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

PHYSICS

Stage 3

WACE Examination 2015

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.

2015/101917

Section One: Short answer **30% (56 Marks)**

Question 1 **(2 marks)**

A child on a playground swing swings higher and higher as a friend pushes.

Circle the correct answers.

The swing is undergoing

free oscillation.	forced oscillation.	natural oscillation.

The swing's behaviour is best described as

resonance.	a standing wave.	an antinode.

Description	Marks
forced oscillation	1
resonance	1
Total	**2**

Question 2 **(3 marks)**

The Milky Way galaxy (our galaxy) and the Andromeda galaxy are approximately 250 000 light years apart, and they are approaching each other at a rate of 110 km s^{-1}. Scientists know this because of the blue-shift of light coming from the Andromeda galaxy.

Read the following statements and circle whether they are True or False. (3 marks)

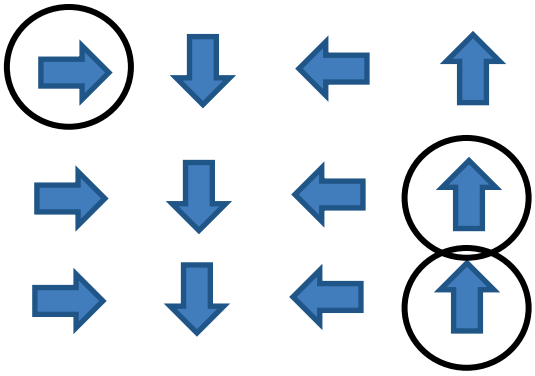
Light reaching the Milky Way from the Andromeda galaxy arrives slightly faster than 3×10^8 m s^{-1}.	True	(False)
Light reaching the Andromeda galaxy from the Milky Way galaxy would be red-shifted.	True	(False)
The Andromeda galaxy must be on a collision course with the Milky Way galaxy.	True	(False)

Description	Marks
False	1
False	1
False	1
Total	**3**

Question 3 **(6 marks)**

(a) Consider the instantaneous motion of the ball **at the moment** that it has maximum contact with the table at Point 'B'. By circling the appropriate arrows, indicate the direction of its

- velocity.
- net acceleration.
- net force.



(3 marks)

Description	Marks
right	1
up	1
up	1
Total	**3**

(b) At which point ('A' or 'C') does the ball experience the greater acceleration? Justify your answer. (3 marks)

Description	Marks
Point C	1
horizontal velocity change at A is $(v - 0) = v$	1
horizontal velocity change at C is greater than at A, e.g. $[v - (-v)] = 2v$	1
Total	**3**

Question 4 **(4 marks)**

A car wheel is held in place by four nuts. Each nut was put on by a machine that tightened it with a torque of 3.00×10^2 N m.

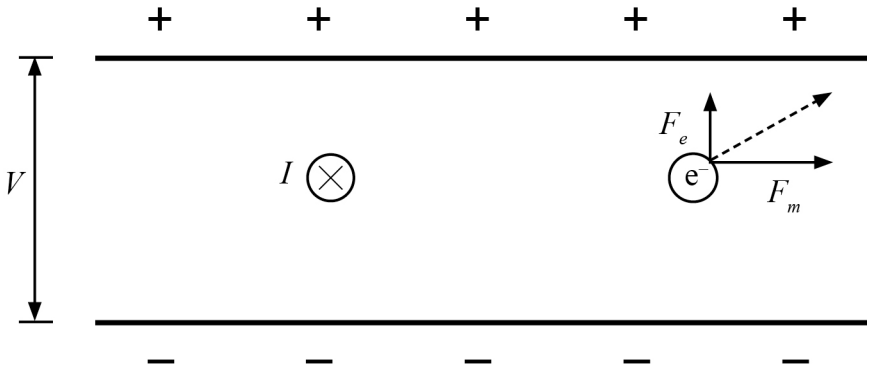
Assuming that it also takes 3.00×10^2 N m to undo the nut, show (by calculation) that if a person of 90.0 kg stands on the end of the lever without bouncing, the weight is **not** enough to turn the wheel nut.

Description		Marks
$\tau = r\,F = rmg$ $0.3 \times 90 \times 9.8 = 265$ N m	$F = \tau/r$ $300/0.3 = 1000$ N $F_w = mg = 882$ N	1–3
$265 < 300$ $\therefore$ not enough	$882 < 1000$ N $\therefore$ not enough	1
	Total	**4**

Question 5 **(6 marks)**

Sketch and label in the diagram above the relative magnitudes and directions of the

- magnetic force on the electron (F_m)
- electric force (F_e) on the electron
- resultant force acting on the electron.



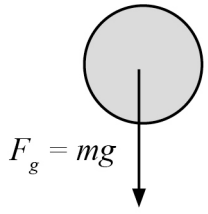
Description	Marks
Labelled vertical electrical force	1–2
Labelled horizontal magnetic force	1–2
Relative magnitude	1
Resultant shown correctly	1
Total	**6**

Note: if diagram is correct in all respects other than labels, allocate 4 marks.

Question 6 **(5 marks)**

At Point A the ball is just in contact with the rail. Draw a free body diagram of the ball when it is at Point A, and calculate the minimum velocity, v, required to keep it in contact with the rail at this point. Show **all** workings.

Free body diagram:



Description	Marks
Force labelled, direction correct Note: allow a small downward reaction force.	1
No irrelevant forces shown	1
Total	**2**

Calculation:

Description	Marks
$F_c = F_g = mg$ $F_c = mv^2/R$	1
or $mv^2/R = mg$	
$\rightarrow v^2 = R\,mg/m$ = 0.5(0.015 × 9.8) / 0.015 = 4.9	1
v = 2.21 m/s	1
Total	**3**

Question 7 **(7 marks)**

Calculate the time taken for the parcel take to drop from the aircraft onto the surfaced submarine, and hence determine the horizontal distance from the submarine at which the aircraft must be when it releases the parcel. Show **all** workings.

Description	Marks
$s = ut + ½\ at^2$; 150 = (0) t + ½ (9.8) t^2; t = $(300/9.8)^{½}$	1–2
5.53 s	1
Conversion to m s^{-1}	1
Calculation of relative speed or subtraction of distance	1
Calculation e.g. $d_x = (v_{xap}).t$ = (216/3.6) (5.53) $d_x = (v_{xboat})$. t = (36/3.6) (5.53) d = (60.0 – 10.0) 5.53 = 277 m	1–2
Total	**7**

Question 8 **(7 marks)**

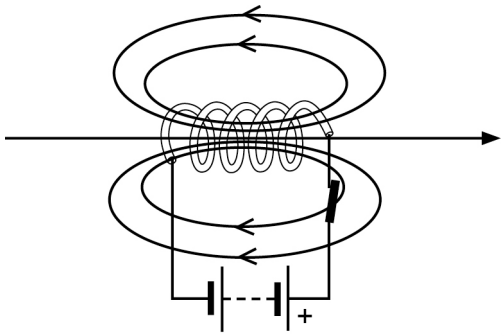
Maxine placed two speakers 12.0 m apart and facing one another. She connected them both to a sound generator, set it to 86.5 Hz, and turned it on. Then she walked at a steady speed of 0.800 m s^{-1} in a straight line from one speaker to the other.

Determine how many maximum loudness locations she walked through, and hence calculate the time it took for Maxine to walk from one maximum loudness point to the next.

Description	Marks
$v=f\lambda$ 346 = 86.5 × λ λ = 4.00 m	1–2
12.0 m ÷ 4 = 3 complete waves Must have max loudness point midway between speakers $\therefore$ 5 or 7 maximum loudness locations	1-2
Distance from one to the next = d=λ/2 = 2.00 m	1
$v = s/t$ v = 2.00/t t = 2 ÷ 0.8	1
Time between max loudness points = 2.50 s	1
Total	**7**

Question 9 **(5 marks)**

(a) On the diagram below, sketch the shape and direction of the magnetic field that will exist around the slinky when the switch is closed. (4 marks)



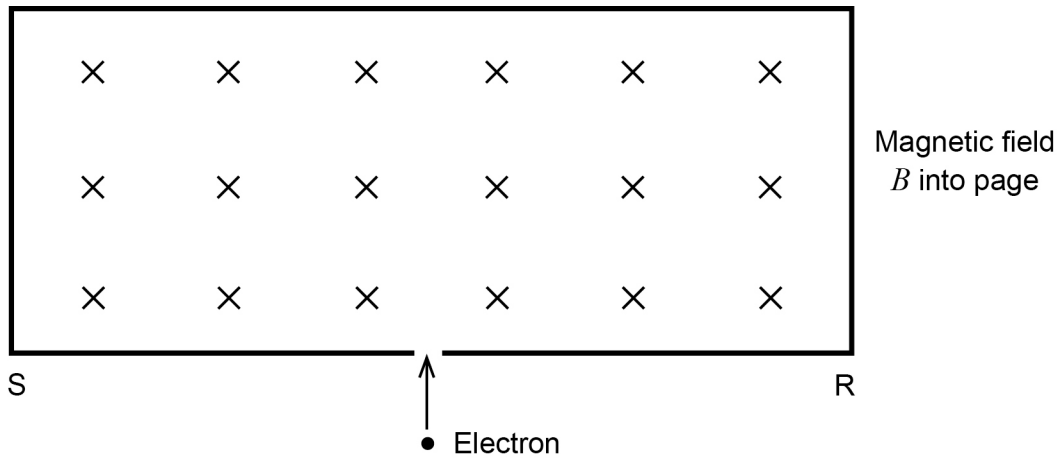
Description	Marks
Arrow direction correct	1
Straight line through centre	1
At least two per side, symmetrical	1
Elliptical not semicircular, lines do not cross	1
Total	**4**

(b) The student also notices that when the switch is closed, there is a small movement in the slinky. Describe this movement. (1 mark)

Description	Marks
Contracts	1
Total	**1**

Question 10 **(4 marks)**

An electron travelling at 1.26×10^7 m s^{-1} entered a uniform magnetic field of intensity 1.50×10^{-3} T at right angles to the field lines, as shown in the diagram.



An electron detector located along the line SR recorded an interaction with the electron. Calculate the distance between the entry point and the detector.

Description	Marks
$F=mv^2/r$ and $F=qvB$	1
$r = mv/qB$	1
$r = (9.11 \times 10^{-31})(1.26 \times 10^7)/(1.6 \times 10^{-19})(1.50 \times 10^{-3})$ $r = 4.78 \times 10^{-2}$ m	1
$d = 2r$ $= 9.57 \times 10^{-2}$ m (accept 9.56×10^{-2} m)	1
Total	**4**

Question 11 **(7 marks)**

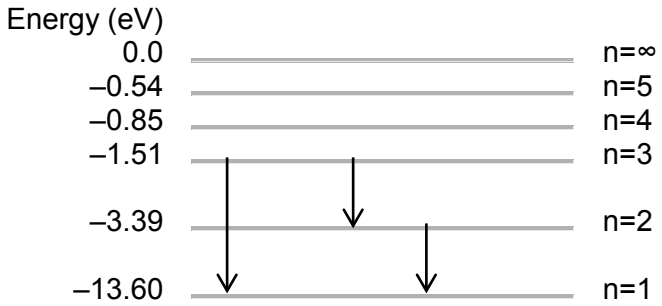
The first five energy levels (not to scale) of a hydrogen atom are shown in the figure below.

(a) Calculate the highest and lowest frequency photons that an excited electron in the n=5 level within a hydrogen atom can emit. Show **all** workings. (4 marks)

Highest: _____ Hz Lowest: _____ Hz

Description	Marks
$E = hf$, thus $f = E/h$	1
n5 to n1: $(13.6 - 0.54) \times 1.6 \times 10^{-19} / 6.63 \times 10^{-34} = 3.15 \times 10^{15}$ Hz	1
n5 to n4: $(0.85 - 0.54) \times 1.6 \times 10^{-19} / 6.63 \times 10^{-34} = 7.48 \times 10^{13}$ Hz	1
Correctly placing both: (follow through allowed) Highest: **3.15×10^{15} Hz**, Lowest: **7.48×10^{13} Hz**	1
Total	**4**

(b) In the diagram below, indicate the possible pathways by which an electron at energy level n=3 can return to ground state. (3 marks)



Description	Marks
n3 to n1 ↓	1
n3 to n2 ↓	1
n2 to n1 ↓	1
Total	**3**

Note: Max. 2 marks if arrows are reversed.

End of Section One

Section Two: Problem-solving **50% (88 Marks)**

Question 12 **(12 marks)**

(a) Show that the magnitude of the gravitational force acting on the exoplanet is 4.97×10^{27} N. (3 marks)

Description	Marks
$F = G\frac{M_s M_p}{r^2}$	1
$\therefore F = \frac{6.67\times10^{-11}\times2.15\times10^{30}\times1.95\times10^{27}}{(7.5\times10^{9})^2}$ $= 4.97 \times 10^{27}$ N	1–2
Total	**3**

(b) Calculate the exoplanet's orbital velocity. Show **all** workings. (3 marks)

Description	Marks
$F = \frac{M_p.v^2}{r}$	1
$4.97 \times 10^{27} = \frac{1.95\times10^{27}\times v^2}{7.5\times10^{9}}$ $\therefore v^2 = 1.912 \times 10^{10}$	1
$v = 1.38 \times 10^5$ m s^{-1}	1
Total	**3**

(c) Calculate the exoplanet's orbital period, and express your answer in hours. Show **all** workings. (3 marks)

Description	Marks
Period = $\frac{2\pi r}{v}$	1
T = $\frac{2\pi\times7.5\times10^{9}}{1.38\times10^{5}}$ s	1
Conversion from seconds to hours Period = 94.7 hours	1
Total	**3**

(d) About 20% of exoplanets discovered to date have a period of 120 hours or less. Explain briefly how red shift and blue shift can be used to identify which stars have such an exoplanet. (3 marks)

Description	Marks
Star wobbles moves it toward and away from the observer	1
Movement toward the observer causes blue shift, away causes red shift	1
Time between successive max red shifts (or max blue shifts) is the orbital period.	1
Total	**3**

Question 13 **(12 marks)**

A mobile phone, of resistance 4.00 Ω was connected to a charger (actually a small step-down transformer). The details of the charger are shown below.

(a) State the power output of the secondary coil of the charger. _____ W (1 mark)

Description	Marks
6.25 W	1
Total	**1**

(b) Calculate the current flowing through the secondary coil while the battery was charging. Show **all** workings. (2 marks)

Description			Marks
$I = \frac{P}{V}$ = 6.25 / 5	or	$I = \frac{V}{R}$ = 5 / 4	1
I = 1.25 A		I = 1.25 A	1
		Total	**2**

(c) When the mobile phone is charging, 5.00 V DC is used to charge the battery.

(i) State the number of joules carried by each coulomb of charge. (1 mark)

Description	Marks
5.00 J	1
Total	**1**

Question 13 (continued)

(ii) Calculate the amount of energy, in joules, carried by each electron as it charges the battery. Show **all** workings. (3 marks)

Description	Marks
1 electron carries 1.6×10^{-19} C 1 coulomb is carried by $1 / 1.6 \times 10^{-19}$ electrons 1 coulomb is carried by 6.25×10^{18} electrons 5 joules is carried by 6.25×10^{18} electrons Each electron carries $5 / 6.25 \times 10^{18}$ J **or** 5 eV = $5 \times 1.6 \times 10^{-19}$ (J)	1–2
Each electron carries 8.00×10^{-19} J	1
Total	**3**

(d) The graph below shows the change in flux experienced by the secondary coil over one complete cycle.

By calculating any required values, and showing **all** workings, determine the magnitudes of the

(i) time interval AE: _____ s. (1 mark)

Description	Marks
2.00×10^{-2} s	1
Total	**1**

(ii) time interval AB: _____ s. (1 mark)

Description	Marks
5.00×10^{-3} s	1
Total	**1**

(iii) flux value F at time B: _____ Wb. (3 marks)

Description	Marks
$emf = -n\frac{\Delta\phi}{t}$	1
$5 = -9\left(\frac{\Delta\phi}{0.005}\right)$	1
$\therefore \Delta\phi = 2.78 \times 10^{-3}$ Wb	1
Total	**3**

Note: accept rms working with answer 2.50×10^{-3} Wb

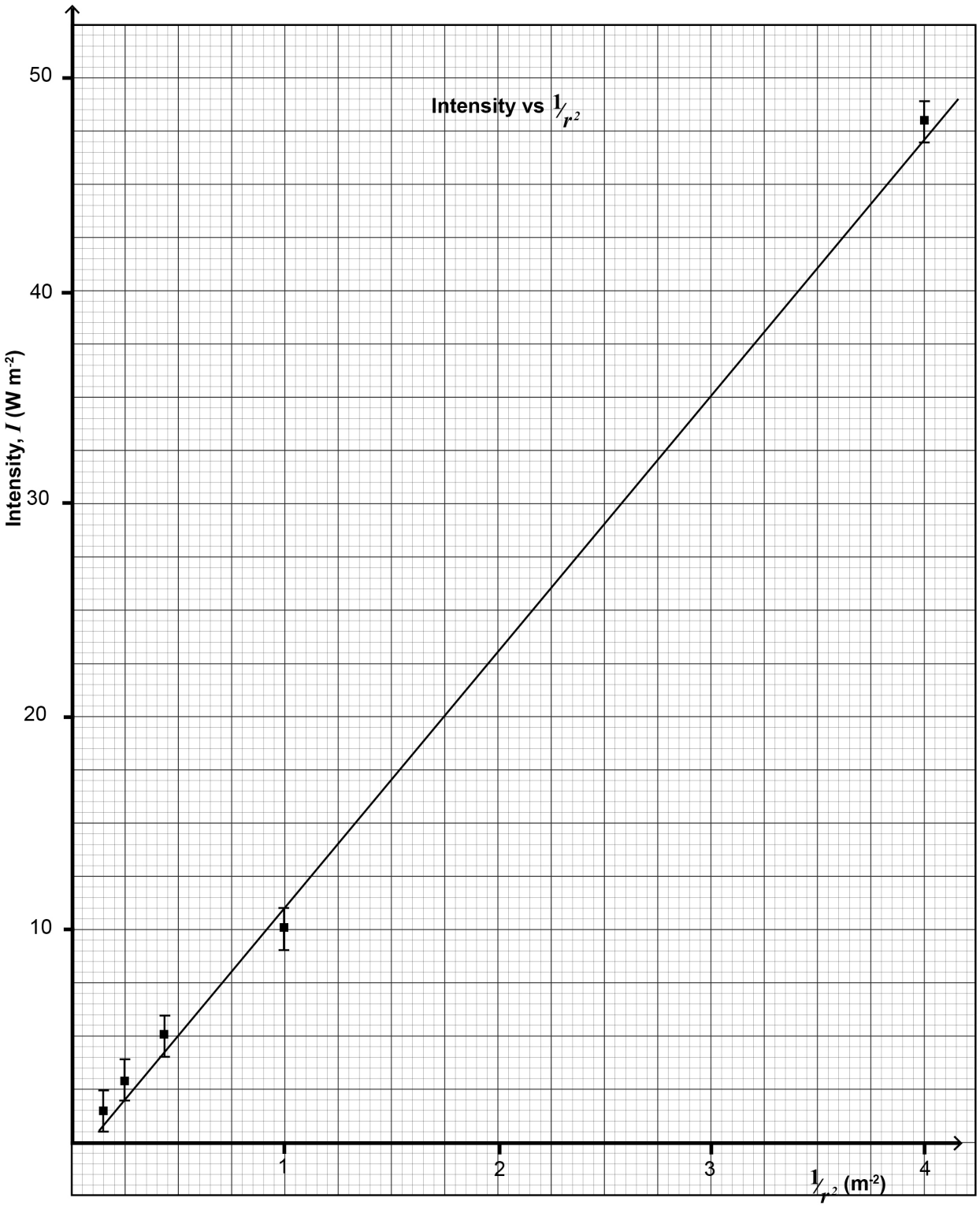
Question 14 **(17 marks)**

(a) Complete the last column in the table above with values expressed to **two** significant figures. (3 marks)

Description	Marks
0.44	1
0.16	1
two significant figures	1
Total	**3**

(b) Use the data from the table to plot a straight line graph (including error bars) on the grid provided demonstrating the relationship between the intensity (W m^{-2}) and $^{1}/_{r^2}$ (m^{-2}).

(5 marks)



Description	Marks
Label axes	1
Plot points accurately	1–2
Error bars	1
Draw line of best fit (not necessarily through origin)	1
Total	**5**

Question 14 (continued)

(c) Determine the gradient of your line of best fit. Show **all** workings, and include units in your answer. (3 marks)

Description	Marks
Uses two points from line of best fit to calculate gradient	1
Determines gradient e.g. gradient = $\frac{47-11}{4-1} = \frac{36 \text{ W m}^{-2}}{3 \text{ m}^{-2}}$ = 12 (accept 11 or 12)	1
Unit: watts or W	1
Total	**3**

(d) Use your graph to determine the intensity at a distance of 0.70 m from the source. Show **all** workings, and express your answer using appropriate significant figures. (3 marks)

Description	Marks
Calculate $1/(0.7)^2 = 2.04$	1
Indicate on graph (2.04 in x-axis to get 23.5 on y-axis) 23.5 W m^{-2} accept 22 to 24	1
two significant figures	1
Total	**3**

(e) Using the answer from (d), calculate the power output of the source. Show appropriate units. (2 marks)

Description	Marks
Working out power = $23.5 \times 4 \times \pi \times 0.7^2 = 145$; accept 140 to 150	1
Unit: W	1
Total	**2**

(f) Using your answers to (c) and (e), did the physics student verify the formula $I = P/A$? (1 mark)

Description	Marks
Yes	1
Total	**1**

Question 15 **(10 marks)**

(a) Assuming that Point O is the pivot, calculate the tension in the cable. Show **all** workings. (6 marks)

Description	Marks
CWM = ACWM	1
1.5 × g × 10 × sin 70° + 2.4 × g × 2.00 × sin 70° = 2.8 × T × sin 30°	1–3
$T = \frac{(147 + 47.04)\,sin\,70°}{1.4}$	1
= 130 N	1
Total	**6**

(b) The cable is then moved up from Point A to Point B while maintaining the angle between the plank and cable at 30.0°. The angle between the plank and ground increases to 25.0°, as in Figure 2. Assume Point O as the pivot,

(i) State whether the tension in the cable increases or decreases. (1 mark)

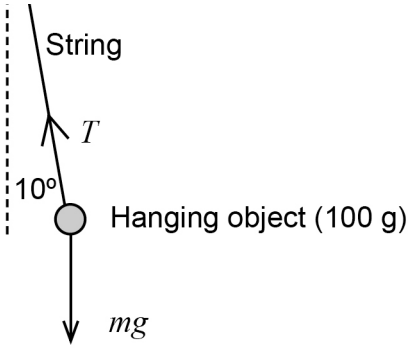
Description	Marks
Decreases	1
Total	**1**

(ii) Justify your answer. (3 marks)

Description	Marks
T is proportional to sin θ where θ is the vertical angle $\therefore$ as θ decreases, T decreases or CWM = ACWM 1.5 × g × 10 × sin (90° – α) + 2.4 × g × 2 × sin (90° – α) = 2.8 × T × sin (30°) $\therefore$as $\alpha\uparrow$, T$\downarrow$	1–3
Total	**3**

Question 16 **(13 marks)**

(a) On the diagram above, draw and label the forces acting on the hanging object. (2 marks)



Description	Marks
Two arrows and appropriate labels	1
No irrelevant forces shown	1
Total	**2**

(b) Calculate the tension in the light string. Show **all** workings. (3 marks)

Description	Marks
$mg = T \cos 10°$	1
$0.1 \times 9.8 = T \cos 10°$ $0.98 = T \cos 10°$	1
T = 0.995 N	1
Total	**3**

(c) Calculate the centripetal force experienced by the hanging mass. Show **all** workings. (3 marks)

Description	Marks
$F = T \sin 10°$	1
$F = 0.995 \times \sin 10°$	1
$F = 0.1728$ N **(0.173 N)**	1
Total	**3**

Note: appropriate alternative methods accepted.

(d) From the information supplied and your previous answers, determine whether the curvature of the road was correct. Show **all** workings. (5 marks)

Description	Marks
(35 km h^{-1} $= 9.722$ m s^{-1})	1
$Mv^2 / r = 0.173$	1
$0.1 \times 9.722^2 / r = 0.173$ $r = 9.452 / 0.173$	1
***r* = 54.6 or 54.7 m** (value depends on rounding)	1
The road is within the tolerance of 50 m ± 5 metres	1
Total	**5**

Note: appropriate alternative methods accepted.

Question 17 **(14 marks)**

(a) Explain why a current is induced in a coil when the magnet enters and leaves it. (4 marks)

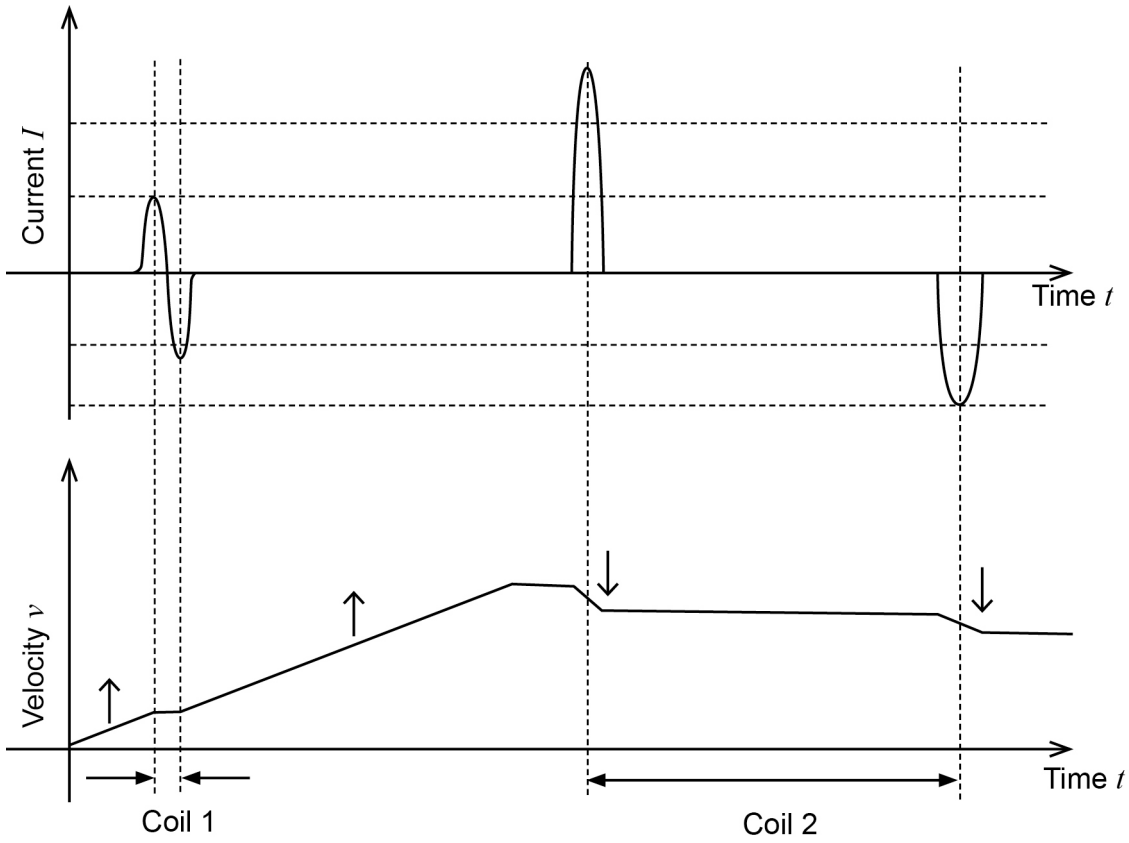
Description	Marks
As the magnet enters or leaves a coil the magnetic flux cutting the coil changes	1–2
An emf is induced as a rate of change of flux, creating a current in the circuit	1–2
Total	**4**

(b) State the expected reading on the galvanometer G as the magnet travels inside Coil 2. Justify your answer. (2 marks)

Description	Marks
Reading = zero	1
no net current induced, as there is no net magnetic flux change	1
Total	**2**

Question 17 (continued)

(c) Sketch the graphs of current versus time and velocity of the magnet versus time on the axes provided below. (8 marks)



Description	Marks
Relative orientation and location of spikes for Coil 1	1
Relative orientation and location of spikes for Coil 2	1
Relative sizes of spikes for Coil 2: first is taller than the second	1
Relative sizes of spikes for Coil 2: second is wider than the first	1
Velocity constant velocity (horizontal) sections	1
Lenz's law effect in Coil 2 ~ two decelerations	1
Acceleration due to gravity – two gradients are the same before Coil 1 and between Coils 1 and 2	1
Lenz's law in Coil 1 ~ acceleration less	1
Total	**8**

Question 18 **(10 marks)**

The recession speed of a Cepheid variable star was determined as 28 800 km s^{-1} moving away from the Earth. Assume that the star's motion is due only to the expansion of space.

The star's recession speed v_{rec} is linked to Hubble's constant, H_0, by the relationship $v_{rec} = H_0 \times d$ where d is the distance of the star from the observer.

(a) Using appropriate assumptions and Hubble's constant of 1.86 × 10^{-5} km s^{-1} light-$year^{-1}$, determine the star's distance from an observer on the Earth. Include units in your answer, and show **all** workings. (3 marks)

Description	Marks
$v_{rec} = H_0 \times d \rightarrow d = v / H_0$	1
d = 28 800 (km/s) / 18.6 (km/s/ 10^6 light-years)	1
= **1.55 × 10^9 light-years**	1
Total	**3**

(b) Estimate the star's current distance from the Earth (in light-years), taking account the distance that the star travelled while the light from the star travelled to Earth. Show **all** assumptions and workings. (5 marks)

Description	Marks
The total time 1.548 × 10^9 years = 1.548 × 10^9 × 60 × 60 × 24 × 365 = 4.88 × 10^{16} s	1
Assume that the expansion of space during transit time can be ignored.	1
The total distance travelled in this time period is 4.88 × 10^{16} s × 2.88 × 10^7 m/s = 1.41 × 10^{24} m 1.41 × 10^{24} m / 9.46 × 10^{15} [m/ly] = 1.49 × 10^8 light-years	1
The current position of this star is d_{now} = 1.49 × 10^8 light-years + 1.548 × 10^9 light-years = **1.7 × 10^9 light-years**	1
Answer given to one or two significant digits	1
Total	**5**

Note: appropriate alternative methods accepted.

(c) Estimate how long it would take for light to travel from the current position of the star to an observer on Earth. Explain why this must be an estimate. (2 marks)

Description	Marks
1.7 × 10^9 years	1
Space will continue to expand while the light travels to the observer so path length is greater. **or** Time is based on a previous estimate (of distance).	1
Total	**2**

End of Section Two

Section Three: Comprehension **20% (35 Marks)**

Question 19 **(21 marks)**

(a) Calculate the force experienced by each electron as it left the cathode. Show **all** workings. (2 marks)

Description	Marks
$F = (q \Delta V) / d = (1.6 \times 10^{-19} \times 1000) / 0.2$	1
$F = 8.00 \times 10^{-16}$ N	1
Total	**2**

(b) Calculate the kinetic energy of each electron just prior to it colliding with a phosphor atom. Show **all** workings. (3 marks)

Description		Marks
Gain in E_k = Work done		1
$W = F \times d$ (since the accelerating force is constant in the uniform magnetic field) Work = $8 \times 10^{-16} \times 0.2$	$W = qV$ $= 1.6 \times 10^{-19} \times 10^{3}$	1
Work = 1.60×10^{-16} J		1
Total		**3**

(c) Calculate the velocity of each electron as it struck the phosphor, assuming that these electrons began their journey from rest (and were free of their parent atoms). Show **all** workings. (3 marks)

Description	Marks
$E_k = ½ m v^2$	1
$1.6 \times 10^{-16} = ½ \times 9.11 \times 10^{-31} \times v^2$ $v^2 = 3.51 \times 10^{14}$	1
$v = 1.87 \times 10^{7}$ m s^{-1}	1
Total	**3**

Note: Follow through marks from (b) to be awarded.

(d) These electrons collided with the phosphor screen to produce a red light of wavelength 700 nm. Calculate the difference, in joules, between energy levels of the phosphor atoms associated with this emission. Show **all** workings. (5 marks)

Description	Marks
$c = f \lambda$	1
$3 \times 10^{8} = f \times 700 \times 10^{-9}$	1
$f = 4.286 \times 10^{14}$ Hz	1
$E = h f$ $E = 6.63 \times 10^{-34} \times 4.286 \times 10^{14}$	1
$E = 2.84 \times 10^{-19}$ J	1
Total	**5**

Note: appropriate alternative methods accepted.

(e) Not all of the electron's kinetic energy was passed on to the phosphor atom to cause the emission of visible light. Give **two** possible ways in which the 'missing' energy might be dissipated. (2 marks)

Description	Marks
Provides two ways in which energy is dissipated, one mark each	1–2
Total	**2**
Answers could include but are not limited to: • residual E_k of incoming electron, i.e. electron continues to travel • wavelength of emitted radiation is not visible to human eye e.g. infrared • electron ionises atoms in the phosphor	

(f) Would the cathode ray tube work if its interior was **not** a vacuum? Justify your answer. (2 marks)

Description	Marks
No	1
Collision of electrons with gases. No electrons arriving at screen with intended amount of E_k	1
Total	**2**

(g) Explain the effects experienced by a person who touched the screen of a CRT while it was operating. (4 marks)

Description	Marks
Explains high potential difference between person and screen	1–2
Explains effect of discharge of charge of screen	1–2
Total	**4**
Answers could include but are not limited to: • Screen accumulates electrons/charge • High potential difference between person and screen • Shock, sparks etc. when high voltage is discharged/current flows	

Question 20 **(14 marks)**

(a) Determine the energy, in joules, of a single emitted gamma ray. (1 mark)

Description	Marks
512 keV = $512 \times 10^3 \times 1.60 \times 10^{-19}$ J = **8.19×10^{-14} J**	1
Total	**1**

Question 20 (continued)

(b) Using the masses of the particles involved, show by calculation that the energy of each gamma ray is 512 keV. (5 marks)

Description	Marks
Mass of electron = 9.11×10^{-31} kg *(from data sheet)* Mass of positron must also be 9.11×10^{-31} kg = mass of electron Mass annihilated = $2 \times 9.11 \times 10^{-31}$ kg = 1.82×10^{-30} kg	1–2
$E = m\,c^2$ $E = 1.82 \times 10^{-30}$ kg $\times (3 \times 10^8)^2$ $E = 1.64 \times 10^{-13}$ J This produces a **pair** of gamma rays	1–2
Each gamma ray carries half of this energy. $E = 1.6398 \times 10^{-13}$ J / 2 = **8.20×10^{-14} J** = 512 keV 8.20×10^{-14} J ÷ 1.60×10^{-19} J/eV = 512 keV	1
Total	**5**

Note: Candidates may calculate energy released from a single mass.

(c) How far from the centre of a LOR would the source of emission be if the temporal gamma rays (travelling at the speed of light) arrive 500 picoseconds apart? Show **all** workings. (4 marks)

Description	Marks
In 500 picoseconds (500×10^{-12} seconds) Light will travel a distance of $(3 \times 10^8) \times (500 \times 10^{-12}) = 0.15$ m	1–2
HOWEVER, the source of emission will be half of this value, i.e. 0.075 m (7.5 cm) from the centre of the LOR since the gamma rays are travelling at equal speed in opposite directions. Remember if the gamma rays were emitted from the centre they would arrive simultaneously. If the source of emission is offset from the centre, then one gamma ray on one side will arrive 250 picoseconds earlier as it travels 7.5 cm less, the opposite gamma ray will travel 7.5 cm more arriving 250 picoseconds later, resulting in a total time difference of 500 picoseconds  7.5 cm	1–2
Alternative working is also acceptable: X + Y = 1 m , X – Y = difference in time × velocity.	
Total	**4**

Question 20 (continued)

(d) As the gamma rays leave the patient's body (mostly water) and travel through air to the detection ring, a slight change in velocity occurs. Name this phenomenon and explain the reason for it. (2 marks)

Description	Marks
Refraction	1
Gamma rays travel at different velocities in different media	1
Total	**2**

(e) What evidence is there for the particle nature of electromagnetic radiation (emr) in the quoted text? (2 marks)

Description	Marks
The two gamma rays leave in opposite directions, preserving the zero initial momentum. or If the rays are picked up at two distinct points, must be particles. A wave radiates as a spherical wave front. or The gammas travel in straight lines from a point source.	1–2
Total	**2**

End of questions

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