence supporting the wave nature of light, and a further description supporting the particle nature of light.

Wave particle duality implies that light can act both as a particle and as a wave. (Have properties common to both wave forms and particles). Examples of light acting of a wave are when it passes through a diffraction grating and an interference pattern is form on the screen behind the grating. Because it diffracts through gaps and around barriers, its shows that light is acting as a wave in this case. Other evidence for light acting as a wave occurs because it refracts when moving between mediums of different acoustic impedence. It also reflects when it meets boundaries (of high acoustic impedence).
Particle nature is seen because when light hits a metal and the incident light particles are of sufficient energy, electrons will be emitted. This shows light acting as a particle; ie as amounts of energy. The light must be of sufficient energy and only some cause photoelectric emission showing that these particles of light are of different set amounts of energy. This Photoelectric emission implies light is acting as a particle.

> Candidate has introduced some incorrect content and irrelevancies. The description of the photoelectric effect is minimal. B2 answer.

QUESTION THREE

Is the voltmeter faulty? Defend your point of view.

No, the voltmeter is not faulty. The voltage across the inductor is 90˚ ($\frac{\pi}{2}$) ahead of the voltage across the resistor. The voltage across the capacitor is 90˚ ($\frac{\pi}{2}$) behind the voltage across resistor. The supply voltage is the vector resultant voltage of the three measured voltages (V_C ; V_R & V_L). See diagram at bottom (Fig 1).

A1 answer.

The vector quantities of voltage across capacitance added to voltage across inductance given a resultant voltage of 9.6V across the inductor. This voltage is then added to the vector quantity of the voltage across the resistor to give the supply voltage (Fig 2)

$\therefore$ supply voltage = $\sqrt{(V_L - V_C)^2 + V_R^2}$ = $\sqrt{9.6^2 + 7.2^2}$ = $\sqrt{144}$ = 12V

Fig. 1

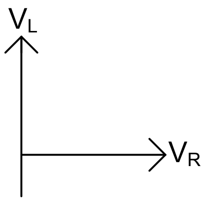
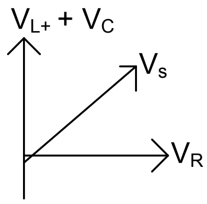


Fig. 2

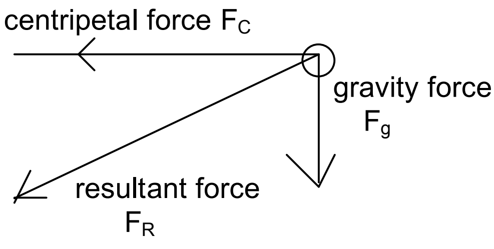


QUESTION FOUR

(i) Assuming the ball is moving at a constant speed in a horizontal circle, explain why the wire from the thrower's hands to the ball cannot be parallel to the ground.

Because the ball is moving at a constant speed, there will also be a constant centripetal force acting towards the centre of the circle (ie along the wire towards the man). However, gravity force will also be acting on the ball, and therefore the resultant force acting on it will be the vector sum of these two forces which will always have a vertical component, acting towards the ground $\therefore$ wire will never be parallel to the ground.

A1 answer.



(ii) Explain how the hammer thrower is able to increase the speed of the ball as he winds up for the throw.

Because angular momentum is conserved, $L = I\varpi$, in order for the speed of the ball to increase, I (the rotational inertia) must decrease. The hammer thrower can decrease the rotational inertia of the system by concentrating his mass closer to the centre of rotation, ie. by standing upright.
If the hammer thrower starts in a crouched position, his rotational inertia will be high and therefore the angular velocity of the hammer will be low. As the hammer thrower straightens his stance, the rotational inertia will decrease and due to the conservation of angular momentum, the angular velocity of the ball will increase $L = I\varpi$ ∴ the speed of the ball increases.
constant

> Candidate has failed to identify the key physics concepts. Evidence does not contribute towards any descriptor.

QUESTION FIVE

(i) Still holding the masses, the student extends her arms slowly.

Her angular velocity will decrease. When her arms are crossed, her mass is more concentrated nearer to the centre of rotation, and therefore her rotational inertia is small. When her arms holding the weights are extended. Her mass is less concentrated near the centre of rotation, meaning her rotational inertia, I increase, $I=\sum mr^2$ ∴ when r is greater, I is greater. Because angular momentum is conserved, $L=I\varpi$ when I is large, ϖ is small and vice versa. Initially when I is small, ϖ (her angular velocity), is large; however, when her arms are extended, I increases, and due to the conservation of angular momentum, ϖ (her angular velocity) must decrease.

> Candidate has identified some of the relevant physics of this situation.
> B1 answer.

(ii) With her arms extended, the student drops one of the masses.

Angular frequency increases. When the student has her arms extended, holding the masses, her rotational inertia is high, $I=\sum mr^2$ when she drops one of the masses, her rotational inertia decreases $I=\sum mr^2$ (∴ as m decrease, I decreases). Due to the conservation of angular momentum, $L=I\varpi$, the angular momentum is constant. ∴ Initially when her rotational inertia is high, her angular frequency is lower; but when she drops a mass, her rotational inertia decreases and because L is constant, her angular velocity, ϖ, must increase.

> Candidate has failed to identify the key physics concepts. Evidence does not contribute towards any descriptor.

QUESTION SIX

(i) Express the distance, r, of the star of mass M_1 from the centre of mass in terms of M_1, M_2 and D.

$$r = \frac{M_1 r_1 + M_2 r_2}{M_1 + M_2}$$

$$r = \frac{M_1 0 + M_2 D}{M_1 + M_2}$$

$$r = \frac{M_2 D}{M_1 + M_2}$$

> B2 answer.

(ii) By equating the gravitational force between the stars with the magnitude of the centripetal force on one of them, show that the orbital period of the binary system, T, is related to the distance between the stars, D, by the relationship.

$$F_g = \frac{GM_1M_2}{r^2}$$

$$F_g = \frac{GM_1M_2}{D^2}$$

$$F_c = \frac{mv^2}{r} \quad F_c = \frac{m_1v^2}{r} \quad v = \varpi r \quad \varpi = \frac{2\pi}{T}$$

$$\frac{GM_1M_2}{D^2} = \frac{M_1v^2}{r}$$

$$\frac{GM_1M_2}{D^2} = \frac{M_1\varpi^2r^2}{r}$$

$$\frac{T^2}{D^2} = \frac{4\pi^2r}{GM_2}$$

$$\frac{T^2}{D^2} = \frac{4\pi^2}{GM_2}\left(\frac{DM_2}{M_1+M_2}\right)$$

$$\frac{T^2}{D^3} = \frac{4\pi^2}{G(M_1+M_2)}$$

A2 answer.

SECTION B: LONG QUESTIONS

QUESTION ONE: ELECTRIC MOTOR

(i) Calculate the resistance, R, of the coil when stationary and graph the relationship that normally exists between I and V for a conductor of resistance, R.

[Candidate's graph omitted.]

V=IR ∴ R= V/I = 0.2 / 0.4 =0.5Ω

For graph of A vs. V ∴ $1 = \frac{I}{V}R$

y=mx y=I x=v

∴ $I = \frac{V}{R}$

$I = \left(\frac{1}{R}\right)V$ ∴ gradient of graph = $\frac{1}{R} = 2$

Resistance = 0.5Ω

B2 answer.

(ii) Give an explanation why the voltage and current measurements obtained for the motor are different from the results you would normally expect for a conductor of resistance, *R*.

> For a normal resistor, Ohms law applys V=IR ∴ R = V/I (if external conditions remain constant eg. temp). However if this case, an induced emf is also being produced due to the changing magnetic flux in the rotating coil. This induced emf will oppose the motion of the coil rotating and therefore the voltage across the motor is not equal to the DC voltage applied to the circuit (due to the induced emf). This will also affect the current passing through the coil.

A1 answer.

(iii) Devise a graphical method that would verify your explanation in part (ii). (*Hint: Are there any variables you would expect to be linearly related?*) Your answer should include a drawn graph.

> $\varepsilon = -\frac{\Delta\phi}{\Delta t}$
>
> The resistance of the coil is not constant due to the induced emf increasing as rotation rate increases. $\varepsilon = -\frac{\Delta\phi}{\Delta t}$ (ie. ϕ is changing faster if rotation rate is faster.
>
> For a normal resistor, a graph of V versus I would produce a straight line, in accordance with Ohm's Law V=IR, the gradient of the line being the constant resistance of the resistor.

Candidate has failed to identify the key physics concepts. Evidence does not contribute towards any descriptor.

(iv) Write a conclusion to summarise and explain your findings.

> As current and voltage increases, the resistance of the coil also increases. This implies that when the coil is rotating in the magnetic field and magnetic flux passing through it is changing, an induced emf. is produced $\varepsilon = -\frac{\Delta\phi}{\Delta t}$ (Faraday's Law). As the rotation rate increases, the induced emf. increases which is implied by the coil increasing resistance. Because the coil's resistance is increasing rotation rate increases, this shows that the induced emf. opposing the voltage passed across the meter by the voltage source (Lenz's Law). This opposing induced emf. opposes the supplied voltage and opposes the rotation producing it.

Candidate has failed to identify the key physics concepts. Evidence does not contribute towards any descriptor.

QUESTION TWO: DOPPLER AND BLOOD FLOW

(i) Does the reflected ultrasound have a lower, higher or the same frequency as the transmitted wave? Explain.

> The reflected ultrasound has a higher frequency then the transmitter wave because the blood is moving towards the transmitter/receiver. This causes the ultrasound waves to reduce in wavelength because the receiver is moving towards them and therefore their frequency increase v=fλ

Candidate has identified some of the relevant physics of this situation.
B1 answer.

(ii) Identify the correct equation, giving reason to justify your choice (a derivation of the correct equation is not required).

Student 2 is correct

$$\Delta f = \frac{cf}{c+v}$$

$$\Delta f = \frac{2cf}{v}\cos\theta$$

Candidate has failed to identify the key physics concepts. Evidence does not contribute towards any descriptor.

(iii) Calculate the speed of the blood.

$$\Delta f = \frac{2fc}{v}\cos\theta$$

$$3.1\times10^{3} = \frac{2(5\times10^{6})\times(1.5\times10^{3})}{v}\cos 30^{\circ}$$

$$v = 4.19\times10^{6}\ m\,s^{-1}$$

[Candidate's graph omitted.]

Candidate has failed to identify the key physics concepts. Evidence does not contribute towards any descriptor.

(iv) Suggest a difficulty in determining the direction of blood flow using the above technique.

The ultrasound receiver receives many different pulses corresponding to ultrasound being reflected off various boundaries. Ultrasound which passes through veins may also pass through arteries and vice versa. This would mean its frequency would not correspond to just one direction of blood flow or just one reflection at one boundary.

Candidate has failed to identify the key physics concepts. Evidence does not contribute towards any descriptor.

QUESTION THREE: BRAGG'S LAW

(i) State the necessary conditions for interference fringes to be produced by two sources of light at a distance of *d* apart.

The two sources of light must be coherent, ie. they must have a constant phase difference. The distance, d, between the gaps must be very small and be approximately equal to the wavelength of the incident light. Gaps should be same size.

Candidate has identified some of the relevant physics of this situation. B1 answer.

(ii) Using your knowledge of the necessary conditions for constructive interference of the rays, derive Bragg's Law.

$$n\lambda = d\sin\theta$$

$$m\lambda = d\sin\theta$$

$$d \simeq \lambda$$

$$n\lambda = \frac{dx}{L}$$

Candidate has failed to identify the key physics concepts. Evidence does not contribute towards any descriptor.

(iii) Calculate the interplanar distance *d*.

$m\lambda = 2d\sin\theta$

$d = \dfrac{m\lambda}{2\sin\theta}$ *see diagram for* α

see diagram for β

$2\alpha + \beta = 180 \quad \beta = 29.2$

$2\alpha = 150.8$

$\alpha = 75.4$

$\theta + \alpha + 90 = 180$

$\theta = 14.6^\circ$

$d = \dfrac{3\times(1.27\times10^{-10})}{2\times\sin14.6^\circ}$

$d = 7.56\times10^{-10}\,m$

A2 answer.

(iv) Given the value of *d* calculated above, comment on why X-rays rather than visible light are used for diffraction experiments with crystals.

Wavelength of light ≈ 500nm = 5 x 10^{-7}m.
Diffraction is most pronounced when the wavelength of the incident light ≈ distance, d, of the gap in the diffraction grating (or, in this case, the distance between planes of atoms). Because wavelength of x-rays is approximately equal to the distance between the planes of atoms
1.27 x 10^{-10}m ≈ 7.56 x 10^{-10}m
the interference pattern produced is easily interpreted. The wavelength of light is much larger than the distance between planes of atoms, and therefore does not diffract much and does not produce a easily interpreted interference pattern
5 x 10^{-7}m ≠ 7.56 x 10^{-10}m.

A1 answer.

QUESTION FOUR: A MAGLEV TRAIN

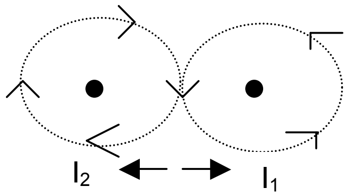
(i) Explain why there is a force acting on the loop.

The long wire has a current, I_2 flowing through it and therefore it produces a magnetic field (circular magnetic field lines around the wire) in the direction implied by the right hand grip rule.
The current flowing in the loop also produces a magnetic field which interacts with the magnetic field caused by the current in the straight wire. The interaction of these two magnetic fields can cause the loop to be repelled or attracted to the straight wire.

A1 answer.

(ii) Explain why the force on the loop acts to move the loop away from I_2.

The direction of current in the loop (I_1) is anticlockwise so therefore when the current is going through the part of the loop closest to and parallel with the straight wire (labelled in diagram), its current will be moving in the opposite direction to that of I_2 in the straight wire. The magnetic fields produced by these two wires will therefore have different directions (ie. one is clockwise, one is anticlockwise) and this causes them to repel ie.



from the perspective as shown in diagram on previous page.

The loop will move therefore away from I_2 because the opposite magnetic fields cause the wires to repel each other.

Candidate has identified some of the relevant physics of this situation.
B1 answer.

(iii) Derive an expression for the magnitude of the force acting on the loop.

$$F = BI_1L$$

$$\therefore \text{repelling force } F = \frac{\mu_0 I_2}{2\pi r} I_1 L$$

$$\therefore F = \frac{\mu_0 I_2 I_1 b}{2\pi d}$$

$$\text{attractive force } F = BI_1L$$

$$F = \frac{\mu_0 I_2 I_1 b}{2\pi (d+a)}$$

$$\therefore \text{overall force} = \frac{\mu_0 I_2 I_1 b}{2\pi d} - \frac{\mu_0 I_2 I_1 b}{2\pi (d+a)}$$

A2 answer.

(iv) From your explanation given above, it can be seen that the relative size of the variables *a* and *d* will have a strong influence on the size of the force. Discuss what would happen to the force in the limited cases where $a \ll d$ and $d \ll a$.

When a<<d, the force would be small because the repelling force would be approximately equal to the attractive force. especially if d is large in the first place. i.e $\frac{\mu_0 I_2 I_1 b}{2\pi d}$

When d<<a. The force would be larger because the repelling force = $\frac{\mu_0 I_2 I_1 b}{2\pi d}$ would be much larger than the attractive $\frac{\mu_0 I_2 I_1 b}{2\pi (d+a)}$ especially if d is small in the first place.

A2 answer.

(v) Calculate the distance *d* between the lower side of the coil and the cable.

$$d = \frac{\mu_0 N I_1 I_2 b}{2\pi F}$$

$$F = 9.8 \times 2 \times 10^7$$

$$F = 196000\,N$$

$$d = \frac{(4\pi \times 10^{-7}) \times 5000 \times 100 \times 100 \times 20}{2\pi \times 196000}$$

$$d = 1.02 \times 10^{-3}\,m$$

B2 answer.

(vi) One of the designers is concerned that the distance *d* will change considerably when people get on the train. Estimate the value of *d* for a full carriage holding 70 people.

$$av.\ weight = 70\,kg$$

$$F = (9.8 \times 2 \times 10^4) + (9.8 \times 4900)$$

$$= 244020\,N$$

$$d = \frac{\mu_0 N I_1 I_2 b}{2\pi F}$$

$$d = \frac{(4\pi \times 10^{-7}) \times 5000 \times 100 \times 100 \times 20}{2\pi \times 244020}$$

$$= 8.20 \times 10^{-4}\,m$$

A2 answer.

(vii) Discuss at least one advantage and at least one disadvantage with the design of this type of train. Your discussion should be relevant and linked to the physics of the situation.

Disadvantage: a large amount of energy will be disappated as heat in both the cable and the coil. This is due to the high values of current passing through both conductors. Energy loss (disappated) = I^2R and therefore with high values of current, there will be a large loss in energy.

Advantage: a large repelling force can be created between the cable and the coil with accessible amount of current provided. The values of d and b can be adjusted to provide different repelling forces as required.

A1 answer.