Edwest Year 12 Physics Semester Two Examination – *Suggested* Marking Guide

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|  |

**Question 1 (5 marks)**

(a) Although the voltage supplied to the motor is 360 V, when operating at maximum power, an electrician measures the voltage across the motor to be only 180 V.   
  
(i) Explain this observation. (2 marks)

|  |  |
| --- | --- |
| Description | Marks |
| Once the motor is running, the spinning coil is cutting flux and it operates as a generator, inducing an emf. | 1 |
| Due to Lenz’s Law, the direction of this induced emf opposes the applied emf and the net voltage is reduced. | 1 |
| Total | 2 |

(ii) Calculate the internal resistance of the DC motor. State an appropriate unit. (3 marks)

|  |  |
| --- | --- |
| Description | Marks |
| R = V/I = 180/10.5 = 17.1 | 1-2 |
| Ohms (Ω) | 1 |
| Total | 3 |

**Question 2 (5 marks)**

(a) Explain briefly how the transformer creates an alternating current in the secondary coil.

|  |  |
| --- | --- |
| Description | Marks |
| An alternating current is applied to the primary coil. This produces an alternating flux in the primary coil.  The secondary coil experiences this change in flux and therefore an alternating current is induced in the secondary coil due to Faraday’s Law. | 1  1-2 |
| Total | 3 |

(3 marks)  
(b) Using information from the diagram, calculate the potential difference that the charger provides to the laptop. (2 marks)

|  |  |
| --- | --- |
| Description | Marks |
| 65/600 = VS/240 | 1 |
| Vs= 26.0 V | 1 |
| Total | 2 |

**Question 3 (5 marks)**(a) Would a positively charged electroscope have been discharged in the same way? Explain.  
 (2 marks)

|  |  |
| --- | --- |
| Description | Marks |
| No | 1 |
| Only electrons (negative) are emitted in the photoelectric process. | 1 |
| Total | 2 |

(b) Calculate the velocity of emitted electrons, if the uv light has a frequency of 1.2 x 1015 Hz. The work function of zinc is 4.3 eV. (3 marks)

|  |  |
| --- | --- |
| Description | Marks |
| KE = hf – W  = (6.63 x 10-34)( 1.2 x 1015) – (4.3)(1.6 x 10-19)  = 1.08 x 10-19 J | 1-2 |
| ½ (9.11 x 10-31) v2 = 1.08 x 10-19 J  V = 4.86 x 105 m s-1 | 1 |
| Total | 3 |

**Question 4 (5 marks)**

(a) Explain the origin of the different colours observed in the mercury spectrum. (2 marks)

|  |  |
| --- | --- |
| Description | Marks |
| Each coloured line corresponds to a specific frequency of light and associated photon that is released when an excited electron makes a downward transition from one energy level to another. | 1-2 |
| Total | 2 |

(i) Show that the photons producing this green line have an energy of 2.28 eV.   
 (2 marks)

|  |  |
| --- | --- |
| Description | Marks |
| E = hc/λ  = (6.63 x 10-34)(3 x 108)/546.1 x 10-9  = 3.64 x 10-19 J  = 2.28 eV | 1-2 |
| Total | 2 |

(ii) Show the electron transition that produced this green line on the energy level diagram. (1 marks)

|  |  |
| --- | --- |
| Description | Marks |
| Arrow drawn from level g to d (-2.48 to -4.76) | 1 |
| Total | 1 |

**Question 5 (5 marks)**

(a) Show that the electrostatic force experienced by the charged sphere is given by:

F = mg tan 5o, where m is the mass of the sphere. (2 marks)

|  |  |
| --- | --- |
| Description | Marks |
| For the string: TH/TV = tan 5o, so TH= TV tan 5o  For vertical equilibrium, TV = mg, for horizontal equilibrium, electrostatic force = TH  Therefore, electrostatic force = mg tan 5o | 1-2 |
| Total | 2 |

(b) Calculate the charge on the sphere. (3 marks)

|  |  |
| --- | --- |
| Description | Marks |
| F = Eq = (V/d)q = mg tan 5o  (4150/0.05)q = (2.21 × 10–4)(9.8) x tan5o  q = 2.28 x 10-9  C | 1  1  1 |
| Total | 3 |

**Question 6 (4 marks)**

(a) Explain what is meant by cosmological microwave background radiation and how its existence supports the Big Bang theory. (2 marks)

|  |  |
| --- | --- |
| Description | Marks |
| Cosmological microwave background (CMB) is remnant radiation from the Big Bang.  CMB has been detected uniformly throughout space and therefore this observation supports our current understanding of the Big Bang Theory. | 1-2 |
| Total | 2 |
| Student answers may include since expansion, the radiation from the Big Bang has stretched to the MW region of the EM spectrum and/or the spectrum of CMB matches the spectrum of a black body at 2.7 K. |  |

(b) Explain how the relative abundance of hydrogen and helium supports the Big Bang theory.

(2 marks)

|  |  |
| --- | --- |
| Description | Marks |
| According to the Big Bang Theory, there was an abundance of light elements such as hydrogen and helium in the early universe.  Spectroscopic analysis of distant stars and galaxies show that most (99%) of all matter in the universe is hydrogen and helium. These observations therefore support the Big Bang Theory. | 1  1 |
| Total | 2 |

**Question 7 (6 marks)**

(a) Explain how the pattern produced on the screen supports the idea that the electron beam is behaving as a wave rather than as a stream of particles. (2 marks)

|  |  |
| --- | --- |
| Description | Marks |
| Interference patterns are evident on the fluorescent screen. Interference is a property of waves, therefore the electrons are behaving as waves.  If the electrons were behaving as a series of particles, we would expect the electrons to clump rather than interfere with each other after passing through the graphite. | 1  1 |
| Total | 2 |

(b) (i) Calculate the potential difference required to accelerate the electrons to this speed.

(2 marks)

|  |  |
| --- | --- |
| Description | Marks |
| KE = ½ mv2 = ½ (9.11 x 10-31)( 2.2 x 107)2 = 2.20 x 10-16 J = Vq  V x 1.6 x 10-19 = 2.20 x 10-16  V = 1,380 V | 1  1 |
| Total | 2 |

(ii) Calculate the de Broglie wavelength of the electrons as they strike the graphite.

(2 marks)

|  |  |
| --- | --- |
| Description | Marks |
| λ = h/p = 6.63 x 10-34/(9.11 x 10-31)( 2.2 x 107)  = 3.31 x 10-11 m | 1  1 |
| Total | 2 |

**Question 8 (5 marks)**

(a) Calculate the time taken, in the frame of reference of the observer, for a π meson to travel between the two detectors. (2 marks)

|  |  |
| --- | --- |
| Description | Marks |
| t = s/v  = 34 / 0.95 x 3 x 108  = 1.19 x 10-7 s | 1  1 |
| Total | 2 |

(b) π mesons are unstable and decay with a half-life of 18 ns. It is found in experiments that approximately 75% of the π mesons that pass the first detector decay before reaching the second detector. Show by calculation how this provides evidence to support the theory of special relativity. (3 marks)

|  |  |
| --- | --- |
| Description | Marks |
| Expected percentage:  n = 1.19 x 10-7/18 x 10-9 = 6.63 (ie: 6.63 ½ lives have elapsed)  A = 100(½ )6.63  = 1.01%  ie: we would expect about 99% to have decayed, the fact that only 75% have decayed suggests that time is running slower for the mesons as predicted by special relativity. | 1  1  1 |
| Total | 3 |

**Question 9 (4 marks)**

Calculate the time difference between the Earth receiving Zocark’s warning and the rocket colliding with the Earth.

|  |  |
| --- | --- |
| Description | Marks |
| For radio signal:  T = s/v = 1.0/1.0 = 1 year  For rocket:    u = (0.5 –(0.8))/(1+ ((0.5)(-0.8)/12)) = -0.5 c  t = s/v = 1/0.5 = 2 years  Therefore, time difference = 2 - 1 = 1 year | 1  1  1  1 |
| Total | 4 |

**Question 10 (5 marks)**

(a) If Commander Scott threw the hammer horizontally at the same time that he released the feather, would they both hit the ground at the same time? Explain. (2 marks)

|  |  |
| --- | --- |
| Description | Marks |
| Yes  Both objects travel the same vertical distance with the same vertical acceleration with zero initial vertical velocity. Therefore time is the same. | 1  1 |
| Total | 2 |

(b) By making an appropriate assumption, estimate the horizontal distance covered by the hammer if it was thrown horizontally at 5.0 m s-1. (3 marks)

|  |  |
| --- | --- |
| Description | Marks |
| Assume dropped from a height of 1.5 m (any reasonable value)  S = ut + ½ a t2  t2 = 1.5 x 2 / 1.62  t = 1.36 s  sh = 5.0 x 1.36  = 6.8 m (2 sf as *estimate*) | 1  1  1 |
| Total | 3 |

**Question 11 (5 marks)**

(a) Calculate the average emf induced in the coil during this strike. ( 4 marks)

|  |  |
| --- | --- |
| Description | Marks |
| = 4π x 10-7/2π x 325 x 103/225  = 2.89 x 10-4 T | 0-2 |
| Induced emf = nBA/t  = 55 x 2.89 x 10-4 x π x 0.82 /50 x 10-6  = 639 V | 0-2 |
| Total | 4 |

(b) On the diagram indicate the direction of the induced emf in the coil. (1 mark)

|  |  |
| --- | --- |
| Description | Marks |
| ACW arrow drawn | 1 |
| Neg discharge to Earth, so positive current up. So ΔΦ into page, induced emf has ΔΦ out of page, therefore ACW emf. |  |
| Total | 1 |

**End of Section One**

**SECTION TWO: Problem-solving** **50% (90 marks)**

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| --- |
|  |

**Question 12 (12 marks)**

(a) In the presence of a suitably directed uniform magnetic field, charged particles move at constant speed in a circular path of constant radius. By reference to the force acting on the particles, explain how this is achieved and why it happens. (4 marks)

|  |  |
| --- | --- |
| Description | Marks |
| The fast moving particles travel at right angles to a uniform magnetic field.  This produces a force at right angles to the path of the particles and does not affect the speed of the particles.  This force is unopposed and produces a net force that causes the particles to travel in a circular path. | 0-4 |
|  | 0-2 |
| Total | 4 |

(b) (i) In one particular experiment, the charged particles travelling around the LHC were protons. Calculate the centripetal force acting on a proton when travelling in a circular path of circumference 27.0 km at one-tenth of the speed of light. Ignore relativistic effects. (3 marks)

|  |  |
| --- | --- |
| Description | Marks |
| circ = 2πr  r = 27.0 x 103/2π  = 4.30 x 103 m  F = mv2/r  = 1.67 x 10-27 x (3 x 107)2 / 4.30 x 103  = 3.50 x 10-16 N | 1  0-2 |
| Total | 3 |

(ii) Calculate the flux density of the uniform magnetic field that would be required to produce this force. State an appropriate unit. (3 marks)

|  |  |
| --- | --- |
| Description | Marks |
| Bvq = 3.50 x 10-16 N  B = 3.50 x 10-16 / (3 x 107 x 1.6 x 10-19)  = 7.00 x 10-5 | 0-2 |
| Unit = T (Tesla) | 1 |
| Total | 3 |

(c) The Large Hadron Collider is an example of a high energy particle accelerator. Explain the importance of high energy particle accelerators to Physicists. (2 marks)

|  |  |
| --- | --- |
| Description | Marks |
| From syllabus:   * high-energy particle accelerators are used to test theories of particle physics, including the Standard Model   Accept any reasonable answer such as experiments using particle accelerators allow Physicists to produce particles that do not occur in nature that provide a better understanding of the building blocks of matter. | 0-2 |
| Total | 2 |

**Question 13 (14 marks)**

(a) In the space below, draw a free body diagram of the beam, clearly labelling all forces acting on it. (4 marks)

|  |  |
| --- | --- |
| Description | Marks |
| FA  FB  4.23 x 104 N  3.18 x 104 N | 0-4 |
| Total | 4 |

(b) Calculate the reaction force provided by each column on the beam. (4 marks)

|  |  |
| --- | --- |
| Description | Marks |
| Take torques about A:  Στcw = Στacw  (3.18 x 104 x 4.50) + (4.23 x 104 x 10.5) = FB x 21  **FB = 2.80 x 104 N**  ΣFy = 0  FA+ 2.80 x 104 = 3.18 x 104 + 4.23 x 104  **FA = 4.61 x 104 N** | 0-2  0-2 |
| Total | 4 |

(c) Calculate the tension in the steel cable. (3 marks)

|  |  |
| --- | --- |
| Description | Marks |
| Take torques about base of column B:  Στcw = Στacw  T x 10.0 x sin 40o = (3.18 x 104 x 16.5) + (4.23 x 104 x 10.5) + (250 x 9.8 x 5.5)  T =1.52 x 105 N | 0-2  1 |
| Total | 3 |

(d) Calculate the force of compression in strut CD. (3 marks)

|  |  |
| --- | --- |
| Description | Marks |
| Take torques about top of column B:  Στcw = Στacw  FCD x sin 60o x 16.5 = (3.18 x 104 x 16.5) + (4.23 x 104 x 10.5)  FCD = 6.78 x 104 N | 0-2  1 |
| Total | 3 |

**Question 14 (17 marks)**

(a) Is the position shown, one of minimum or maximum torque? Explain. (2 marks)

|  |  |
| --- | --- |
| Description | Marks |
| Maximum | 1 |
| AB and CD are at a maximum perpendicular distance from the axis of rotation, therefore their forces will provide maximum torque. | 1 |
| Total | 2 |

(b) For the coil in the position shown calculate the magnitude of the force on

(i) side AB of the coil (2 marks)

|  |  |
| --- | --- |
| Description | Marks |
| τ = r x F  Ftotal = 2.1 x 10-3/0.014  = 0.15 N  Therefore 0.075 N on each side. | 0-2 |
| Total | 2 |

(ii) side BC of the coil (2 marks)

|  |  |
| --- | --- |
| Description | Marks |
| 0 N  (current is parallel to field therefore no force) | 2 |
| Total | 2 |

Answer \_\_\_\_\_\_\_\_\_\_ N

(c) Calculate the strength of the magnetic field experienced by the sides of the coil. (4 marks)

|  |  |
| --- | --- |
| Description | Marks |
| For AB:  F = nBIL  B = 0.075/(140 x 0.170 x 0.045)  = 0.0700 T | 1  0-2  1 |
| Total | 4 |

(d) The above diagram does not show how the coil is connected to a potential difference. Of the two mechanisms shown below, which mechanism should be used for the coil to rotate as a DC motor. Name the mechanism and explain your choice. (3 marks)

|  |  |
| --- | --- |
| Description | Marks |
| Mechanism 2 | 1 |
| Mechanism 2 illustrates a *split ring*  *commutator* | 1 |
| This device reverses the direction of current every ½ turn, ensuring that the motor spins in a constant direction. | 1 |
| Total | 3 |

(e) Once the coil has started rotating as a DC motor, does the maximum torque increase, decrease or remain the same. Explain. (4 marks)

|  |  |
| --- | --- |
| Description | Marks |
| Decrease. | 1 |
| As the motor spins, the rotating coil cuts flux producing its own emf that opposes the applied emf. i.e. a *back emf*. This reduces the net emf applied to the motor. | 1 |
| Therefore there is less current drawn by the motor. | 1 |
| Max torque is directly proportional to the current, therefore the max torque is reduced. | 1 |
| Total | 4 |

**Question 15 (16 marks)**

(a) By considering conservation of energy, calculate the velocity of the bob at its lowest point. (3 marks)

|  |  |
| --- | --- |
| Description | Marks |
| PElost = KEgained  1.80 x 9.80 x 0.0780 = ½ x 1.80 x v2  v = 1.24 m s-1 | 1-2  1 |
| Total | 3 |

(b) Calculate the tension in the cord at the lowest point of its path. (3 marks)

|  |  |
| --- | --- |
| Description | Marks |
| T – mg = mv2/r  T = 1.8 x 1.242/1.55 + 1.8 x 9.8  = 19.4 N | 1  1  1 |
| Total | 3 |

(c) On the above diagram, indicate all forces acting on the bob as clearly labelled arrows **and** indicate the direction of the net force on the bob as a dashed arrow ( ). (3 marks)

|  |  |
| --- | --- |
| Description | Marks |
| Tension  Weight  Net force | 1  1  1 |
| Total | 3 |

(d) Show that the tension in the cord is now 18.0 N. (4 marks)

|  |  |
| --- | --- |
| Description | Marks |
| θ = sin-1(0.29/1.55)  = 10.8o  ΣFy = 0  T cos 10.8o = 1.80 x 9.8  T = 18.0 N | 1  0-2  1 |
| Total | 4 |

(e) Calculate the magnitude of the velocity of the bob at the position shown. (3 marks)

|  |  |
| --- | --- |
| Description | Marks |
| Tcosθ = Fc = mv2/r  18.0 x cos 10.8o = 1.90 x v2 /0.29  v = 1.64 m s-1 | 1  1  1 |
| or other method, eg: tanθ = v2/rg |  |
| Total | 3 |

**Question 16 (16 marks)**

(a) In the picture, there is an error with the indicated orbit a GEO satellite. Indicate this error and explain why the orbit shown must be an error. (3 marks)

|  |  |
| --- | --- |
| Description | Marks |
| A geostationary satellite must not only have an orbital period of 24 hours, but the orbit must be above the Earth’s equator.  This way, as the earth rotates, the relative position of the satellite and the earth remains unchanged, allowing satellite dishes to continually receive a signal from the satellite. | 1  0-2 |
| Total | 3 |

(b) Which of these satellites experiences the greatest gravitational force from the Earth? Circle the correct answer from the choices below. Explain your answer in the space provided.

(3 marks)

|  |  |
| --- | --- |
| Description | Marks |
| LEO | 1 |
| LEO satellites have the lowest orbit.  Gravitational force is inversely proportional to distance.  LEO satellites have the smallest orbital radius, therefor the greatest gravitational attraction. | 1  1 |
| Total | 3 |

(c) Which of these satellites is travelling at the greatest speed relative to the Earth? Circle the correct answer from the choices below. Explain your answer in the space provided.

(3 marks)

|  |  |
| --- | --- |
| Description | Marks |
| LEO | 1 |
| LEO satellites have the lowest orbit.  Gravitational force is inversely proportional to distance.  By Kepler’s third law, low orbit means lower period, therefore higher speed. | 1  1 |
| Or other accurate mathematical argument. |  |
| Total | 3 |

(d) Kepler’s Third Law is given on your data sheet. By using relevant equations, in the space below, derive Kepler’s Third Law. (3 marks)

|  |  |
| --- | --- |
| Description | Marks |
| GMm/r2 = mv2/r  GM/r = v2  GM/r = (2πr/T)2  GM/r = 4π2r3/T2  GMT2 = 4π2r3T2  T2 = 4π2/GM x r3 | 1  1  1 |
| Total | 3 |

(e) Using the information in the picture, calculate the minimum period of a LEO satellite. Provide your answer in minutes and seconds. (4 marks)

|  |  |
| --- | --- |
| Description | Marks |
| Minimum period = lowest altitude = 500 km  Orbital radius = 6.87 x 106 + 500 x 103  = 6.87 x 106  T2 = 4π2/GM x r3  = 4π2/(6.67 x 10-11 x 5.97 x 1024) x (6.87 x 106)3  T = 5,670 s  = 1 hr 34 min 30 sec | 1  0-2  1 |
| Total | 4 |

**Question 17 (15 marks)**

(a) Show how baryon number, lepton number and charge are conserved in this interaction. (3 marks)

|  |  |
| --- | --- |
| Description | Marks |
| |  |  |  |  |  | | --- | --- | --- | --- | --- | |  | Ko | p | n | π+ | | Baryon number | 0 | 1 | 1 | 0 | | Lepton number | 0 | 0 | 0 | 0 | | Charge | 0 | +1 | 0 | +1 | | 1  1  1 |
| Total | 3 |

(b) Given that the neutral kaon has a strangeness of +1. Give the quark structure of the following particles. (4 marks)

|  |  |
| --- | --- |
| Description | Marks |
| Ko D p UUD  n UDD  π+  Note: strangeness not necessarily conserved in weak interactions. | 1 1 1 1 |
| Total | 4 |

(c) Name the interaction and gauge boson involved in this interaction? (2 marks)

|  |  |
| --- | --- |
| Description | Marks |
| Weak interaction  W+ boson | 1  1 |
| Total | 2 |

(d) (i) What is the charge of X? Explain your answer. (2 marks)

|  |  |
| --- | --- |
| Description | Marks |
| neutral  RHS has neutral charge, so X must be neutral for charge to be conserved. | 1  1 |
| Total | 2 |

(ii) Deduce whether X is a baryon, meson or lepton. Explain your choice. (2 marks)

|  |  |
| --- | --- |
| Description | Marks |
| X is a baryon  p is proton which is a baryon, so X must be a baryon to conserve baryon number. | 1  1 |
| Total | 2 |

(iii) Which of the three particles involved in this interaction is the most stable? Explain.

(2 marks)

|  |  |
| --- | --- |
| Description | Marks |
| proton is most stable  Protons are abundant in nature. Along with neutrons make up most of the known universe. | 1  1 |
| Total | 2 |

**Question 18 (18 marks)**  
(a) Explain the relationship between the concept of *escape velocity* and the concept of a *black hole*. (2 marks)

|  |  |
| --- | --- |
| Description | Marks |
| Escape velocity is the minumum velocity that an object must have to be able to escape the gravitational attraction of an object. The more dense an object, the larger its escape velocity.  Some objects – black holes, are so massive and dense that the speed of light is less than the escape velocity within a certain radius so not even light can escape. | 1  1 |
| Total | 2 |

(b) The article states that:   
  
*“When the rocket escapes the pull of the earth it has effectively travelled to infinity, that is, r = ∞, and its velocity at that time is reduced to zero, that is, v = 0.”*  
  
(i) Use Newton’s Law of Universal Gravitation to support the argument that at r = ∞, the rocket has escaped the pull of the Earth. (2 marks)

|  |  |
| --- | --- |
| Description | Marks |
| From Newton’s Law of Universal Gravitation:  As r approaches , F approaches zero. Therefore zero gravitational attraction when r = ∞. | 1  1 |
| or use g = GM/r2 … |  |
| Total | 2 |

(ii) If an object left the Earth with the minimum *escape velocity*, why would this value be zero, when r is equal to infinity? (2 marks)

|  |  |
| --- | --- |
| Description | Marks |
| When leaving Earth at the *escape velocity*, the kinetic energy is equal in magnitude (bot opposite to) the absolute Potential Energy.  It follows that as the PE becomes less negative (as *r → ∞*), KE must reduce as well. As PE approaches zero, so too does KE. Therefore v approaches zero too. | 1  1 |
| Total | 2 |

(c) (i) Show that the escape velocity for an object to leave the Earth’s gravitational pull is equal to 1.12 x 104 m s-1. (2 marks)

|  |  |
| --- | --- |
| Description | Marks |
| = √(2 x 6.67 x 10-11 x 5.97 x 1024 / 6.37 x 106)  = 1.12 x 104 m s-1 | 0-2 |
| Total | 2 |

(ii) Show that the total energy of 12.0 tonne space craft launched at its escape velocity from the surface of the Earth is zero. (3 marks)

|  |  |
| --- | --- |
| Description | Marks |
| A picture containing object  Description automatically generated  = ½ x 12000 x (1.12 x 104)2 – 6.67 x 10-11 x 5.97 x 1024 x 12000 x (1/6.37 x 106)  = 7.51 x 1011 - 7.51 x 1011  = 0 J | 0-2 |
| Accept logical algebraic argument based on ve being the velocity when ⏐KE⏐ = ⏐PE⏐ at Earth’s surface. |  |
| Total | 2 |

(iii) At what speed would this space craft be travelling in deep space at a distance of 325 million kilometres from the Earth? (3 marks)

|  |  |
| --- | --- |
| Description | Marks |
| PE = - GMEm/r  = -6.67 x 10-11 x 5.97 x 1024 x 12000/(6.37 x 106 + 325 x 109)  = -1.47 x 107 J  KE = 1.47 x 107 J  1.47 x 107 = ½ x 12000 x v2  v = 49.5 m s-1 | 0-2 |
| Total | 2 |

(d) One of the largest stars in our galaxy is Betelgeuse. This star has a radius 887 times that of our Sun and a mass 11.6 times that of our Sun. Explain what is meant by the *Schwarzschild radius* for this star and calculate is value. (4 marks)

|  |  |
| --- | --- |
| Description | Marks |
| The Schwarzschild Radius is the minimum distance that an object can be from a black hole to be beyond the event horizon.  Rs = 2GM/c2  = 2 x 6.67 x 10-11 x 11.6 x 1.99 x 1030/(3 x 108)2  = 3.42 x 104 m | 0-2  0-2 |
| Total | 4 |

**Question 19 (18 marks)**

(a) Briefly outline Paul Dirac’s contribution to our understanding of antimatter. (2 marks)

|  |  |
| --- | --- |
| Description | Marks |
| Combined Quantum Physics and Special Relativity to produce an equation that suggested the existence of antimatter.  He predicted that for every kind of regular matter there should be a corresponding antiparticle. | 0-2 |
| Total | 2 |

(b) Carl Anderson studied the tracks of electrons and positrons as they moved in a magnetic field as shown in the picture. State one similarity and one difference in the paths that he would have observed. (2 marks)

|  |  |
| --- | --- |
| Description | Marks |
| Similarity: Same radius of curved path  Difference: Paths are in opposite directions (CW and ACW) | 1  1 |
| Total | 2 |

(c) Explain why the particles *spiral inward* as can be seen in the picture. (2 marks)

|  |  |
| --- | --- |
| Description | Marks |
| As the particles interact with matter, they slow down. The radius of curvature is proportional to velocity so therefore they spiral inwards. | 0-2 |
| Total | 2 |

(d) Carl Anderson used cosmic rays created in our atmosphere as his main source of electrons and positrons. Why would he not have observed protons and antiprotons?  
 (2 marks)

|  |  |
| --- | --- |
| Description | Marks |
| Protons and antiprotons are much larger than electrons and positrons.  They are absorbed in the atmosphere and therefore would not be observed at the Earth’s surface. | 0-2 |
| Total | 2 |

(e) Calculate the amount of gamma energy released when a positron and an electron annihilate each other. Give your answer in eV. (3 marks)

|  |  |
| --- | --- |
| Description | Marks |
| E = mc2  = (2 x 9.11 x 10-31) x (3 x 108)2  = 1.64 x 10-13 J  = 1.64 x 10-13 / 1.6 x 10-19 = eV  = 1.02 x 106 eV | 1-2  1 |
| Total | 3 |

(f) The article states that:   
  
 “For a proton and antiproton, annihilation produces four particles called pions. So the signature of antihydrogen annihilation is four pions and a pair of gamma rays, all coming from the same place, and with the right directions and energies”.

Explain why:

(i) They must come from the same place. (1 mark)

|  |  |
| --- | --- |
| Description | Marks |
| Both of the gamma rays will come from the point of impact of the two particles. | 1 |
| Total | 1 |

(ii) They must have the right directions. (1 mark)

|  |  |
| --- | --- |
| Description | Marks |
| They must be in opposite directions to conserve momentum. | 1 |
| Total | 1 |

(iii) They must have the right energies. (1 mark)

|  |  |
| --- | --- |
| Description | Marks |
| The energies of the gamma rays can be accurately predicted by calculation. | 1 |
| Total | 1 |

(g) The emission spectrum of normal hydrogen is well understood. How do Scientists expect the emission spectrum of antihydrogen to compare with the that of Hydrogen? (1 mark)

|  |  |
| --- | --- |
| Description | Marks |
| Thy expect it to be identical to the emission spectrum of normal hydrogen. | 1 |
| Total | 1 |

(h) Explain why the atomic spectrum of antihydrogen is yet to be studied. (1 mark)

|  |  |
| --- | --- |
| Description | Marks |
| So far, the number of antihydrogen particles isolated has been insufficient to conduct spectroscopy experiments. | 1 |
| Total | 1 |

(i) Briefly explain how the study of antihydrogen could help cosmologists understand the beginning of the universe. (2 marks)

|  |  |
| --- | --- |
| Description | Marks |
| Big Bang should have produced matter and antimatter in equal amounts.  Observed universe only consists of matter.  Question of the missing antimatter could be explained by discovering differences between hydrogen and antihydrogen. | 0-2 |
| Total | 2 |

End of Questions