Government of **Western Australia**
School Curriculum and Standards Authority

WACE
Western Australian Certificate of Education

PHYSICS

Stage 3

WACE Examination 2013

Marking Key

Marking keys are an explicit statement about what the examiner expects of candidates when they respond to a question. They are essential to fair assessment because their proper construction underpins reliability and validity.

Section One: Short answers **30% (54 Marks)**

Question 1 **(5 marks)**

Mindy flicks a coin across a desk. The coin leaves the edge of the desk and lands at a point 0.455 m below the desk top and 1.45 m from the edge of the desk. Calculate the velocity in m s^{-1} of the coin as it leaves the desktop.

Description	Marks
$s_v = u_v t + 1/2 at^2$ $0.455 = 0 + 1/2(9.8)t^2$ $t = \sqrt{(2 \times 0.455/9.8)}$ $t = 0.305$ s	1–3
$v_h = s_h/t = 1.45/0.305$ $v_h = 4.76$ m s^{-1}	1–2
Total	**5**

Question 2 **(3 marks)**

A distant star is seen by an astronomer using a powerful telescope to be travelling toward the Earth with a velocity of 0.1c.

(a) At what velocity does the light reach the telescope? (1 mark)

Description	Marks
c or 3×10^8 m s^{-1}	1
Total	**1**

(b) What is it about the starlight's spectrum that tells the astronomer that the star is approaching? Explain your answer. (2 marks)

Description	Marks
The light will be blue shifted	1
Incoming light will appear to be the same, but spectrum will show signature lines to be shifted towards the blue side of the spectrum	1
Total	**2**

Question 3 **(3 marks)**

Explain, using an appropriate formula, why high-voltage power lines are used when transporting electrical power over large distances.

Description	Marks
Power lost is equal to I^2R	1
And P = VI	1
Therefore increasing V decreases I, reducing power lost **or** lower current means less voltage drop across the power lines due to V = I R	1
Total	**3**

Question 4 **(3 marks)**

Table of quarks		
Name	**Symbol**	**Electrostatic charge**
Up	u	+ ⅔ e
Down	d	-⅓ e
Strange	s	-⅓ e
Charmed	c	+ ⅔ e
Bottom	b	-⅓ e
Top	t	+ ⅔ e

Table of baryons	
Particle	**Composition**
p^+	u u d
n	u d d
Σ^+	u u s
Σ^0	u d s
Σ^-	d d s
Ω^-	s s s

(a) Use the information in the above tables to explain why the electrostatic charge on the Σ^0 particle is neutral. (2 marks)

Description	Marks
Σ^0 = u d s	1
= + ⅔ e & -⅓ e & -⅓ e = 0	1
Total	**2**

(b) It is possible for another baryonic particle to exist in nature with a positive electrostatic charge equal to that of the proton. What would its quark composition be, given that this particle contains two up quarks and is **not** a proton? (1 mark)

Description	Marks
u u b **or** u u s	1
Total	**1**

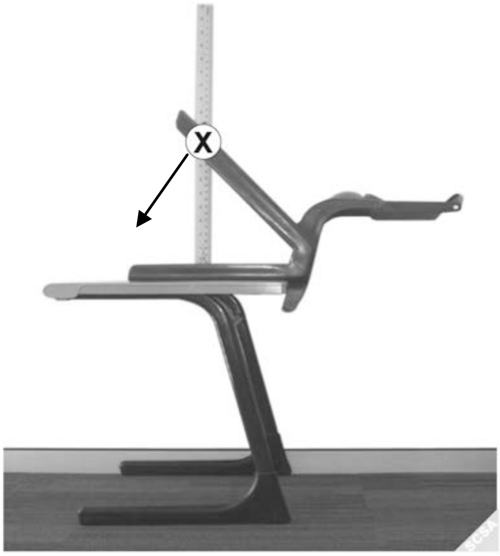
Question 5 **(8 marks)**

The photographs above show the same chair in two different positions. A metre rule is included to provide scale. Photograph A shows the chair in the instant after the person holding it in place let go.

In Photograph A the chair will begin to rotate and fall to the floor as soon as the hand is removed, while in Photograph B the chair will stay in the position as shown. Explain why the chair will rotate in Photograph A but not in Photograph B. (3 marks)

Description	Marks
Uses or refers to a photograph to aid explanation eg indicates centre of mass, pivot point, forces or torques.	1
Explanation involving concept of a rigid body in equilibrium – clockwise torque is unbalanced in A but not in B	1
States chair will rotate about a pivot point.	1
Total	**3**

(b) On the photograph below, indicate the direction of the force that you could apply at Point X in order to prevent the chair from rotating. Estimate the magnitude of this force, stating clearly any assumptions that you make. (5 marks)



Description	Marks
Force drawn that would result in a restoring torque (should be anticlockwise, unless part (a) is incorrect) to the chair, see above.	1
Assumptions mass of chair = 3 kg (1-10) Distance of weight force from the pivot point = 0.05 m (0.01-0.15)	1
Estimation of clockwise torque = rF = $0.05 \times 3 \times 9.8 = 1.47$ N m (includes estimate of perpendicular distance)	1
Provides a reasonable answer Type example: $F = \tau / r = 1.47/0.5 = 2.9$ N (no units required)	1
to one or two significant figures	1
Total	**5**

Question 6 **(3 marks)**

A car is driving over a hill with a radius of 250 m at a speed of 30.0 m s^{-1}. Determine the magnitude of the net force experienced between a 65.0 kg passenger and their seat or seat belt.

Description	Marks
$F_r = F_g – F_c$ So $F_r = mg - mv^2/r$	1
$F_r = 65 \times 9.8 - 65 \times 30^2/250$	1
$F_r = 403$ N	1
Total	**3**

If stated 'net force = F_c' and calculates F_c correctly, then 2 only.

Question 7 **(4 marks)**

The element helium gets its name from the Greek sun-god 'Helios'. This is because helium is the only element to have been discovered in the Sun before it was isolated on the Earth. Helium was identified from unknown lines in the solar spectrum.

With reference to the discovery of helium, explain the origin and significance of lines in the solar spectrum.

Description	Marks
The sun emits a continuous spectrum with absorption lines	1
The absorption lines are specific to orbital energy differences of atoms/molecules	1
Atoms absorb energy and re emit in all directions creating dark lines (scattered).	1
The absorption lines (Fraunhofer Lines) could all be accounted for by known elements except for a set of 'unknown' lines which must be from a new (unknown) element… this element was named helium prior to its detection of Earth.	1
Total	**4**

Question 8 **(4 marks)**

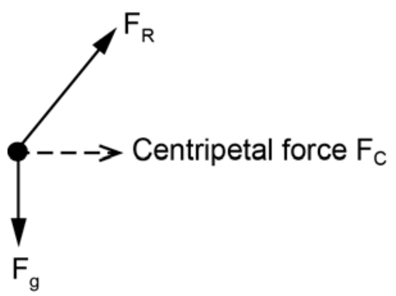
When a satellite is launched it is placed in an initial circular orbit around the Earth. Later some small jets on board the satellite will fire compressed gas for a set period of time to move it to the precise final circular orbit required. These gas jets point backward relative to the satellite's motion only and **not** toward or away from the Earth.

How can backward facing gas jets be used to raise the satellite to a higher final circular orbit?

Description	Marks
The gas jets increase speed and E_k	1
The E_k is converted to E_p	1
This results in a higher orbit	1
This higher orbit is at a slower speed ($r \propto 1/v^2$)	1
Total	**4**

Question 9 **(5 marks)**

Use a labelled free body diagram to help explain why a runner or a cyclist needs to lean when making a turn.

Description	Marks
Uses a diagram  Draws and labels two forces F_g and F_R (can include components of normal and frictional forces) Explains or draws a resultant F_c is produced	1–3
The unbalanced force is directed towards the centre of the circle	1
which provides the acceleration to move the object in a circle	1
Total	**5**

Question 10 **(3 marks)**

A geostationary satellite orbits the Earth at an altitude of 35 000 km. It travels at a speed of approximately 3000 m s^{-1}.

Relativistic effects may cause a clock on board the satellite to run a little slower or a little faster than the same clock on the surface of the Earth. Considering the factors that may lead to relativistic effects, complete the table below.

Factor leading to relativistic effect	**Change in factor**	**Effect on time shown by clock**
gravitational field	decreased	faster
velocity	**increased**	**slower**

Description	**Marks**
correct entry in table, 1 mark	1–3
Total	**3**

Question 11 **(6 marks)**

(a) Assume that one such charging system runs directly from the mains power (240 V AC) to charge a device that requires an input of 4 V. Describe the transformer and the relationship between the two coils. (3 marks)

Description	**Marks**
This will be a step down transformer	1
Ratios are Vs/Vp=Ns/Np=4 V:240 V	1
so the turn ratio will be 1:60	1
Total	**3**

Note: Allow full marks for inverse or decimal turn ratio answer, but only if the appropriate ratio is indicated.

(b) Use appropriate formulae or relationships to explain how this inductive charging system works. (3 marks)

Description	**Marks**
A changing magnetic flux is generated in the primary coil.	1
This cuts the secondary coil	1
Induced emf = $-N\Delta BA/t$	1
Total	**3**

Question 12 **(7 marks)**

A satellite orbits 4.22×10^7 m above the Earth's centre. At a certain point in its orbit around the Earth, the satellite and the Moon line up as shown in the diagram below. Show that in this position the influence of the Moon on the satellite is negligible, compared with the influence of the Earth.

Description	Marks
The satellite will feel a force of attraction from both the Earth and the Moon ← $F_E = GM_EM_s / r^2$ and → $F_m = GM_mM_s / r^2$	1
Attraction by the Earth: $F = 6.67\times10^{-11}\times5.97\times10^{24} \times m_s / (4.22\times10^7)^2$ $F = 0.2236\times m_s$ N	1–2
Satellite moon distance $3.84\times10^8-4.22\times10^7=3.418\times10^8$ Attraction by the Moon: $F = 6.67\times10^{-11} \times7.35\times10^{22} \times1\ m_s / (3.418\times10^8)^2$ $F = 4.20\times10^{-5} \times m_s$ N	1–3
Therefore the force of attraction of the Earth is significantly larger by a factor of 5330 (or Moon's attraction is less by a factor of 0.00019), so the satellite will remain in a stable orbit not significantly affected by the gravitational pull of the Moon.	1
Total	**7**

(NB: other methods of determining ratios are possible for full marks)

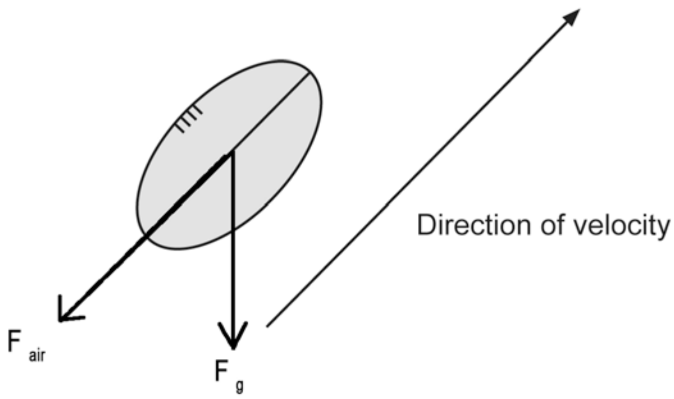
End of Section One

Section Two: Problem-solving **50% (90 Marks)**

Question 13 **(14 marks)**

Gary is playing in a park and decides to kick a ball over a branch of a large tree. He places the ball on the ground to kick it. The path of the ball is shown in the diagram. The tree is 10.0 m away. Gary kicks the ball with a velocity *v* at an angle of 23.5° to the horizontal. The ball will just clear the branch.

(a) Draw the force(s) acting on the ball just after it has been kicked. (2 marks)



Description	Marks
F_g down	1
Air resistance in the opposite direction to motion	1
Total	**2**

(NB: arrows not labelled only 1 mark)

(b) The ball is in the air for 1.33 s. Assuming no air resistance, determine:

(i) the initial velocity of the ball in m s^{-1} (4 marks)

Description	Marks
$v_h = s_h/t = 2 \times 10/1.33$ $= 15.0$ m s^{-1}	1–2
$v = v_h/\cos 23.5° = 15.0/\cos 23.5° =$ $v = 16.4$ m s^{-1} (or 16.3)	1–2
Total	**4**

(ii) the height of the branch (3 marks)

Description	Marks
$s_v = u_v t + ½at^2$ and $u = v - at$ $s_v = v_v t - ½at^2$ (or realising the distance is the same if falling for 1.33/2 s) $= 0 \times 1.33/2 - ½(-9.8) \times (1.33/2)^2$ = 2.17 m (no penalty for lack of units if number expressed in metres)	1–3
Total	**3**

(iii) the distance in metres on the opposite side of the tree that Gary should place his sister so she can catch the ball when it is 1.25 m above the ground. (5 marks)

Description	Marks
2.17-1.25 = 0.92 m down from the branch $s_v = u_v t + ½at^2$ $t = \sqrt{(2 \times s_v/a)} = \sqrt{(2 \times (0.92)/(-9.8))} = 0.433$ s past the tree	1–3
$s_H = v_H \times t = 15 \times 0.433$ $s_h = 6.50$ m	1–2
Total	**5**

(NB: A range of methods can be used giving answers of 6.4–6.6 depending on prior rounding)

Question 14 **(16 marks)**

a) Use the photograph below of an ammeter's scale to determine the magnitude of the current passing through it, as well as the absolute and relative uncertainty for this value. (3 marks)

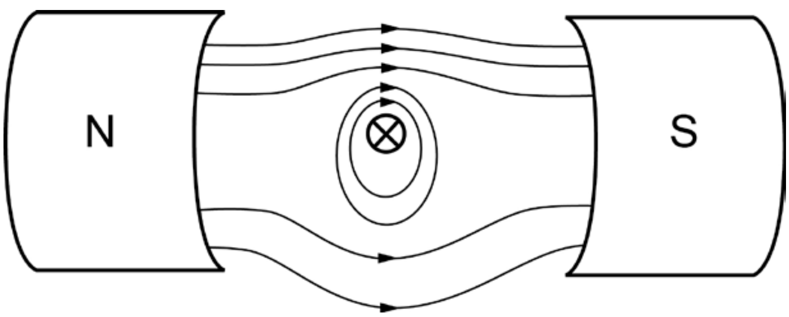
Current: ______________________________ mA

Absolute uncertainty: ____________________

Relative uncertainty: ____________________

Description		Marks
24 (units not needed)		1
±1 (in the value)	or ±0.5 (in the reading)	1
% uncertainty 1/24 × 100 = 4.2%	0.5/24 × 100 = 2%	1
	Total	**3**

(b) A simplified diagram representing one current-carrying wire of the ammeter's coil between two magnets, is shown below. Draw at least **five** field lines to show the resultant magnetic field between the magnets. (4 marks)



Description	Marks
At least five field lines drawn	1
From N to S **or** clockwise around wire	1
Diagram shows good understanding of field interaction	1–2
Total	**4**

(c) Calculate the magnitude of the force, in newtons, acting on the wire carrying a current of 1.45 A in the simplified diagram on page 14, given that the magnetic field strength is 4.25×10^{-2} T and the length of the wire in the field is 2.50×10^{-2} m. (2 marks)

Description	Marks
$F = I\ell B = 1.45\times 2.50\times10^{-2} \times4.25\times10^{-2}$	1
$= 1.54\times10^{-3}$ (N)	1
Total	**2**

(d) The actual ammeter shown has 250 turns of wire that form a square coil with sides of 3.20×10^{-2} m. Determine the magnitude of the current in amperes, given that the spring provides a restoring torque of 2.65×10^{-2} N m in the magnetic field strength of 4.25×10^{-2} T. (4 marks)

Description	Marks
$\tau = Fr = 2NI\ell Br$ (or torque = N I AB) $I = \tau/2N\ell Br$	1–2
$= 2.65\times10^{-2}/(2\times250\times3.20\times10^{-2}\times 4.25\times10^{-2}\times3.20\times10^{-2}/2)$ = 2.44 (A)	1–2
Total	**4**

(e) When the ammeter is disconnected, the spring rotates the coil so that the marker needle returns to zero. This causes a change in flux of 2.18×10^{-5} Wb to occur in the coil in 0.115 s. Determine the average potential difference induced in the coil during this change. Include the units in your answer. (3 marks)

Description	Marks
$emf = -N\,\Delta\Phi/t = 250 \times 2.18 \times 10^{-5} /0.115$	1
$= 4.74 \times 10^{-2}$ (or -4.74×10^{-2})	1
V (units)	1
Total	**3**

Question 15 **(18 marks)**

(a) The tyre swung with a period of 3.84 s. Determine the length of the rope in metres. (2 marks)

Description	Marks
$L = \frac{T^2 g}{4\pi^2} = \frac{3.84^2 \times 9.8}{4\pi^2}$	1
L=3.66 m	1
Total	**2**

(b) Andrew and Sarah decided to conduct an investigation to determine the relationship between the length of a pendulum and its period.

A table of results for this investigation is shown below:

Length of pendulum ℓ (m)	**Time for ten swings (s)**	**Time for one swing T (s)**	**Period squared T^2 (s^2)**
0.10	5.5	**0.55**	**0.30**
0.20	6.9	**0.69**	**0.48**
0.30	10.9	**1.09**	**1.19**
0.40	12.5	**1.25**	**1.56**
0.50	15.0	**1.50**	**2.25**
0.60	18.5	**1.85**	**3.42**

(i) Complete the above table. (2 marks)

Description	Marks
One mark for each column (significant figures are not assessed here)	1–2
Total	**2**

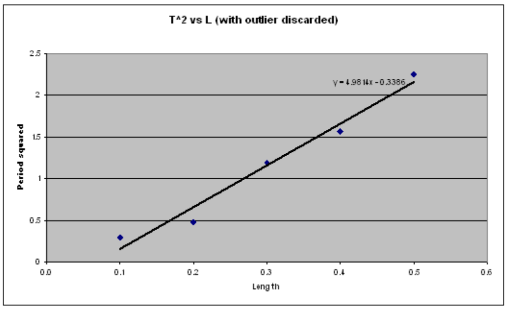
(ii) Use the data from the table to plot a straight line graph on the grid provided to demonstrate the relationship between the length of the pendulum and the square of the period (plot ℓ on the x-axis). (4 marks)

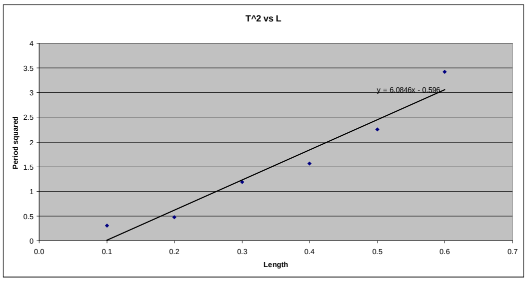
Description	Marks
Correct axes, labelled with units	1
Points correct	1
Line of best fit	1
Not through the origin	1
Total	**4**

(iii) Use your graph to determine the pendulum length that gives a period of 1.0 s. (3 marks)

Description	Marks
Shows evidence of using graph	1
0.2 – 0.3 metres (determined by graph)	1
1-2 significant figures	1
Total	**3**

(iv) Determine the gradient of your graph using a line of best fit. (4 marks)





Description	Marks
Gradient = $\frac{\text{rise}}{\text{run}}$	1
Value = 4–6	1
Units = $\frac{s^2}{m}$	1
Uses line of best fit and not data points	1
Total	**4**

(v) Use your gradient to determine the experimental value of g. (3 marks)

Description	Marks
$T^2 = \frac{4\pi^2}{g} L$ so gradient $= \frac{4\pi^2}{g}$	1
G = $4\pi^2/4.6$	1
= 8.6 (range 6.6 – 9.9) m s^{-2} (units not important)	1
Total	**3**

Question 16 **(16 marks)**

Assume the average initial velocity of a thermal electron is zero. The anode voltages are V_1= 1500 V and V_2 = 4500 V and the distances between the cathode and anodes are as shown above.

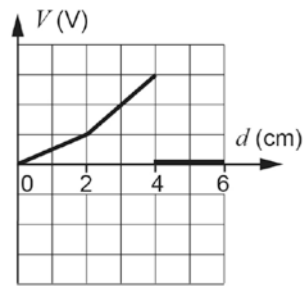
(a) Calculate the velocity in m s^{-1} of the thermal electrons as they pass through the first anode. (4 marks)

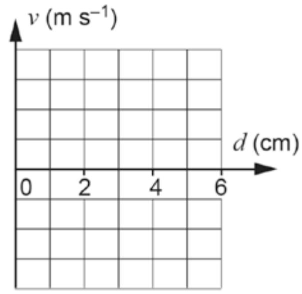
Description		Marks
W = qV = ½ mv^2	or F/q=V/d and F=ma	1
v=√(2qV/m)	a=Vq/md=1.32×10^{16} m s^{-2}	1
=√(2×1.6×10^{-19}×1500/9.11×10^{-31})	v=√(2as)= √(2×1.32×10^{16}×0.02)	1
=2.30×10^{7} m s^{-1}		1
Total		**4**

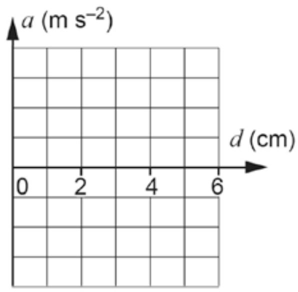
(b) Calculate the average acceleration in m s^{-2} of an electron in the region between the cathode and the first anode. (3 marks)

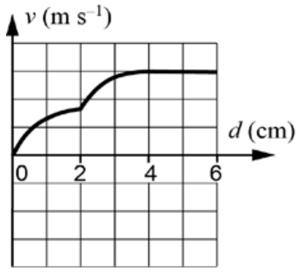
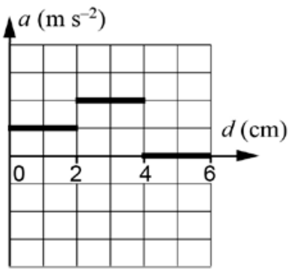
Description	Marks
$v^2 = u^2 + 2as$ $a = (v^2 - u^2)/2s$	1
$a = ((2.30\times10^7)^2 - 0^2)/(2\times0.02)$	1
$a = 1.32\times10^{16}$ m s^{-2} (may have been calculated in a)	1
Total	**3**

(c) Complete the sketches that qualitatively represent the situation on the axes below. The first graph, of distance versus potential difference, has been completed for you. (6 marks)







Description		Marks
	Shows increasing velocity as √ function with second rise (Δv) smaller than first continuing velocity after 4 cm (accept slight decrease)	1 1 1
	Shows constant acceleration (positive or on the same side of x axis as above) with 1/3 and 2/3 step, 0 acceleration (or slight negative) after 4 cm	1 1 1
	Total	**6**

(d) Calculate the electrical work done by the electric field in moving one electron from the first anode to the second anode. Include units with your answer. (3 marks)

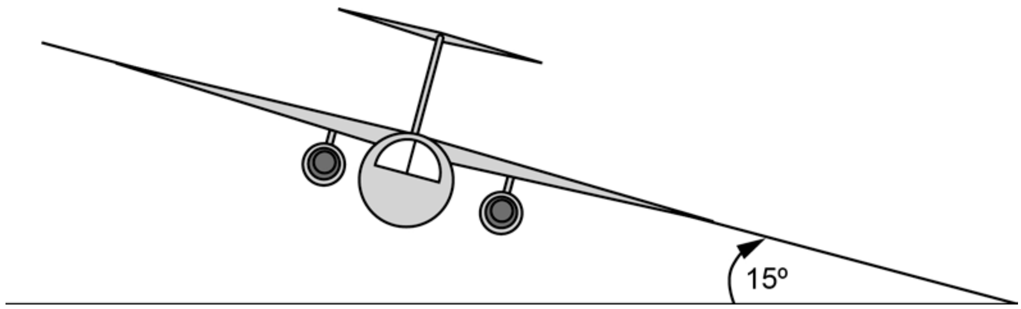
Description	Marks
$W = qV = 1.6\times10^{-19}\times(4500\ V - 1500\ V)$ $=4.8\times10^{-16}$	1–2
J	1
Total	**3**

Question 17 **(12 marks)**

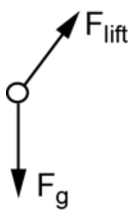
(a) Show that the mass of the aircraft must be 1.00×10^4 kg. (3 marks)

Description	Marks
For the plane to be in level flight, forces need to be balanced $F_{up}=F_g=mg$	1–2
$m=F/g=98000/9.8$ $m=10\ 000$ kg	1
Total	**3**

(b) The pilot begins a turn by tilting the aircraft so that its wings are at 15.0° to the horizontal as shown. Assume that the airspeed does not change, and that the size and angle to the wing of the lift force remain constant.



Draw a free body diagram below labelling the forces acting on the aircraft. Ignore drag/friction and thrust forces directed into and out of the page. (2 marks)

Description	Marks
 F_{lift} drawn same size as F_g (approximately) Only two forces drawn	1
F_g drawn downwards; F_{lift} drawn perpendicular to wings	1
Total	**2**

(c) Calculate the horizontal radius of the aircraft's turn, assuming the airspeed does not change. (5 marks)

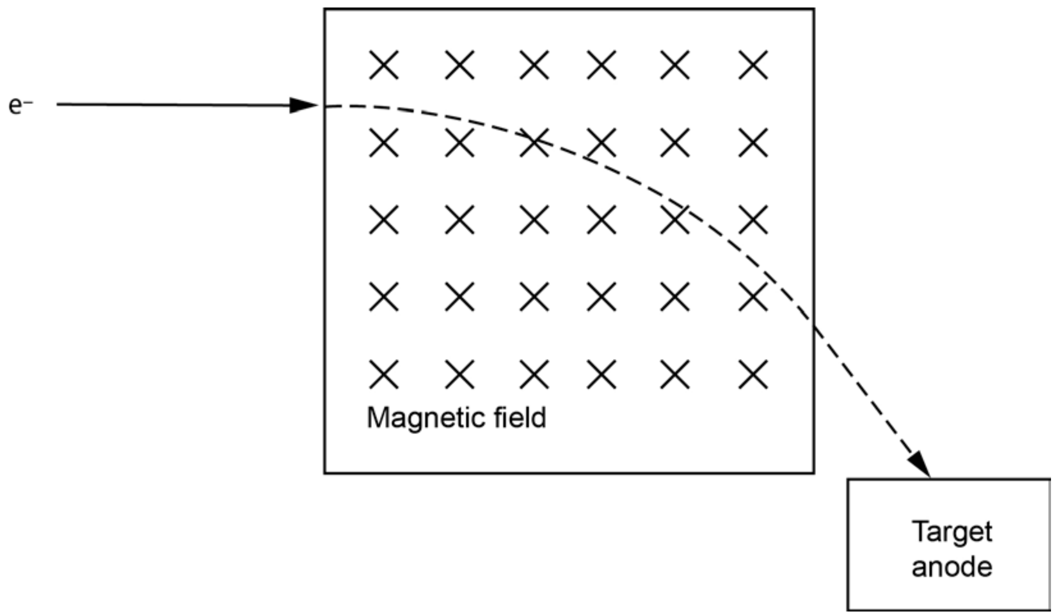
Description	Marks
600 km h^{-1} = 166.67 m s^{-1}	1
F_c = 98 000 Sin 15^0 = 25 364.27 N	1
$F_c = mv^2 / r$ $r = mv^2 / F_c$	1
= (10 000 × 166.67^2) / 25 364.27	1
r = 10 951.97 m = 1.10 ×10^4 m or 11.0 km	1
Total	**5**

(d) Describe any effects that this turn will have on the altitude of the aircraft. No calculations are required. (2 marks)

Description	Marks
The up and down forces are no longer balanced as the plane turns	1
So the plane's height decreases	1
Total	**2**

Question 18 **(14 marks)**

An electron moving at 0.9c enters a region of space and follows a path that has a constant radius of 0.348 m while in the magnetic field shown on the diagram, before striking a target anode.



(a) Draw the magnetic field enclosed in the indicated space. (2 marks)

Description	Marks
Uniform magnetic field	1
Into the page	1
Total	**2**

(b) (i) Derive the formula $B = \frac{mv}{qr}$. (2 marks)

Description	Marks
$F_c = F_B$	1
$mv^2/r = qvB$ (must show some progression to arrive at the answer)	1
B=mv/qr	
Total	**2**

(ii) Use this formula to calculate the field strength needed to direct an electron along this path. Include units in your answer. (4 marks)

Description	Marks
$v = 0.9 \times 3 \times 10^8$	1
$B = mv/qr = (9.11 \times 10^{-31} \times 0.9 \times 3 \times 10^8)/(1.6 \times 10^{-19} \times 0.348)$	1
$B = 4.42 \times 10^{-3}$	1
T (unit)	1
Total	**4**

(iii) Describe how each of the changes below affect the charged particle's path in the magnetic field. (4 marks)

Property changed	Effect on radius
Particle's charge is reversed	
Particle's charge is increased	
Particle's velocity is increased	
Magnetic field is increased	

Description	Marks
Bends up instead of down and/or unchanged radius	1
Radius decreases	1
Radius increased	1
Radius decreased	1
Total	**4**

(c) Relativistic effects were not considered when calculating the electron's path. Outline briefly the effects that special relativity predicts about the radius of the electron's motion. (2 marks)

Description	Marks
Increasing the speed of a particle increases its mass	1
The more massive a particle (with everything else constant) the larger the radius	1
Total	**2**

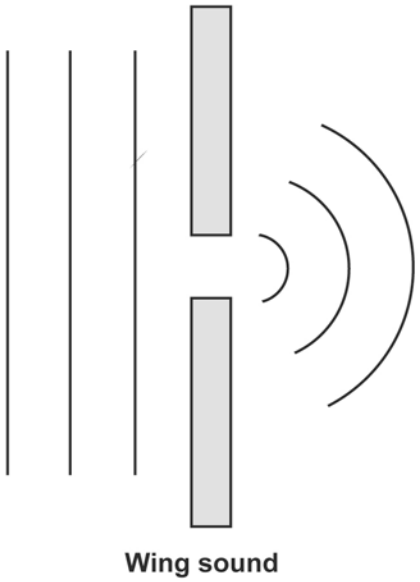
Section Three: Comprehension **20% (36 Marks)**

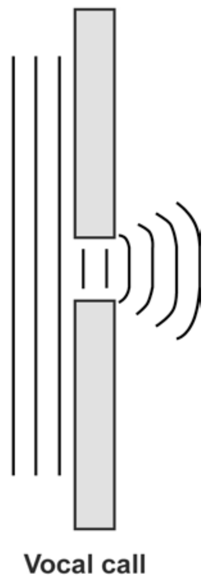
Question 19 **(20 marks)**

(a) Using the information contained in the passage, calculate the frequency of the sound (including units) the feathers produce. (4 marks)

Description	Marks
seven ridges, each plucked twice = 14, multiplied by 107 = 1498 (1 mark for each piece of information)	1–3
1500 Hz (answer with units) (107 Hz max. 2 marks only, 749 Hz max. 3 marks)	1
Total	**4**

(b) The sound produced by a manakin's wings is shown interacting with a gap below (left). Draw at least **five** wave fronts, showing the difference in the interaction as a manakin's vocal call passes through a similar gap, using the diagram on the right. (3 marks)

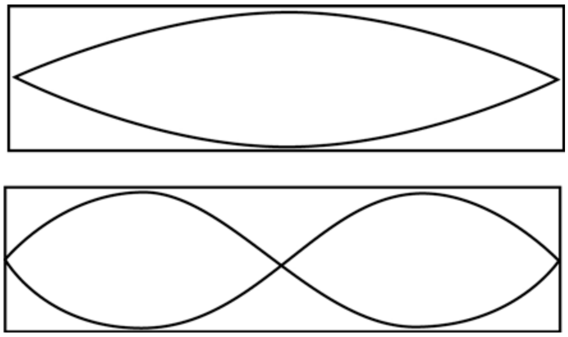




Description	Marks
Draws at least 5 lines	1
Draws a shorter wavelength	1
Diffracts less	1
Total	**3**

(c) The two specialised feathers produce standing waves when excited.

(i) Using the boxes provided, draw the two standing waves as described in the passage. Each box represents the resonant space inside a hollow specialised feather. (2 marks)



Description	Marks
Draws a fundamental (½λ)	1
Draws a second harmonic (λ)	1
If a closed pipe is used (1/4λ) only one mark to be awarded overall if second harmonic is doubled (½λ) or third harmonic is used (3/4λ)	
Total	**2**

NB: Drawing can be displacement or pressure of particles. Needs to be consistent.

(ii) Determine the length of a specialised feather's air space. (4 marks)

Description	Marks
λ =v/f =346/1498	1
=0.231cm (allow follow through)	1
At fundamental frequency the length of 'pipe' = (½λ)	1
length = ½ × 0.231 = 0.115 m (allow follow through)	1
Total	**4**

(d) The average speed of sound in bone is 3000 m s^{-1}. The length of the manakin's longest solid bone is about 5 cm.

(i) Determine the lowest frequency of sound that would be present. (3 marks)

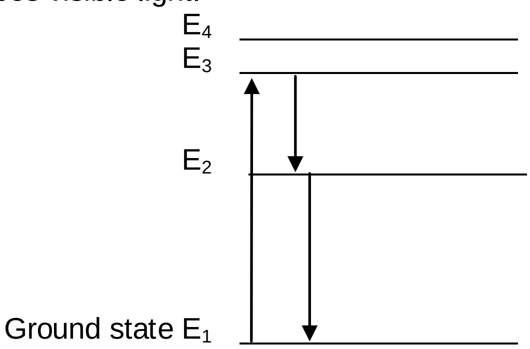
Description	Marks
λ=2×0.05=0.1	1
f =v/λ =3000/0.1	1
f=30 000 Hz	1
Total	**3**

(ii) One scientist hypothesised that the bones are solid so that they can be resonant structures. Explain what 'resonance' means and explain whether this is a reasonable hypothesis in this context. (4 marks)

Description	Marks
Resonance - energy transfers from the driving frequency	1
Matches the natural frequency of the bone	1
The bone will vibrate, reinforcing the frequency making it louder	1
Not a reasonable hypothesis, the two frequencies are nowhere near each other (30 000 Hz compared to 1500 Hz)	1
Total	**4**

Question 20 **(16 marks)**

(a) Use the simplified sketch of an atom's energy levels below to explain how a phosphor produces visible light. (3 marks)



Description	Marks
Uses diagram showing upward(absorption) and downward (emission) transitions	1
Upward (absorption) has larger energy/frequency than downward (emission) transition(s)	1
Specifies absorption is non-visible while emission is visible	1
Total	**3**

(b) Explain how plasma screens are able to create different colours of light by varying the potential difference across the individual cells. (3 marks)

Description	Marks
There are different cells of red, green and blue.	1
Which are combined in different intensities to form the different colours.	1
Changing a cell's potential difference changes the intensity	1
Total	**3**

(c) The first ionisation energy of xenon is 1.94×10^{-18} J. Determine the minimum speed in m s^{-1} of an electron that can ionise the xenon atom through collision. (3 marks)

Description	Marks
$E = ½mv^2$ $v = \sqrt{(2E/m)}$	1
$v = \sqrt{(2 \times 1.94 \times 10^{-18} / 9.11 \times 10^{-31})}$	1
$v = 2.06 \times 10^6$ m s^{-1}	1
Total	**3**

(d) Given that one ampere is equivalent to a charge transfer rate of one coulomb per second, determine the current flow needed in a plasma sub-pixel to generate 1.00 μW of red light at a frequency of 4.00×10^{14} Hz. (7 marks)

Description	Marks
$E = hf = 6.63 \times 10^{-34} \times 4.00 \times 10^{14}$Hz	1
$E = 2.65 \times 10^{-19}$J per photon	1
1μW = 1×10^{-6} J s^{-1} $1 \times 10^{-6} / 2.65 \times 10^{-19} = 3.77 \times 10^{12}$ photon needed	1
Assuming 1 electron per collision, then 3.77×10^{12} electrons are needed per second	1
$q = 1.6 \times 10^{-19} \times 3.77 \times 10^{12} = 6.03 \times 10^{-7}$ C	1
$I = qt = 6.03 \times 10^{-7} \times 1 = 6.03 \times 10^{-7}$	1
Efficiency is stated at 40% so current should allow for this $I = 6.03 \times 10^{-7} / .4 = 1.50 \times 10^{-6}$ A	1
Total	**7**

NB: Minimum value assumed for 100% collision rate. Larger current value will result if a decreased collision rate is assumed. Must be stated.

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