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

WACE
Western Australian Certificate of Education

PHYSICS

Stage 3

WACE Examination 2012

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.

When examiners design an examination, they develop provisional marking keys that can be reviewed at a marking key ratification meeting and modified as necessary in the light of candidate responses.

Section One: Short response **30% (54 marks)**

Question 1 **(3 marks)**

The string is vibrating with a frequency of 100 Hz.
For each of the positions **a**, **b**, and **c,** indicate whether these are nodes or antinodes, and calculate the speed of the wave.

Description	Marks
a & c– node b – antinode – ALL correctly marked	1
Length of string = ½ λ so λ = 2 ×250 cm = 500 cm = 5 m	1
Speed = f×λ = 100 × 5= 500 m s^{-1} (must have units for this mark)	1
Total	**3**

Question 2 **(6 marks)**

(a) Explain why absorption spectra appear as dark lines on an otherwise continuous electromagnetic spectrum. (3 marks)

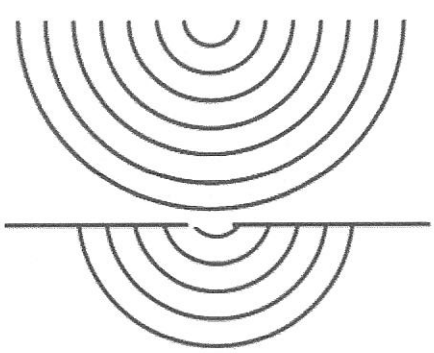
Description	Marks
Any three of the following: • Stars are black bodies that emit a continuous spectrum • Light passing through calcium has energy that corresponds to energy difference between electron energy levels • Electron absorbs the light and rises to a higher energy level • Re-emitted photons are scattered so that intensity in the original direction is reduced	1–3
Total	**3**

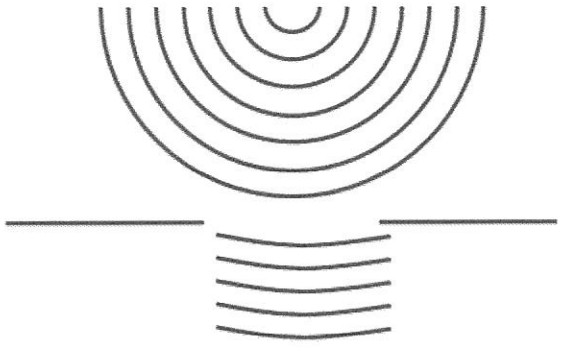
(b) Which galaxy is further away from Earth? Justify your answer. (3 marks)

Description	Marks
Galaxy NGC 3147	1
Its absorption lines are shifted further towards the red end of the spectrum	1
The more redshifted a spectrum is the further away an object is	1
Total	**3**

Question 3 **(4 marks)**

The two diagrams below show wavefronts incident on gaps of different width. On each diagram draw **five (5)** wavefronts to show how the waves behave after they have passed through the gap.

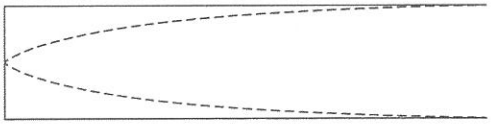
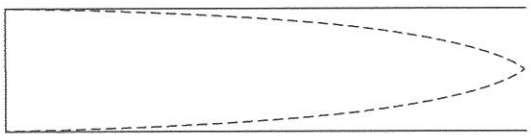




Description	Marks
5 lines on each diagram	1
Small gap acts as new source, lines indicate significant diffraction occurs	1
Wide gap, lines indicate little or no diffraction (less than that of small gap)	1
In both cases wavelength is unchanged	1
Total	**4**

Question 4 **(4 marks)**

You should assume that air at 25°C is in the whistle.
Determine the distance moved by the plunger when changing the fundamental note from 18 kHz to 21 kHz, and draw a diagram of the fundamental wave in the whistle

Description	Marks
Whistle is a closed (at 1 end) pipe, $f_{fundamental} = v/4L$	1
When f = 18,000 Hz L = 346/4×18,000=0.0048 m When f = 21,000 Hz L=346/4 × 21,000 = 0.0041 m	1
Distance moved = 0.0048 – 0.0041 = 0.000687 m (0.69 mm) (must have unit)	1
 Or  Diagram may be in the whistle diagram, or a separate diagram.	1
Total	**4**

Question 5 **(4 marks)**

Calculate the minimum single equivalent wind force on the center of the screen needed to tip the laptop over.

Description	Marks
$\Sigma \tau cw = \Sigma \tau acw$	1
$2 \times 9.8 \times 0.11 = 0.6 \times 9.8 \times 0.11 \sin 40° + F_W \times 0.11 \sin 50°$	1–2
$F_W = 20.7$ N	1
Total	**4**

Question 6 **(5 marks)**

(a) Calculate the tension in the bowler's arm, due to the bowling ball, as the ball is released. You should assume the ball is released from the lowest point. (4 marks)

Description	Marks
v (swing) = 11.5-3.0 = 8.5 m s^{-1}	1
T = weight + centripetal force = $mg + mv^2/r$	1
T = $(9.8 \times 6) + 6 \times 8.5^2/(0.7+0.125)$	1
T = 584 N	1
Total	**4**

Note: If the candidate gives only T = mg = 59 N, 1 mark only

(b) Draw an arrow on the diagram to show the direction of the tension in the bowler's arm. (1 mark)

Description	Marks
Arrow directly up the arm	1
Total	**1**

Question 7 **(4 marks)**

The electric field strength is now doubled. If another electron, having initial kinetic energy E_{Ki} enters the field, determine this electron's final kinetic energy in terms of E_{Ki}.

You should ignore the effects of gravity.

Description	Marks
$W = Fd = Eqd$	1
$W = 4E_{ki} - E_{ki} = 3E_{ki} \Rightarrow Eqd = 4E_{ki} - E_{ki} = 3E_{ki}$;	1
If E is double, the difference in kinetic is $6E_{ki}$,	1
So the final is $7E_{ki}$.	1
Total	4

Question 8 **(7 marks)**

A GPS system uses the signals from four satellites to establish a position on the Earth's surface. The satellites have an orbital period of 12.0 hours but they are in different planes of orbit. Each satellite has an atomic clock that allows a signal to be emitted at prescribed intervals. The time difference between the four signals is used by the receiver to establish a position.

(a) By equating the relationship for centripetal force and gravitational force show that the orbital velocity of each satellite is close to 3.90×10^3 m s^{-1}. (5 marks)

Hint: $v = \frac{2\pi r}{T}$

Show all your workings.

Description		Marks
$\frac{mv^2}{r} = G\frac{m_E m}{r^2}$	Or: derive Kepler's third law	1
$v^2 = G\frac{m_E}{r}$ but $r = \frac{vT}{2\pi}$ so $v^3 = 2\pi G\frac{m_E}{T}$	Calculate r from T, then calculate $v = \frac{2\pi r}{T}$.	1–2
$v = \sqrt[3]{\frac{2\pi \times 6.67 \times 10^{-11} \times 5.98 \times 10^{24}}{12 \times 3600}}$ $v = \sqrt[3]{5.80 \times 10^{10}}$		1
$v = 3.87 \times 10^3$ m s^{-1}		1
	Total	**5**

Note: If candidates quote Kepler's third law, max 4 marks
Note: If candidates omit logical steps, allow 1 mark for each step actually shown

(b) The manufacturers of the satellites deliberately build in a correction to the rate at which the clocks tick so that they run a little fast before they are put into orbit. Explain why they do this. (2 marks)

Description	Marks
Velocity is large	1
relativistic time dilation becomes significant to a very accurate atomic clock.	1
Total	**2**

Note: If candidates use a general relativity approach, with correct reasoning, 1–2 marks

Question 9 **(5 marks)**

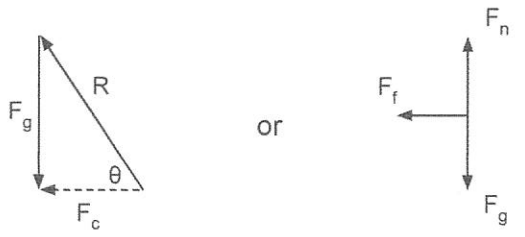
Determine, in terms of v, the time at which Ball B begins to move.

Hint: Consider the positions of the balls at the moment that Ball B begins to move.

Description	Marks
Recognition that ball B will begin to move after A passes the mid-point of the beam.	1
At tipping point $\Sigma\tau CW = \Sigma\tau ACW$	1
Moment of A = moment of B $d \times 2 \times 9.8 = 0.25 \times 9.8 \times 1$ So Ball A's distance from the pivot at tipping time is d = 0.125 m	1
But Ball A has travelled 1 m along the beam already so s = 1.125 m	1
$t = \frac{1.125}{v}$	1
Total	**5**

Question 10 **(6 marks)**

(a) Show that the angle between the motorcyclist and the road is independent of the mass of the motorcyclist. Draw a vector diagram to assist your answer. (3 marks)

Description	Marks
	1
Tan θ = mgr/mv^2 or $mg/(mv^2/r)$	1
Tan θ = gr/v^2 therefore only r and v determine θ To gain full marks candidates must show how equation for tan θ is derived Note: candidates who try to construct a solution using angular momentum and/or precession should be given appropriate credit	1
Total	**3**

Note: If candidates correctly derive tan θ = v^2/gr, using wrong angle, allow 1–2 marks

(b) Using an appropriate calculation, estimate the velocity of the motorcyclist in the photograph. Use the photograph as a guide. (3 marks)

Description	Marks
Estimates: r = 7.5m (5 m – 10 m); θ = 60° (50° – 70°)	1
$v^2 = rg/\tan\theta = 7.5 \times 9.8/\tan 60°$	1
v = 7 m s^{-1} to 1 or 2 s.f. accept answers in the range 4 to 9 m s^{-1} (must have units)	1
Total	**3**

Note: If candidates use incorrect formula from (a), then allow 'follow-through' marks e.g. If they use $\tan \theta = v^2/gr$, $\theta = 60°$, then $v = 12$ m s^{-1} for full marks

Question 11 **(6 marks)**

Estimate the angle at which the toy should be held if it is to be used to spray water from the surface of a swimming pool onto a person 4 m away. Show all your workings.

You should assume that air resistance is negligible.

You may need to use the trigonometric identity $\sin 2\theta = 2 \sin\theta \cos\theta$ to answer this question.

Description	Marks
Rearrange $s= ut + ½ at^2$ to give $u= (s – ½ at^2)/t$ (This solution assumes up is positive)	1
Substitute $u = -1 –(½ \times -9.8 \times 9)/3 = 14$ m s^{-1} speed that water leaves plunger	1
Horizontally t=s/u vertically t = (v-u)/a	1
Equate times $4/14 \cos\theta = (-14 \sin\theta - 14 \sin\theta)/-9.8$	1
Rearrange $39.2 = 14 \times 14 \times 2 \sin\theta \cos\theta$	1
Solve $\theta=6°$ to **1 or 2 sig fig** (if students use u = 14.367 then $\theta = 5°$)	1
Total	**6**

End of Section One

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

Question 12 **(11 marks)**

(a) Calculate the wavelength of electromagnetic radiation absorbed by the silicon, which causes electrons to become conducting electrons. State which part of the electromagnetic spectrum this wavelength belongs to. (3 marks)

Description	Marks
$1.1 \times 1.6 \times 10^{-19} = 1.76 \times 10^{-19}$ J	1
$\lambda = hc/E = 6.63 \times 10^{-34} \times 3 \times 10^{8} / 1.76 \times 10^{-19} = 1.1 \times 10^{-6}$ m	1
Belongs to infra red region of em spectrum	1
Total	**3**

(b) Calculate the efficiency of the solar panel. Assume that there is no gap between the cells on the panel. (3 marks)

Description	Marks
Area of 1 panel = $0.125 \times 0.125 \times 72 = 1.125$ m	1
Energy falling on panel $1000 \times 1.125 = 1125$ W	1
Efficiency = $(190/1125) \times 100 = 16.9\%$	1
Total	**3**

A wind turbine generates electricity at a rate of 2000 kW at a voltage of 690 V. The turbine is connected to a transformer which increases the voltage to 33 kV before connecting it to the electricity grid.

(c) Determine the turns ratio for the transformer used in a wind turbine. (2 marks)

Description	Marks
$V_s/V_p = N_s/N_p$ $33\,000/690 = N_s/N_p$	1
$48:1 = N_s:N_P$	1
Total	**2**

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

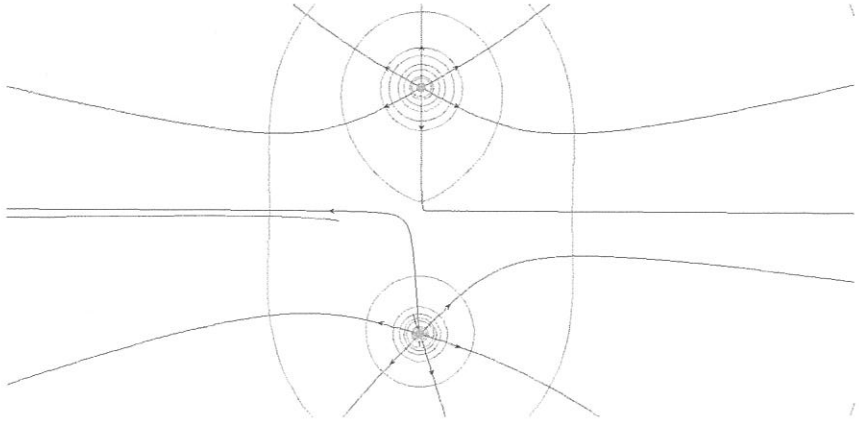
(d) Explain why the voltage is increased before it is transmitted. (3 marks)

Description	Marks
If electricity is transmitted at low V then from P=IV I is high	1
With high I get large heating losses since $P_{loss} \alpha I^2$	1
So increase V to reduce I	1
Total	**3**

Question 13 **(9 marks)**

A and B are two identical very small particles. They are both positively charged with charge + Q. They are fixed in position 10 units apart.

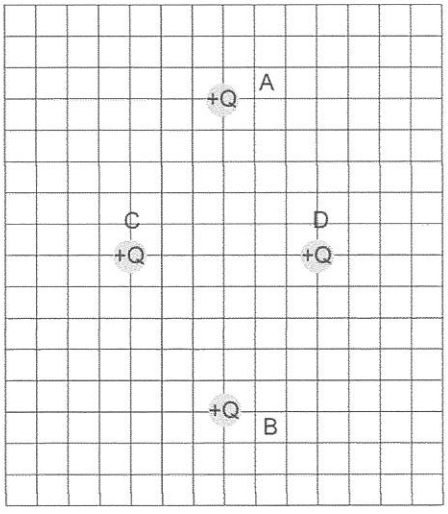
(a) On the diagram below draw the resultant electric field around the charged particles. You should draw at least **five (5)** field lines around each particle. (3 marks)



Description	Marks
Lines should show direction of field	1
Lines should be perpendicular to particle's surface	1
Lines should indicate that the two particles are repelling each other	1
Total	**3**

Note: If lines touch or cross, allow max 2 marks.

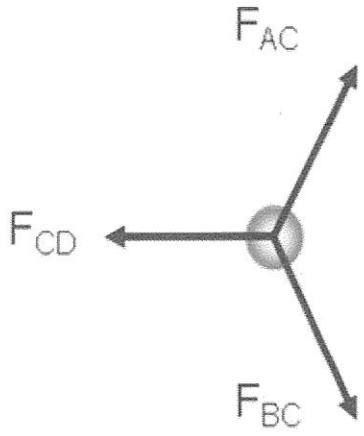
(b) C and D are two particles with identical mass and volume to A and B but they have charge –Q. Draw particles C and D on the diagram below so that the four particles will be in static equilibrium. (3 marks)



Description	Marks
C and D on same horizontal line	1
C and D ½ way between A & B vertically	1
C and D equally spaced from the central line	1
Total	**3**

Note: Allow C and D on vertical line between A and B and touching A and B

(c) On the diagram above draw and label **three (3)** arrows on particle C to indicate the forces acting on particle C due to the other three particles. (3 marks)



Or its mirror image as appropriate.

Description	Marks
1 mark for each arrow correctly drawn $\|F_{AC}\| = \|F_{BC}\|$	1–3
Total	**3**

Note: If the candidate has shown C and D on vertical line between A and B and touching A and B, they must show forces on C that give a net force of zero in order to score full marks.

Question 14 **(15 marks)**

(a) A light year is an astronomical unit of distance. It is defined as the distance travelled by light in one year. Calculate the distance from Kepler 20 to Earth in kilometres. (2 marks)

Description	Marks
$s = v \times t$	1
$s = 950 \times 3\times10^{8}\times365\times24\times60\times60/1000 = 8.99 \times 10^{15}$ km	1
Total	**2**

Note: Allow full marks for 9.00×10^{15} km if candidate has used 365.25 days per year.

(b) Astronomers express the mass of Kepler 20 as $(0.912 \pm 0.035) \times \text{mass}_{SUN}$. Calculate the maximum value astronomers expect for the mass of Kepler 20. (2 marks)

Description	Marks
For max value 0.912+0.035 = 0.947	1
$0.947 \times$ sun mass $= 0.947 \times 1.99\times10^{30} = 1.88 \times 10^{30}$ kg	1
Total	**2**

(c) Calculate the orbital radius of Kepler 20e around Kepler 20. You should use the mass for Kepler 20 quoted in the table and assume the orbit is circular. (4 marks)

Description	Marks
Equate $mv^2/r = Gmm_{star}/r^2$ & substitute for $v=2\pi r/t$ leads to $r^3 = Gm_{star}t^2/4\pi^2$	1–2
$r^3 = (6.67 \times 10^{-11} \times 0.912\times 1.99\times10^{30})\times(6.1\times24\times60\times60)^2/4\pi^2$	1
$r^3 = 8.52 \times 10^{29}$ m $r = 9.48\times10^{9}$ m	1
Total	**4**

(d) The mass of Kepler 20b is unknown but it has been speculated that it may have a density similar to that of the Earth, 5520 kg m^{-3}. Calculate the surface gravity of Kepler 20b if its density is 5520 kg m^{-3}. (4 marks)

Description	Marks
Volume of K20b $= 4/3\pi r^3 = 4/3\pi\times(2.4\times6.38\times10^{6})^3 = 1.50\times10^{22}$ m^3	1
Mass = density × volume $= 5520 \times 1.50\times 10^{22} = 8.28\times10^{25}$ kg	1
$g=GM/r^2=6.67\times10^{-11}\times8.28\times10^{25}/(2.4\times6.38\times10^{6})^2$	1
$g = 23.6$ m s^{-2} (must have units)	1
Total	**4**

Note: Allow full marks for $g = g_{EARTH} \times r = 23.5$ m s^{-2}.

(e) By comparing the Kepler 20 system and our own solar system, suggest which planet in the Kepler 20 system is most likely to lie in the habitable zone. Explain your answer. (3 marks)

Description	Marks
Kepler 20b	1
Given that the star is approximately the same size as our own the planet small orbital periods will place planets too close for liquid water	1
20b has orbital period most similar to Earth's so most likely to be habitable	1
Total	**3**

Question 15 **(13 marks)**

(a) The vehicle moves between Position I and Position II in 3.00 s, driven by a 3.00 V, 20.0 mA motor. The energy conversion efficiency of the vehicle is 70.0% and the mass of the vehicle is 120.0 g. You may assume that air resistance and frictional forces acting on the vehicle are negligible.

Show that the velocity of the vehicle at Position II is 1.45 m s^{-1}. (3 marks)

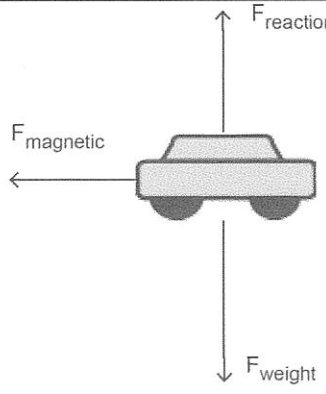
Description	Marks
$P=VI = 3 \times 20\times10^{-3} = 60\times10^{-3}$ J s^{-1}	1
For 3s at 70% efficient energy supplied = $60 \times 10^{-3}\times3.00\times0.70 = 0.126$ J	1
$E_K = ½ mv^2$ so $v= \sqrt{(2\times0.126)/0.12} = 1.45$ m s^{-1}	1
Total	**3**

(b) The motor is switched off at Position II and the vehicle continues to move from Position II to Position V, and then back through Position IV. The metal rails are 0.170 m apart and a magnetic field, B, is arranged so that the field strength acting anywhere along the rails between Position IV and Position V is perpendicular to the rails, and has magnitude 0.550 T .

Calculate the induced EMF when the vehicle is at position IV. (4 marks)

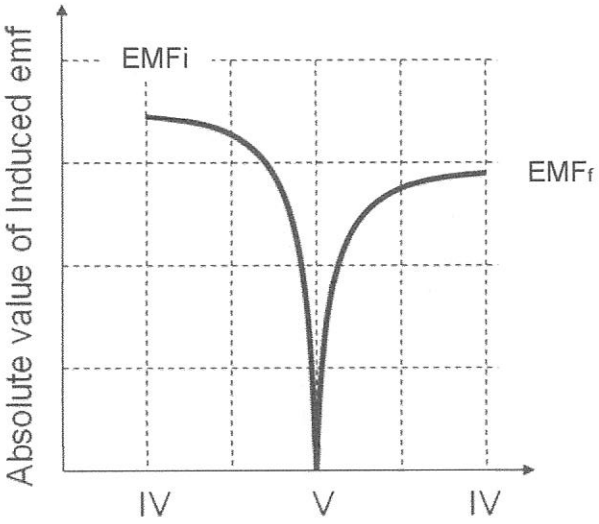
Description	Marks
Gain in energy due to fall = mgh = 0.12×9.8×0.75 = 0.882 J	1
New E_k. = 0.882+0.126 = 1.008 J	1
$v= \sqrt{(2\times1.008)/0.12} = 4.1$ m s^{-1} $E_K = ½ mv^2$ $v = \sqrt{2E_K/m}$	1
EMF = $\ell vB = 0.170 \times 4.1 \times 0.55 = 0.383$ V	1
Total	**4**

(c) Draw a labelled free body diagram to show the forces acting on the vehicle at Position IV. (3 marks)

Description	Marks
 3 marks, take 1 off for each force missing or each 'imaginative' force Note: when car is stationary $F_{reaction}$ = weight when car is moving then $F_{reaction} = mg + mv^2/r$	1–3
Total	**3**

Note: $F_{reaction}$ must be greater than F_{weight}.
Note: $F_{magnetic}$ can be in the opposite direction to that shown.

(d) Sketch a graph of the magnitude (absolute value) of induced EMF versus position as the vehicle moves from Position IV to Position V and then back again to IV. (3 marks)



Description	Marks
From IV to V, emf decreases to zero	1
Then from V to IV, increases to a lower value	1
Shape (initial emf > final emf because part of mechanical energy has converted to electromagnetic energy (Eddy current losses).	1
Total	**3**

Question 16 **(10 marks)**

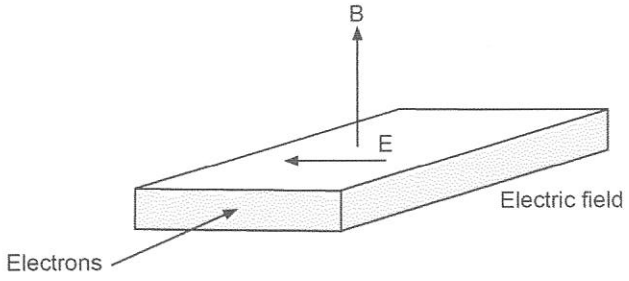
(a) Explain why electrons will begin to collect on the right hand edge of the strip and why an electric field develops across the strip. Express the voltage (*V*) due to the electric field in terms of the electric field strength (*E*) and the distance across the strip (*d*). (4 marks)

Description	Marks
Moving charges in a magnetic field experience a force	1
The electrons are moving perpendicular to the field and so collect on right hand edge	1
If electrons are collecting on r.h.s then l.h.s. must be comparatively positive therefore an electric field is generated across the strip	1
V = Ed	1
Total	**4**

Note: No mark for just stating that E = V/d.

The phenomenon of a voltage being produced across a current carrying conductor due to the presence of a magnetic field is called the Hall effect, and the voltage is termed the Hall voltage. It is utilised in probes used to measure magnetic field strength.

(b) For the probe in the diagram below draw to an arrow to indicate the direction of the electric field in the strip. (1 mark)



Description	Marks
Arrow pointing in correct direction	1
Total	**1**

(c) The Hall voltage can be calculated using the equation $V = \frac{IB}{tne}$.

where
I = electric current
B = magnetic field strength
t = thickness of the strip
n = number of electrons per m^3
e = charge on an electron

Calculate the magnetic field strength when V = 2.25 mV, I = 1.80 A, t = 1.25 × 10^{-4} m and n = 1.52 × 10^{25} m^{-3}. (3 marks)

Description	Marks
Rearrange equation to give $B=Vtne/I$	1
B = $2.25\times10^{-3}\times1.25\times10^{-4}\times1.52\times10^{25}\times1.6\times10^{-19}/1.80$	1
B = 0.38 T (must have correct units)	1
Total	**3**

d) Calculate the magnetic force exerted on the electrons if they are moving with velocity 1.17 m s^{-1}. (2 marks)

Description	Marks
$F=qvB=1.6\times10^{-19}\times1.17\times0.38$	1
F= 7.11×10^{-20} N	1
Total	**2**

Question 17 **(14 marks)**

(a) Calculate the current used by the saw when it is operating normally. (2 marks)

Description	Marks
Rearrange P=VI to give I=P/V = $2.2\times10^3/240$	1
I=9.2 A	1
Total	**2**

(b) Calculate the size of the EMF generated by the coil if the supply is exactly 240 V and the losses due to inefficiency are 28 V. (2 marks)

Description	Marks
240 V-28 V	1
= 212 V	1
Total	**2**

(c) When the motor is switched on, it speeds up until it reaches a maximum. Explain how the EMF generated in the coil restricts the speed of the motor. (4 marks)

Description	Marks
As rotational velocity increases then induced (back emf) EMF increases	1
Induced EMF opposes driving EMF	1
When Induced EMF +losses = driving EMF then a constant velocity is reached	1–2
Total	**4**

(d) As the saw is operating it suddenly stops spinning because it gets stuck in a brick. The current through the saw will

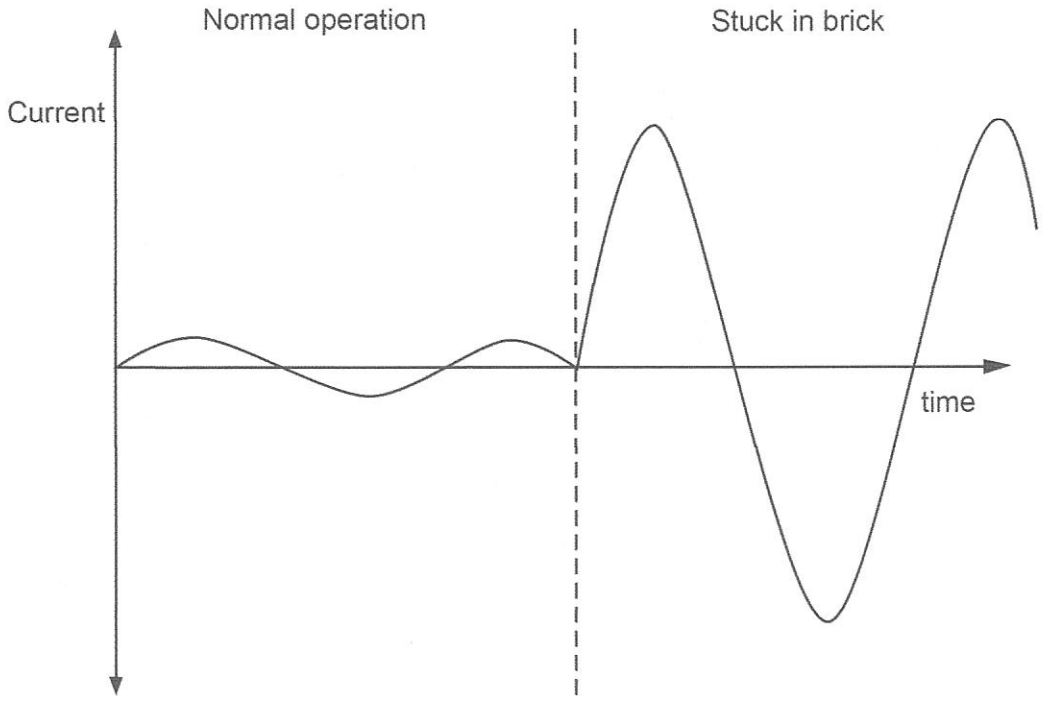
(i) Increase

(ii) Decrease

(iii) Remain the same

Description	Marks
increases	1
As induced (back) EMF is resistive, removing induced (back) EMF increases current	1–2
Total	**3**

(e) On the axes below sketch the current in the saw when the saw is operating normally and when it gets stuck in a brick. (3 marks)



Description	Marks
Graph should be sinusoidal	1
2nd part should have increased amplitude	1
But period remains unchanged	1
Total	**3**

Question 18 **(18 marks)**

(a) Explain why a current is detected by the galvanometer when the copper rod moves. (2 marks)

Description	Marks
The copper rod is a conductor when it moves it cuts the magnetic field lines	1
This generates current (Faraday's Law)	1
Total	**2**

(b) Explain why there is a force opposing the rod's motion down the rails. (2 marks)

Description	Marks
The induced current creates a field to oppose the change in flux	1
A resultant magnetic force acts up the plane as a consequence of the two proximate fields (the two fields repel)	1
Total	**2**

Note: 1 mark for just quoting Lenz's law.
Note: Using and explaining $F = I\ell B$ and the right-hand rule, allow 1–2 marks.

(c) Express the value of terminal speed, when $\sin\theta = 0.5$ in the form $y \pm \Delta y$, where y is the value of terminal speed and Δy is the uncertainty in the measurement. (2 marks)

Description	Marks
speed = 0.83 or 0.84 cm s^{-1}	1
tolerance = $\pm$ 0.04 cm s^{-1}	1
Total	**2**

(d) Describe the trend in uncertainty for the terminal speed and for the sin of the angle θ. (4 marks)

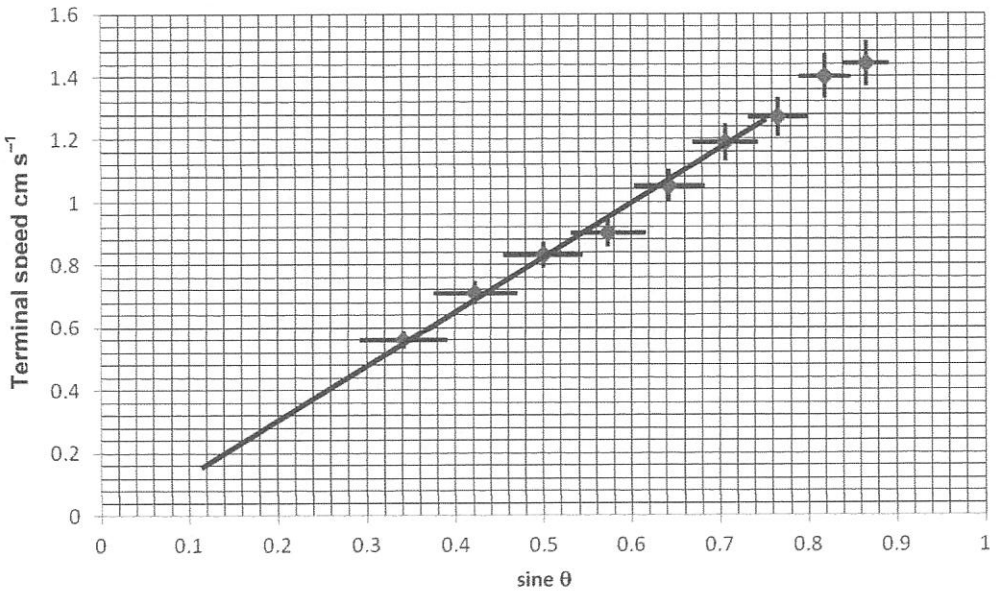
Description	Marks
As sin θ increases the uncertainty in sin θ decreases	1–2
As terminal velocity increases the uncertainty increases	1–2
Total	**4**

(e) When drawing the line of best fit the students chose not to include the two largest terminal speed measurements from their data because they thought these two measurements were less reliable. Refer to the graph to explain why they thought this. (3 marks)

Description	Marks
The value of terminal velocity when $\sin\theta = 0.82$ lies within the uncertainty range of the terminal velocity when $\sin\theta = 0.87$	1–2
Without further measurement it is difficult to determine whether the line is curving at the top	1
Total	**3**

Note: Using a good experimental justification, allow 1–2 marks.

(f) Draw a line of best fit onto the graph and determine the gradient of the line. (3 marks)



Description	Marks
Reasonable line of best fit	1
Evidence of how gradient was determined (not using 2 data points) unless they are on the line	1
Gradient = 1.7 cm s^{-1} (must have unit) (Range 1.5 →1.9)	1
Total	**3**

(g) The rod's terminal speed can be calculated from the equation $v_{ts} = \frac{(mg\ sin\alpha)R}{l^2B^2}$ where m = 44.0 g, R = 1.4 × 10^{-4} Ω and l = 20.0 cm. Use your value of the gradient to calculate a value of the magnetic field strength B. If you were unable to determine a value for the gradient you should use 1.57 cm s^{-1}. (2 marks)

Description	Marks
$B = \sqrt{mgR/l^2 \times 1.70}$	1
$B = \sqrt{44 \times 10^{-3} \times 9.8 \times 1.4 \times 10^{-4} / 0.2^2 \times 0.017} = 0.3$ T If use 1.57 then B = 0.31 T	1
Total	**2**

Note: Must use the gradient value for full marks.

Section Three: Comprehension **20% (54 marks)**

Question 19 **(15 marks)**

(a) Explain why a series of dark and light fringes may be observed at the detector of an interferometer. (3 marks)

Description	Marks
Light recombining after travelling different paths will interfere	1
Dark fringes occur where there is destructive interference	1
Light fringes occur where there is constructive interference	1
Total	**3**

(b) In an interferometer the distance from the half-silvered mirror to Mirror 1 is 1.5 m. The distance from the half-silvered mirror to Mirror 2 is 1.85 m. The light used in the interferometer has a wavelength of 694 nm. Calculate the difference in path length between the light beams arriving at the detector in terms of number of wavelengths. You should express your answer to 1 significant figure. (2 marks)

Description	Marks
Path difference = $(1.85 \times 2)-(1.5\times2) = 0.7$ m	1
$0.7/694\times10^{-9} = 1\times10^{6}$ wavelengths (to 1 sig fig)	1
Total	**2**

(c) Two stars, separated by an angle of 0.5°, are both emitting radio waves with a frequency of 1×10^{6} Hz. Can they be seen as separate sources by a telescope with a diameter of 76 m? You should show the calculations you have used to justify your answer. (4 marks)

Description	Marks
$\lambda=c/f=3\times10^{8}/1\times10^{6} = 300$ m	1–2
$R= 57.3 \times 300/76=226°$	1
No they would not be distinguishable	1
Total	**4**

(d) Determine the resolution of two telescopes, 5 km apart receiving radio waves with a wavelength of 1.71 m. (2 marks)

Description	Marks
$R= 57.3\times1.71/5\times10^{3}$	1
$R = 0.0196°$ (must show degree sign)	1
Total	**2**

(e) Give 3 reasons why radio waves are used to explore very distant regions of the universe instead of visible light by comparing the characteristics of the two regions of the electromagnetic spectrum. (4 marks)

Description	Marks
Comparison of visible and radio characteristics eg. energy, wavelength	1
Any three valid points, such as: • Visible light covers only a very narrow band of the em spectrum, radio waves cover a much wider range of wavelengths • Radio waves due to their much larger wavelengths (up to km in length) can diffract around objects • Even very low energy processes can produce radio waves so more information is available • Enables detection of more distant or more ancient objects, as radiation from distant sources has red shifted toward the radio wave region	1–3
Total	**4**

Question 20 **(21 marks)**

Measuring the Age of the Universe

In 1929 Edwin Hubble published a claim that the recession velocities of galaxies are proportional to their distance from any observer in the Universe. The redshift of a galaxy is a measure of its recession velocity. The plot below shows Hubble's 1929 data.

(a) Use the gradient of Hubble's graph to calculate a value of H_0 in yr^{-1}. (3 marks)

Description	Marks
$H_0 = 464 \times 365 \times 24 \times 3600 / 3.068 \times 10^{19}$	1–2
H_o (in yr^{-1}) = 4.74×10^{-10} yr^{-1}	1
Total	**3**

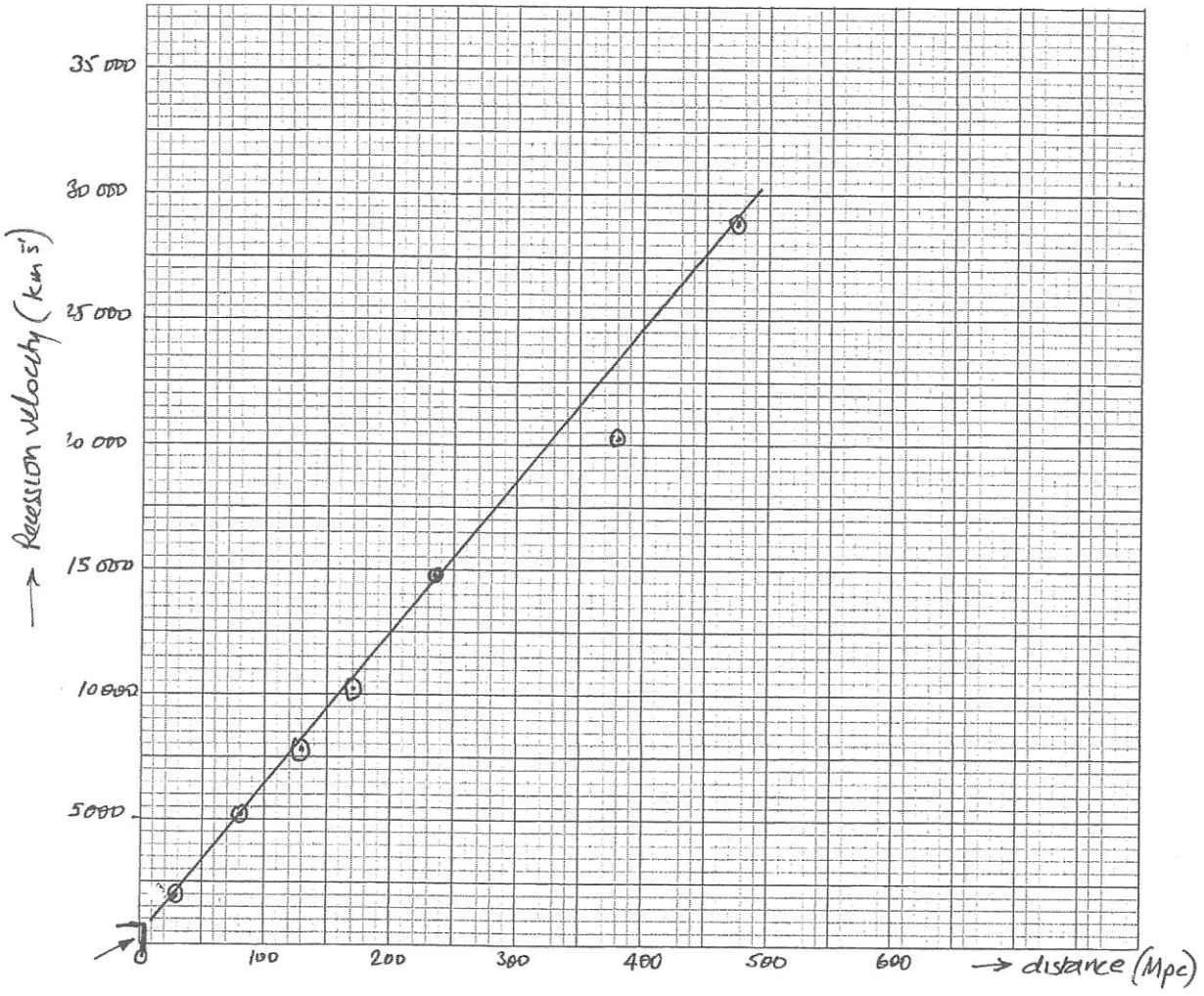
(b) Use the plot of Hubble's data to explain why there would be scepticism about his proposed relationship between the velocities of the galaxies and the distance from the observation point. (2 marks)

Description	Marks
Data is scattered	1
and linear relationship is weak (unreliable)	1
Total	**2**

Note: "Range of data is very narrow (from 0 – 2 Mpc)" is mentioned later in text; allow max 1 mark

(c) Use the data from the table to plot a straight line graph on the grid provided.

(4 marks)



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

Note: Candidates can plot distance versu s recession velocity for full marks.

(d) Using the graph, calculate the value for Hubble's constant in yr^{-1} provided by this set of data.

(3 marks)

Description	Marks
Correct determination of gradient (uses line of.best fit, not data points)	1
Gradient in range 56 to 64 km s^{-1} Mpc^{-1} (must have unit)	1
H_0= gradient ×365×24×3600/3.068×10^{19} H_0 in range (5.7 to 6.6)×10^{-11} yr^{-1}	1
Total	**3**

Note: Allow inverse value for gradient, but H_0 must be correct.

(e) Use the value of Hubble's constant, derived from the data above, to calculate the age of the Universe in years. (2 marks)

Description	Marks
$1/H_0$ = age of universe	1
Age of Universe in range (1.5 to 1.8) × 10^{10} years	1
Total	**2**

(f) Indicate on your graph the extent of the data collected by Hubble in 1929. Refer to this to explain why Hubble's value for the age of the Universe was so different to current estimates. (3 marks)

Description	Marks
Indicates both d and v range	1
Larger range = more accurate gradient	1
Error in small range becomes very large when extrapolated	1
Total	**3**

(g) The table below shows four key points about the Steady State model. Use this table to compare the Big Bang model of the Universe with the Steady State model. (4 marks)

Description		Marks
Steady State Model	**Big Bang Model**	
the Universe is expanding	the Universe is expanding (agrees)	1
Universe has no beginning or end	the Universe began with a large explosion (disagrees)	1
the Earth is in a unique position in the Universe	space itself expands – there is no centre to the Universe (disagrees)	1
the Universe does not change its look over time	the appearance of the Universe changes over time (disagrees)	1
	Total	**4**

End of questions