**Semester 2 Examination, 2021**

**Question/Answer booklet**

# PHYSICS
# UNITS 3 & 4

# Marking Guide

## Time allowed for this paper

| | |
|---|---|
| Reading time before commencing work: | ten minutes |
| Working time: | three hours |

## Materials required/recommended for this paper

***To be provides by the supervisor***
This Question/Answer booklet
Formulae and Data booklet

***To be provided by the candidate***

| | |
|---|---|
| Standard items: | pens (blue/black preferred), pencils (including coloured), sharpener, correction fluid, eraser, ruler, highlighters. |
| Special items: | up to three non-programmable calculators approved for use in the WACE examinations, drawing templates, drawing compass and a protractor. |

## Important note to candidates

No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised material. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

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

This section has ten (10) questions. Answer **all** questions. Write your answers in the spaces provided.

Suggested working time: 50 minutes.

**Question 1** **(4 marks)**

(a) State the direction in which the current will be flowing – North or South.

(1 mark)

| | |
|---|---|
| North | 1 mark |

(b)

(3 marks)

| | |
|---|---|
| $B = \frac{\mu_0}{2\pi} \frac{I}{r}; \therefore I = \frac{2\pi r B}{\mu_0}$ | 1 mark |
| $I = \frac{2\pi \times 0.135 \times 3.56 \times 10^{-6}}{4\pi \times 10^{-7}}$ | 1 mark |
| $I = 2.40\ A$ | 1 mark |

**Question 2** **(4 marks)**

(a) Give the quark composition of the following hadrons:

(i) The baryon lambda-zero $\Delta^0$ which has Q = 0, B = 1, S = -1 and c = t = b = 0 (1 mark)

| Description | Marks |
|---|---|
| uds | 1 |
| **Total** | **1** |

(ii) The meson pion-plus $\pi^+$ which has Q = +1, B = 0, S = 0 and c = t = b = 0 (1 mark)

| Description | Marks |
|---|---|
| u$\bar{d}$ | 1 |
| **Total** | **1** |

(iii) The baryon omega-minus $\Omega^-$ which has Q = -1, B = 1, S = - 3 and c = t = b = 0 (1 mark)

| Description | Marks |
|---|---|
| sss | 1 |
| **Total** | **1** |

(b) Give two (2) reasons, referring to the known rules involving quantum numbers, why the quark combination of ud is not possible.

(2 marks)

| Description | Marks |
|---|---|
| fractional charges cannot exist in a single particle | 1 |
| fractional baryon number cannot exist is a single particle | 1 |
| **Total** | **2** |

**Question 3** **(5 marks)**

(a) Calculate the gravitational field strength on the surface of Portia.

| | |
|---|---|
| $g_{Portia} = G\frac{m}{r^2} =$ | 1 mark |
| $g_{Portia} = \frac{6.67 \times 10^{-11} \times 1.70 \times 10^{18}}{\left(\frac{135.2 \times 10^3}{2}\right)^2} = 2.48 \times 10^{-2}\ m\ s^{-2};$ | |
| $= 2.48 \times 10^{-2}\ m\ s^{-2};$ | 1 mark |
| | |
| | |

(b) By comparing your answer to part (a) with the gravitational field strength of the Earth, explain – using relevant equations of motion – why an object launched vertically upwards on Portia will reach a higher vertical displacement than when launched the same way on Earth.

| | |
|---|---|
| $v^2 = u^2 + 2as;\ \therefore$ maximum height achieved, $h = \frac{u^2}{2g}$ | 1 mark |
| $g_{Portia} < 9.8\ (g_{earth})$ | 1 mark |
| 'h' is inversely proportional to 'g'; hence, the projectile on Portia will reach a maximum height that is higher than on the Earth. | 1 mark |

**Question 4** **(4 marks)**

In a particular photoelectric experiment, a stopping voltage of 2.10 V is measured when ultraviolet light of wavelength 292 nm is incident upon the metal. Calculate the work function of the metal in eV.

| Description | Marks |
|---|---|
| $\frac{hc}{\lambda} = qV + W$ , W $= \frac{hc}{\lambda} - qV$ | 1 |
| $= \frac{6.63\times10^{-34}(3.00\times10^{8})}{292\times10^{-9}} - (1.60\times10^{-19})(2.10)$ | 1 |
| = $3.45 \times 10^{-19}$ J | 1 |
| ÷$1.60 \times 10^{-19}$ = 2.16 eV | 1 |
| **Total** | **4** |

**Question 5** **(4 marks)**

The transition from n = 3 to n = 2 causes a visible light photon to be emitted – the other transition shown does not. Name a region in the electromagnetic spectrum that the photon emitted by the transition from n = 3 to n = 1 is likely to come from. Explain your choice.

| | |
|---|---|
| Any of ultraviolet, X-rays or gamma rays. | 1 mark |
| $\Delta E = E_3 - E_1 > E_3 - E_2$.<br>The energy difference is largest between n=3 and n=1 | 1 mark |
| The emitted photon, therefore, will have a greater energy than that emitted for n = 3 to n = 2. | 1 mark |
| Hence, the emitted photon will have a higher frequency and a lower wavelength than visible light. | 1 mark |

**Question 6** **(7 marks)**

a) State **one** light phenomena described in the passage above and state which model of light this phenomenon supports. (1 mark)

| Description | Marks |
|---|---|
| Polarisation of light supports transverse wave model | 1 |
| Diffraction of signal around objects support the wave model | 1 |
| Time varying electric field interacting with electrons supports wave model | 1 |
| Total internal reflection of wave in atmosphere supports wave model | 1 |
| **Total** | **1** |

(b) Explain why the antenna must be installed horizontally. (2 marks)

| Description | Marks |
|---|---|
| The electric field is polarized to the horizontal plane | 1 |
| The electrons in the antenna must be aligned horizontally also to allow for them to interact with the electric field and hence, receive the signal | 1 |
| **Total** | **2** |

(c) Calculate the maximum and minimum ideal lengths of the TV aerial to be used in Australia.

(4 marks)

| Description | | Marks |
|---|---|---|
| $c = f\lambda$ | | 1 |
| $3.00 \times 10^{8} = 90.0 \times 10^{6}\ \lambda$ | $3.00 \times 10^{8} = 108 \times 10^{6}\ \lambda$ | 1 |
| $\lambda = 3.33$ | $\lambda = 2.78$ m | 1 |
| L = 3.33 / 2 = 1.67 m | L = 2.78 / 2 = 1.39 m | 1 |
| | **Total** | **4** |

**Question 7** **(5 marks)**

(a) Circle the option (A-D) that best describes how Nancy would expect Lilly to see these two events.

A Lilly sees the light from John first.
B Lilly sees the light from Liam first.
C Lilly sees the light from both simultaneously.
D Lilly will only ever see the light from Liam.

(1 marks)

| | |
|---|---|
| B | 1 mark |

(b) Lilly measures the carriage she is travelling in to be 20.0 m long. Nancy measures the platform she is standing on to be 10.0 m long. The train rushes past at such a high speed that Nancy sees the carriage and the platform to be the same length. Calculate the speed (in m $s^{-1}$) at which the train is moving.

(4 marks)

| | |
|---|---|
| $L = 10.0\ \text{m};\ L_0 = 20.0\ \text{m}; v = ?$ | 1 mark |
| $L = L_0\sqrt{1 - \frac{v^2}{c^2}}$ | |
| $10.0 = 20.0\sqrt{1 - \frac{v^2}{c^2}};\ \ 0.5 = \sqrt{1 - \frac{v^2}{c^2}}$ | 1 mark |
| $0.25 = 1 - \frac{v^2}{c^2};\ \frac{v^2}{c^2} = 0.75$ | 1 mark |
| $v = \sqrt{0.75}\ \times c = 0.866c = 2.60 \times 10^8\ ms^{-1}$ | 1 mark |

**Question 8** **(5 marks)**

Explain how this braking system works and how the current can control the climber speed.

| | |
|---|---|
| When the electromagnets are switched on, their magnetic field interacts with the rotating aluminium disc. | 1 mark |
| The disc experiences a change in flux which creates eddy currents in the aluminium. | 1 mark |
| The direction of these eddy currents are such that – according to Lenz's Law – they will oppose the rotation of the disc – thus slowing the descent speed of the climber. | 1 mark |
| The climber's speed can be decreased further by increasing the size of the eddy currents by creating a greater change in flux. | 1 mark |
| This can be achieved by increasing the current flowing in the electromagnets. | 1 mark |

**Question 9** **(6 marks)**

(a) Compare and explain the 'apparent weight' experienced by the occupants at the top and bottom of the vertical circular path as they travel through these points. Use appropriate mathematical expressions in your answer.

(4 marks)

| | |
|---|---|
| The normal forces experienced at the top and bottom of a vertical circle are (respectively): $$N = mg - \frac{mv^2}{r} \quad \text{and} \quad N = \frac{mv^2}{r} + mg$$ | 1-2 mark |
| Hence, the apparent weight of an occupant at the top of the vertical circle will be less than their apparent at the bottom of the circle. | 1 mark |
| Further, their apparent weight will increase more at the bottom, due to higher speeds at the bottom of the vertical circle. | 1 mark |

(b) In one loop-the-loop design, the rollercoaster can travel upside down at the top of the vertical circle. Obviously, the occupants are strapped in very securely. However, it is possible for them to travel upside down without falling out of the rollercoaster. Explain how this can be achieved.

(2 marks)

| | |
|---|---|
| This can be achieved if the normal contact force N>0; ie, $F_c$=W. | 1 mark |
| This is achieved when the minimum circular speed (v) at the top of the circle is given by: $$v = \sqrt{gr}$$ | 1 mark |

**Question 10** **(6 marks)**

(a) State the type of charge (positive/negative) on each particle.

(1 mark)

| | |
|---|---|
| Positive | 1 mark |

(b) Which path represents the particle with the largest charge? Explain.

(2 marks)

| | |
|---|---|
| The radius of the path is given by the expression: $r = \frac{mv}{qB}$ | 1 mark |
| Hence, path 1 represents the path for the particle with the largest charge. | 1 mark |

(c) If the chamber was filled with air instead of a vacuum, describe the shape of the paths and explain your answer.

(3 marks)

| | |
|---|---|
| The paths would be spirals with a decreasing radii. | 1 mark |
| The charged particles would continually collide with air particles, thus reducing their speed (v). | 1 mark |
| Given $r = \frac{mv}{qB}$, a constant decrease in speed 'v' would result in a constant decrease in radius 'r'. | 1 mark |

**OR**

| | |
|---|---|
| The paths would be chaotic/random | 1 mark |
| The charged particles would continually collide with air particles, | 1 mark |
| The random nature of these collisions produce a range of scattering directions | 1 mark |

**Question 11** **(4 marks)**

A group of Physics students constructed an AC generator out of a single rectangular coil, a reasonably strong horseshoe magnet and other materials lying round the house.

Once they started to rotate the coil at 3.00 Hz, they measured an RMS voltage output of 0.0249 mV.

The coil has dimensions of 1.50 cm x 2.50 cm. Calculate the strength of the horseshoe magnet's field (B).

| | |
|---|---|
| $\text{Maximum EMF} = \sqrt{2} \times V_{RMS} = \sqrt{2} \times 0.0249 \times 10^{-3} = 3.52 \times 10^{-5}$ | 1 mark |
| $\text{Maximum EMF} = -2\pi\text{fnBA};$<br>ie, $3.52 \times 10^{-5} = -2\pi \times 3.00 \times 1 \times \text{B} \times (0.0150 \times 0.0250)$ | 1 mark |
| $\therefore \text{B} = \dfrac{3.52 \times 10^{-5}}{7.07 \times 10^{-3}}$ | 1 mark |
| $\text{B} = 4.98 \times 10^{-3}\ \text{T}$ | 1 mark |

## Section Two: Problem Solving 50% (90 marks)

This section contains six (6) questions. Answer **all** questions. Answer the questions in the space provided.

Suggested working time is 90 minutes.

### Question 12 (9 marks)

(a) Calculate the mass of the kite.

(5 marks)

| | |
|---|---|
| Vertical component of the LIFT force = 68.2 x cos 51° = 42.9 N up | 1 mark |
| Vertical component of the TENSION = 25 x sin 51° = 19.4 N down | 1 mark |
| $\sum F = 0$; $19.4 + W_K = 42.9$ | 1 mark |
| $W_K = 42.9 - 19.4 = 23.5$ N down | 1 mark |
| Hence: $m = \frac{23.5}{9.80} = 2.40\ \text{kg}$ | 1 mark |

(b) If the kite is travelling in a horizontal circular path with a radius of 15.6 m, calculate the average circular speed achieved.
[If you were unable to calculate an answer for part (a), use a value of 2.50 kg]

(4 marks)

| | |
|---|---|
| Horizontal component of the LIFT force = 68.2 x sin 51° = 53.0 N left.<br><br>Horizontal component of the TENSION = 25 x cos 51° = 15.7 N left | 1 mark |
| Hence, $\sum F_h = F_c = 53.0 + 15.7 = 68.7$ N | 1 mark |
| $F_c = \frac{mv^2}{r}$; $\therefore 68.7 = \frac{2.40 \times v^2}{15.6}$ | 1 mark |
| $v = \sqrt{\frac{68.7 \times 15.6}{2.40}} = 21.1\ \text{m s}^{-1}\ \ (20.7\ \text{m s}^{-1})$ | 1 mark |

**Question 13** **(15 marks)**

(a) Using formulae from the Formulae and Data Booklet, show that the relationship between the threshold voltage ($V_0$) and the maximum wavelength ($\lambda$) for an LED is given by:

$$\mathbf{V_0 = \frac{hc}{q_e \lambda}}$$

**where h = Planck's constant; c = speed of light; $\mathbf{q_e}$ = charge on an electron.**

(2 marks)

| | |
|---|---|
| $E_{PHOTON} = hf = \frac{hc}{\lambda}$ | |
| $E_{ELECTRON} = E_{PHOTON};\ V_0 q_e = \frac{hc}{\lambda}$ | 1 mark |
| $\therefore\ V_o = \frac{hc}{q_e \lambda}$ | 1 mark |

The students perform the experiment using four (4) different LED's and gather the following results.

| LED colour | $V_o$ (V) | $\lambda$ (nm) | $1/\lambda$ (x $10^6$ $m^{-1}$) |
|---|---|---|---|
| Infrared | 1.24 | 1000 | 1.00 |
| Red | 1.79 | 695 | 1.44 |
| Yellow | 1.88 | 660 | 1.52 |
| Green | 1.97 | 630 | 1.59 |

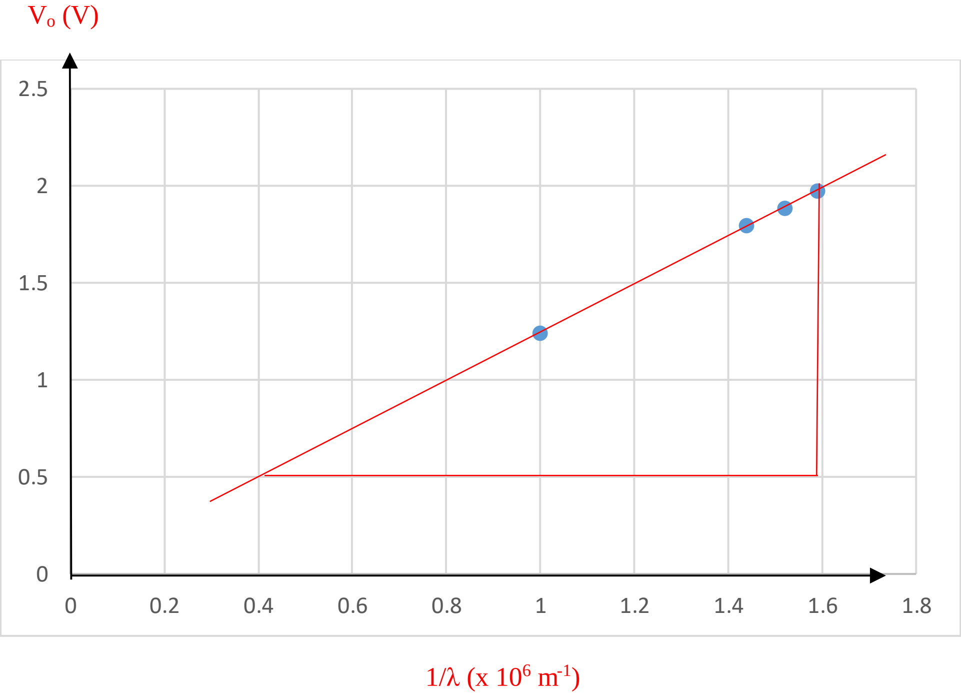
(b) Complete the table by filling in the missing value in the '1/λ' column.

(1 mark)

| | |
|---|---|
| (i) 1.44 | 1 mark |

(c) On the graph paper provided on the next page, plot a graph of '$V_o$' against '$1/\lambda$'. Place '$1/\lambda$' on the horizontal axis. Draw a line of best fit for the data.

(4 marks)




| | |
|---|---|
| Labelled axes | 1 |
| Units on axes | 1 |
| Accuracy of points for V against 1/wavelength | 1 |
| Suitable LoBF | 1 |

(d) Calculate the slope of your line of best fit. Include units in your answer.

(4 marks)

| | |
|---|---|
| Picks two points from the graph: ($1.6 \times 10^6$, 2.00) and ($0.40 \times 10^6$, 0.50) | 1 mark |
| $\text{Slope} = \dfrac{(2.00 - 0.40)}{(1.6 - 0.40) \times 10^6}$ | 1 mark |
| $\text{Slope} = 1.33 \times 10^{-6}$ | 1 mark |
| Vm | 1 mark |

(e) Use the slope from part (d) to calculate an experimental value for Planck's constant (h).

(4 marks)

| | |
|---|---|
| $\text{SLOPE} = \dfrac{\Delta V_o}{\Delta \frac{1}{\lambda}} = V_o \lambda$ | 1 mark |
| $V_o \lambda = \dfrac{hc}{q_e}$ | 1 mark |
| $\therefore h = \dfrac{\text{SLOPE} \times q_e}{c} = \dfrac{1.33 \times 10^{-6} \times 1.60 \times 10^{-19}}{3.00 \times 10^8}$ | 1 mark |
| $h = 7.11 \times 10^{-34}$ Js | 1 mark |

**Question 14** **(15 marks)**

(a) Calculate the magnitude (in Volts) of the accelerating electric potential. Show working.

(4 marks)

| | |
|---|---|
| $E_K = Vq;\ {}^{1}\!/_{2}\, mv^2 = Vq$ | 1 mark |
| $V = \dfrac{mv^2}{2q}$ | 1 mark |
| $V = \dfrac{9.11 \times 10^{31} \times (2.50 \times 10^{5})^2}{2 \times 1.60 \times 10^{-19}}$ | 1 mark |
| $V = 0.178\ \text{V}$ | 1 mark |

(b) State what the experiment demonstrated about the behaviour of the electrons.

(1 mark)

| | |
|---|---|
| The electrons possess wave-like properties. | 1 mark |

(c) Explain how the dark and light fringes are formed.

(4 marks)

| | |
|---|---|
| As the electrons pass through the two slits, they experience the wave behaviour of diffraction. | 1 mark |
| As they spread out in a wave-like manner, the electrons superposition and interfere as they travel from the double slit to the optical screen. | 1 mark |
| The dark fringes occur when constructive interference occurs. | 1 mark |
| The light fringes occur when destructive interference occurs. | 1 mark |

(d) Calculate the minimum de Broglie wavelength for these electrons.

(3 marks)

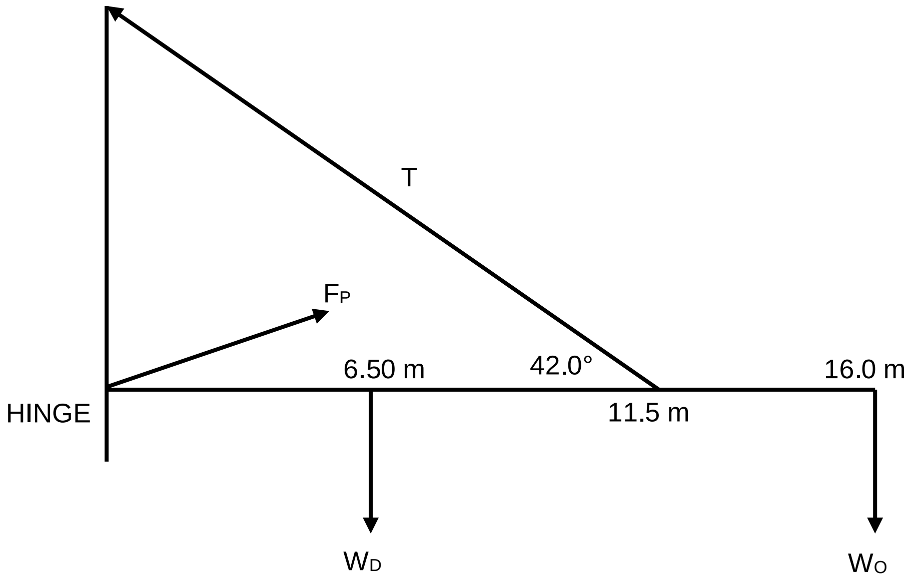
| | |
|---|---|
| $\lambda = \frac{h}{p} = \frac{h}{mv}$ | 1 mark |
| $\lambda = \frac{6.63 \times 10^{-34}}{9.11 \times 10^{-31} \times 2.50 \times 10^{5}}$ | 1 mark |
| $\lambda = 2.91 \times 10^{-9}$ m | 1 mark |

**Question 15** **(17 marks)**

(a) Draw a free-body diagram to represent the drawbridge when it is in the horizontal position shown. Include all important dimensions and angles.

(4 marks)

| | |
|---|---|
| Vectors for the four (4) forces (weight of bridge; weight of object; force at hinge and tension in cable) are correctly shown. | 1 mark |
| Force at hinge must point either upwards OR downwards to the right. | 1 mark |
| Distances and 42.0° angle are labelled correctly. | 1 mark |
| Forces are labelled appropriately. | 1 mark |



(b) Calculate the tension (T) in the cable when the drawbridge is in this horizontal position.

(4 marks)

| | |
|---|---|
| Take moments about the hinge; $\sum M = 0$; $\sum M_C = \sum M_A$. | |
| $(250.0 \times 9.80 \times 6.50) + (70.0 \times 9.80 \times 16.0) = T \times 11.5 \times \sin 42.0°$ | 1-3 marks |
| $T = \dfrac{2.69 \times 10^4}{7.70} = 3.50 \times 10^3$ N | 1 mark |

(c) Hence, calculate the force (magnitude and direction) the wall exerts on the drawbridge at point 'P'.

(5 marks)

| | |
|---|---|
| $\sum F = 0$ | |
| $\Sigma F_{LEFT} = \Sigma F_{RIGHT}$<br>$F_H = 3.50 \times 10^3 \times \cos 42.0° = 2.60 \times 10^3$ N to the right | 1 mark |
| $\Sigma F_{UP} = \Sigma F_{DOWN}$<br>$3.50 \times 10^3 \times \sin 42.0° + F_V = 2.45 \times 10^3 + 6.86 \times 10^2$<br>$F_V = 8.01 \times 10^2$ N upwards | 1-2 mark |
| $F_{total} = \sqrt{(2.60 \times 10^3)^2 + (8.01 \times 10^2)^2} = 2.72 \times 10^3$ N | 1 mark |
| $\theta = \tan^{-1}\left(\dfrac{8.01 \times 10^2}{2.60 \times 10^3}\right)$<br><br>$= 17.1°$ above the horizontal | 1 mark |

(d) The drawbridge is elevated into a position where the object just begins to slide towards the hinge. If the maximum frictional force experienced between the object and the drawbridge is 320 N, calculate the angle to the horizontal to which the drawbridge has been elevated.

(4 marks)

| | |
|---|---|
| When object begins to slide: $F_{FRICTION} = F_{SLOPE} = 320\text{ N}$ | 1 mark |
| $\therefore 320 = 70.0 \times 9.80 \times \sin\theta$ | 1 mark |
| $\theta = \sin^{-1}\left(\frac{320}{686}\right)$ | 1 mark |
| $\theta = 27.8°$ | 1 mark |

**Question 16** **(19 marks)**

(a) Using the orbital data for our Sun, show that the mass of the Milky Way is about 1 × $10^{11}$ solar masses (1 solar mass = mass of Sun).

(5 marks)

| | |
|---|---|
| $r = 2.60 \times 10^4 \times 365 \times 24 \times 3600 \times 3.00 \times 10^8 = 2.46 \times 10^{20}$ m | 1 mark |
| $T = 225 \times 10^6 \times 365 \times 24 \times 3600 = 7.10 \times 10^{15}$ s | 1 mark |
| $T^2 = \frac{4\pi^2}{GM} r^3; \;\; M = \frac{4\pi^2 r^3}{GT^2}$ | 1 mark |
| $M = \frac{4\pi^2 (2.46 \times 10^{20})^3}{6.67 \times 10^{-11} \times (7.10 \times 10^{15})^2} = 1.75 \times 10^{41}$ kg | 1 mark |
| $\text{Number of solar masses} = \frac{1.75 \times 10^{41}}{1.99 \times 10^{30}} = 8.78 \times 10^{10} \approx 10^{11}$ | 1 mark |

(b) Using formulae from the Formulae and Data Booklet, derive the expression that shows a stars orbital speed ($v$) with an orbital radius ($r$) as it orbits the Milky Way's centre of mass ($M$) is given by $v = \sqrt{\frac{GM}{r}}$.

(3 marks)

| | |
|---|---|
| $F_G = F_c; \;\; G\frac{m_1 m_2}{r^2} = \frac{m_1 v^2}{r}$ **OR** $a_c = \frac{v^2}{r} = \frac{GM}{r^2}$ | 1 mark |
| $\frac{Gm}{r} = v^2$ | 1 mark |
| $v = \sqrt{\frac{Gm}{r}}$ | 1 mark |

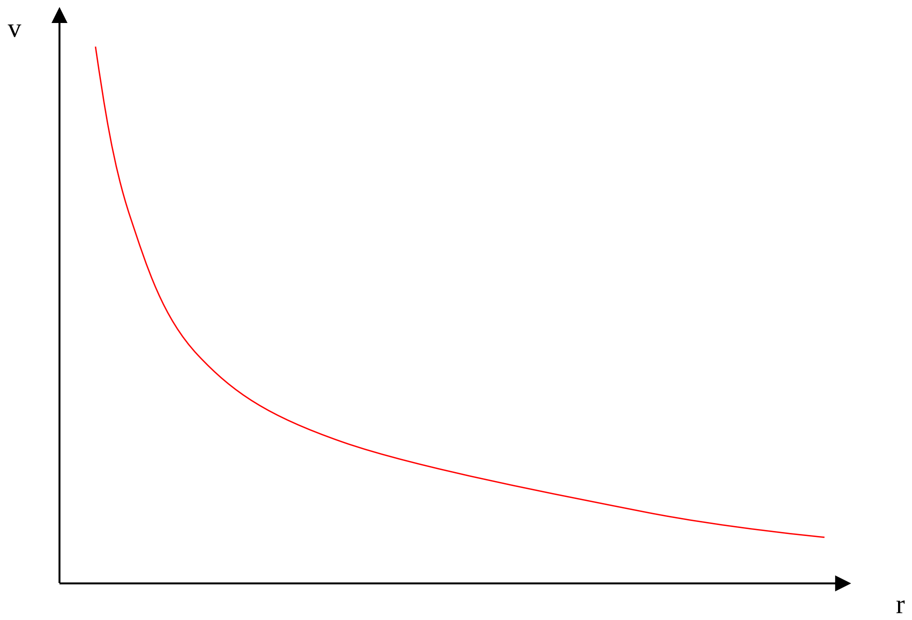
(c) Use this expression to calculate the orbital speed of the Sun.

(2 marks)

| | |
|---|---|
| $v = \sqrt{\frac{Gm}{r}}$ | |
| $v = \sqrt{\frac{6.67 \times 10^{11} \times 1.75 \times 10^{41}}{2.46 \times 10^{20}}}$ | 1 mark |
| $v = 2.18 \times 10^5 \text{ m s}^{-1}$ | 1 mark |

(d) On the axes below, sketch a graph that shows how the orbital speed (v) of stars in the Milky Way should vary with their orbital radius (r). There is no need to provide any values on the axes.

(2 marks)




| | |
|---|---|
| Graph shows as r increases, v decreases | 1 mark |
| The graph indicates an inverse relationship between $\sqrt{r}$ and 'v'. | 1 mark |

(e) It is predicted that, from the outer edge of the galaxy, stars with a small orbital radius would be observed to produce a repeating pattern of red and blue shifted light throughout as they orbit and that the magnitude of the shift increases with decreasing orbital radius. Explain these two observations.

(4 marks)

| | |
|---|---|
| Stars orbiting around the galactic centre will alternate between moving towards and away from an observer at the far edge<br>**Moving towards produces a blue shift.**<br>**Moving away produces a red shift** | 1-2 mark |
| The amount of red- and blue-shift for stars with smaller orbital radii will be greater than those with greater orbital radii due to their higher orbital speeds. | 1-2 mark |

**Question 17** **(15 marks)**

(a) Calculate the emission speed of the beta particle from the radioisotope's frame of reference.

(3 marks)

| Description | Marks |
|---|---|
| u' = $\frac{v-u}{1-\frac{vu}{c^2}}$ = | 1 |
| = $\frac{0.950c-(0.400c)}{1-\frac{(0.400c)(0.950c)}{c^2}} = \frac{0.55\ c}{1-0.380}$ | 1 |
| = 0.887 c | 1 |
| **Total** | **3** |

(b) Calculate the momentum of the beta particle as measured from the stationary observer.

(3 marks)

| Description | Marks |
|---|---|
| $p = \frac{m_0 v}{\sqrt{1-\frac{v^2}{c^2}}}$ | 1 |
| = $\frac{9.11\times10^{-31}(0.950\times3.00\times10^{8})}{\sqrt{1-0.950^2}}$ | 1 |
| = $8.31\text{x}10^{-22}$ kg m $s^{-1}$ | 1 |
| **Total** | **3** |

(c) Calculate the distance that the radioisotope travels from its frame of reference. (5 marks)

| Description | Marks |
|---|---|
| $t = \frac{t_0}{\sqrt{1-\frac{v^2}{c^2}}}, t_0 = t.\sqrt{1-\frac{v^2}{c^2}},$ | 1 |
| $= 0.120\sqrt{1-0.400^2}$ | 1 |
| = 0.110 μs | 1 |
| s = v.t<br>= $0.400 \times 3.00 \times 10^8 (0.110 \times 10^{-6})$ | 1 |
| = 13.2 m | 1 |
| **Total** | **5** |

May also use the following steps:

1. Find distance observed by stationary observer (this is the proper length)
2. Find the contracted length (length observed by radioisotopes)

**Question 18**

(a) Using the blackbody curve of the 5000 K radiator, provide a calculation of Wein's constant.

(3 marks)

| Description | Marks |
|---|---|
| Shown on graph; peak wavelength is 600 nm | 1 |
| B = $\lambda$T<br>= 600x$10^{-9}$(5000) | 1 |
| = 3.0 x$10^{-3}$ **m K (or K m)** | 1-2 |
| **Total** | **3** |

(b) Hence, calculate the peak wavelength of the sun's blackbody curve, whose surface temperature is 5800 K. If you could not obtain an answer to part (a), you may assume a value of $3.5 \times 10^{-3}$.

(3 marks)

| Description | Marks |
|---|---|
| $\lambda = \frac{B}{T}$ | 1 |
| $= \frac{3.0 \times 10^{-3}}{5800}$ | 1 |
| $= 5.17 \times 10^{-7}$ m | 1 |
| **Total** | **3** |

(d) Calculate the total power (J $s^{-1}$ or W) output of the sun whose surface temperature is 5800 K. Note: the surface area of the sun can be calculated using the formula SA = $4\pi r^2$ and intensity, (power per unit area) can be expressed as I = P / A. (3 marks)

| Description | Marks |
|---|---|
| I = P / A  P = I A $= \sigma T^4 (4\pi r^2)$ | 1 |
| $= 5.67 \times 10^{-8}(5800^4)(4\pi \times 6.96 \times 10^8)^2$ | 1 |
| $= 3.91 \times 10^{26}$ W | 1 |
| **Total** | **3** |

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

This section has two (2) questions. Answer **both** questions. Answer the questions in the spaces provided.

Suggested working time: 40 minutes.

**Question 19** **(18 marks)**

(a) The article states: "… a football, once kicked or handpassed, follows a parabolic path".

Assume the football is launched and lands at the same vertical height. By examining important aspects of a projectile's path, explain why a parabolic path is followed by the football.

[Note – a projectile's path is an inverted parabola which is symmetrical around the maximum height achieved by the projectile]

(4 marks)

| | |
|---|---|
| VERTICAL PLANE: acceleration due to gravity is constant ($g = 9.80\ m\ s^{-2}$ downwards). | 1 mark |
| Hence, time taken to reach maximum height from the ground is equal to the time taken to travel from maximum height to the ground. | 1 mark |
| HORIZONTAL PLANE: horizontal component of velocity is constant. | 1 mark |
| Hence, distance travelled horizontally from the ground to maximum height is equal to the distance travelled horizontally from maximum height to the ground. | 1 mark |

(b) "In reality, the football's path is NOT a perfectly parabolic path; this is because its path is not only affected by gravity, but also by air resistance - which is created by drag in the air and even wind."

(i) In the table below, state how the following aspects of a projectile's path would change from an 'ideal situation' when air resistance is taken into account.

(2 marks)

| | |
|---|---|
| RANGE | Range would be less than in an ideal situation |
| MAXIMUM HEIGHT | Maximum height would be less than in an ideal situation |

| | |
|---|---|
| Range would be less than in an ideal situation | 1 mark |
| Maximum height would be less than in an ideal situation | 1 mark |

(ii) Let the time taken for the football to travel from the ground **to maximum height be '$t_{UP}$'**.

Let the time taken for the football to travel from maximum height **to the ground be '$t_{DOWN}$'**.

**When air resistance is ignored,** these two values are the same (ie – $t_{UP} = t_{DOWN}$).

Compare these two values when **air resistance is taken into account**. Explain any differences between these values. As part of your answer, consider how gravity's effects would be affected by air resistance.

(3 marks)

| | |
|---|---|
| $t_{UP} < t_{DOWN}$ | 1 mark |
| On the way up: $\sum a = g + a_{resistance}$ | 1 mark |
| On the way down: $\sum a = g - a_{resistance}$ | 1 mark |

(c) If air resistance is ignored, for a projectile launched at an angle of 'θ' to the horizontal and with a speed of 'v', the horizontal and vertical components of the launch velocity are given by:

$$\mathbf{v_h = v\ \cos\theta \quad and \quad v_v = v\ \sin\theta}$$

Use these expressions - and appropriate formulae from the Formulae and Data Booklet – to show that for a projectile that is launched and lands at the same height, the maximum horizontal distance achieved will be:

$$\mathbf{s_h = \frac{v^2}{g} \times \sin 2\theta}$$

NOTE: you may find the following trigonometric identity useful in the solution of this question:

$$\mathbf{\sin 2\theta = 2\ \sin\theta\ \cos\theta}$$

(4 marks)

| | |
|---|---|
| $S_v = 0; s = ut + {}^1/_2\, at^2; 0 = ut + {}^1/_2\, at^2; 0 = u + {}^1/_2\, at$ | 1 mark |
| $t = \frac{s_h}{v\cos\theta};\ 0 = (v\sin\theta) - \frac{g \times s_h}{2 \times v\cos\theta}$ | 1 mark |
| $0 = 2v^2(\cos\theta)(\sin\theta) - g \times s_h$ | 1 mark |
| $\therefore s_h = \frac{v^2}{g} \times \sin 2\theta$ | 1 mark |

(d) A football is kicked with a velocity of 15 m s$^{-1}$ at angle of 35° to the horizontal. Calculate the maximum horizontal distance achieved by the football if air resistance is ignored.

(2 marks)

| | |
|---|---|
| $s_h = \frac{15^2}{9.80} \times \sin 70°$ | 1 mark |
| $s_h = 21.6 \text{ m}$ | 1 mark |

(e) A football is kicked with a velocity of 14 m s$^{-1}$ and achieves a maximum height of 7.00m. Calculate the angle 'θ' at which the football is launched. Ignore air resistance.

(3 marks)

| | |
|---|---|
| $s_v = \frac{v^2}{2g} \times (\sin\theta)^2; 7.00 = \frac{14^2}{19.6} \times (\sin\theta)^2$ | 1 mark |
| $\sin\theta = \sqrt{\frac{7.00 \times 19.6}{196}} = 0.837$ | 1 mark |
| $\therefore \theta = \sin^{-1} 0.837 = 56.8°$ | 1 mark |

**Question 20** **(18 marks)**

Explain why liquid hydrogen is used to detect particles rather than gaseous hydrogen.
(2 marks)

| Description | Total |
|---|---|
| The phase change can be detected as a bubble/must start as a liquid as a gas cannot vaporise | 1 |
| Liquid is a higher density so more interactions will occur | 1 |
| These lead to easier detection of the bubbles/tracks | 1 |
| **Total** | **2** |

(b) Explain, making reference to relevant equations, how a death spiral indicates an electron of low momentum continuing to lose kinetic energy.

(3 marks)

| Description | Total |
|---|---|
| $r = \frac{mv}{qB}$ with q and B constant, $r \propto mv$ | 1 |
| As the radius of the spiral decreases, this is a reduction in velocity and hence momentum | 1 |
| As v reduces, so too does kinetic energy | |
| **Total** | **3** |

(c) Explain why, if one of the particles created from the proton-pion interaction is neutral, the other particle that is created must also be neutral.

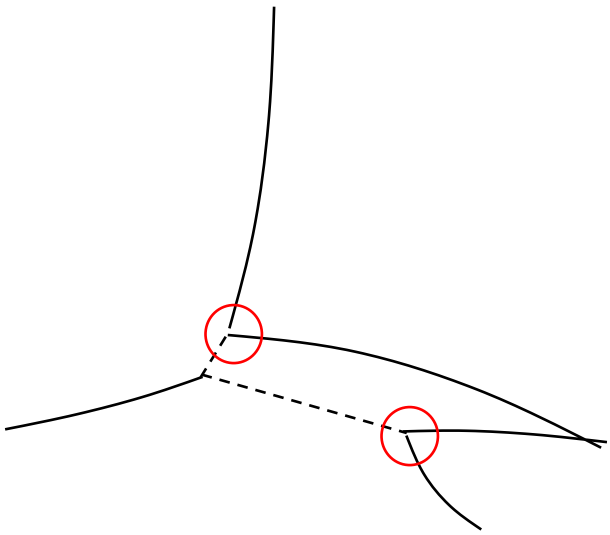
(3 marks)

| Description | Total |
|---|---|
| The proton has a charge of +1 and the pion a charge of -1 | 1 |
| Charge must be conserved | 1 |
| If one product particle is neutral, the other must neutral to create a net zero charge | 1 |
| **Total** | **3** |

(d) Given that the death spirals in Figure 1 are created by electrons entering from the left, state and explain the direction of the magnetic field in the bubble chamber. (2 marks)

| Description | Total |
|---|---|
| An explanation that includes factors that help determine the direction of the field. This may include:<br>• death spirals are occurring in an anticlockwise direction.<br>• Required centripetal force must always act towards centre<br>• Electrons are negatively charged<br>• As per the right hand rule/left hand rule | 1-2 |
| Magnetic field must be coming out of the page. | 1 |
| **Total** | **3** |

(e) Circle two (2) areas on figure 2 where a neutral particle has decayed. (2 marks)



(f) Show that the speed of the particle is 1.89 x$10^8$ m $s^{-1}$.

(4 marks)

| Description | Total |
|---|---|
| $E_T = \frac{m_0c^2}{\sqrt{1-\frac{v^2}{c^2}}}$, | 1 |
| v/c = 1.89/3 = 0.631c | 1 |
| identifies that rest mass=180 MeV/$c^2$ $E_T = \frac{180\times1.60\times10^{-13}}{\sqrt{1-0.631^2}}$ | 1 |
| = 232 MeV | 1 |
| **Total** | **4** |
| Note: students can solve for velocity, given $E_k$ = 52 MeV but is a much more complicated solution. | |

**OR**

Converts into kg and J 1

$E_T = \frac{m_0c^2}{\sqrt{1-\frac{v^2}{c^2}}}$, 1

Rearranges for $v = \sqrt{1-\left(\frac{mc^2}{E_T}\right)^2}$ 1

Converts units of c into units in m $s^{-1}$ 1