Physics 12 exam Semester 2 2019 SOLUTIONS

|  |  |
| --- | --- |
| Section One: Short response | 30% (54 Marks) |

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**Question 1 (4 marks)**

Give one example where each of the following light-based phenomena can be observed:

1. Dispersion (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| States suitable example  E.g: Rainbow, white light through triangular prism, etc. | 1 |
| **Total** | **1** |

1. Reflection (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| States suitable example  E.g: Mirror, shiny surface, etc. | 1 |
| **Total** | **1** |

1. Refraction (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| States suitable example  E.g: Light through glass, water, etc. | 1 |
| **Total** | **1** |

1. Polarisation (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| States suitable example  E.g: Sunlight reflection from water surface, polarioid film/sunglasses, etc.  SUNGLASSES accepted, but in WACE POLAROID SUNGLASSES would probably be needed for the mark | 1 |
| **Total** | **1** |

**Question 2 (6 marks)**

A photoemissive metal plate is used as the target sample in a photoelectric effect experiment.

When 320 nm light is used, a 0.685 V stopping voltage is required. When 250 nm light is used,

the stopping voltage is 1.77 V.

1. Explain why decreasing the wavelength of the light increases the stopping voltage.

(3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Relates a decrease in wavelength to an increase in light energy  “The energy of a photon of light in inversely proportional to the wavelength E E = Vq and relate V inversely proportional to λ 3 marks | 1 |
| Relates the increase in light energy to more energetic electrons  “Higher energy photons can eject photoelectrons with more energy.” | 1 |
| Relates faster electrons needing a larger stopping voltage/electric field to stop the electrons  “To bring these faster electrons to a stop requires a larger stopping voltage.” | 1 |
| **Total** | **3** |

1. Calculate the work function of the photoemissive metal plate. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
|  | 1 |
|  | 1-2 |
| **Total** | **3** |
| **Note:** May also use the other pair of wavelength/stopping voltage values to obtain same answer. | |

**Question 3 (4 marks)**

Muon’s produced in a CERN experiment are travelling at 0.920 relative to the particle accelerator. They cover a 728 km distance as measured from the reference frame of the particle accelerator before hitting their intended target. Calculate the time the muon’s spend on their journey to the intended target from the reference frame of the muon.

|  |  |
| --- | --- |
| **Description** | **Marks** |
|  | 1-2 |
|  | 1-2 |
| **Total** | **4** |

**Question 4 (4 marks)**

In 2019, a dark matter detector that had been running for two years has not detected any dark matter but has detected 126 incredibly rare cases of xenon decay. In xenon decay, a pair of electrons are captured simultaneously by two protons and emit two neutrinos.

Confirm whether this reaction is possible by checking conservation of baryon number and lepton number.

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Baryon number  Must show all numbers  1 + 1 to 1 + 1 etc 3 marks total  Possible | 1-2 |
| Lepton number      Possible | 1-2 |
| **Total** | **4** |

**Question 5 (5 marks)**

The graph below reveals the relationship between distance of galaxies from Earth and each

galaxy’s recessional velocity from Earth.

Recessional Velocity

Distance

0

1. Explain what causes the relationship revealed in the graph. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| States the core reason  “Space is expanding.” | 1 |
| Describes how expansion of space can explain relationship  “As space expands, it increases the distance between the galaxies. The further away a galaxy is, the greater the rate of expansion of space between the Earth and the galaxy, giving the galaxy a larger recessional velocity.” | 1-2 |
| **Total** | **3** |

1. Explain why the cluster of galaxies closest to Earth have a negative recessional velocity despite your answer to part (a). (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Compares a small expansion of space to velocity through space  “These galaxies are close enough that the expansion of space between them and Earth is small and, they can still have a velocity through space towards the Earth”  or: Observed velocity greater than recessional; velocity  “Moving towards Earth” 1 mark only | 1-2 |
| **Total** | **2** |

**Question 6 (5 marks)**

Stars are approximate black bodies. Their colour can be used as reliable method of determining

the temperature of a star – a red star is cooler than a blue star. The spectrum of a red star is

shown below.

1. On the same axes, draw the spectrum observed for a blue star. You may assume the

stars are identical apart from their temperature. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Curve is of a black body, with a peak shifted to the left compared to red star | 1 |
| Blue curve is always above red curve | 1 |
| **Total** | **2** |

1. Explain how colour is an indication of the temperature of these stars. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Relates temperature to energy and peak frequency/wavelength  “Hotter black bodies have on average more energetic photons emitted, produce peak intensity at lower wavelengths/higher frequencies” | 1-2 |
| Relates peak frequency/wavelength to colour  “Blue light has a higher frequency than red light, thus the blue star is hotter.” | 1 |
| **Total** | **3** |

Hotter = more energy = higher frequency = blue 3 marks

**Question 7 (6 marks)**

An electron annihilates with its antiparticle, the positron to produce two gamma rays. In the rest frame of the annihilation, the two gamma rays have equal energy.

1. Calculate the rest energy of an electron. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
|  | 1-2 |
| **Total** | **2** |

1. If the electron and positron **each** had 2.05 × 10-13 J of kinetic energy prior to the annihilation, calculate the frequency of the pair of gamma rays in the frame of the annihilation.

(4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Energy prior to collision | 1-2 |
| Energy shared between equally between photons, find frequency | 1-2 |
| **Total** | **4** |

Better:

For 1 electron:

Total E = 2.05 x 10-13 + 8.2 x 10 -14 = 2.87 x 10 -13 J (-1 mark if missing 8.2 x 10 -14 )

Frequency = E/h = 2.87 x 10 -13 / 6.63 x 10-34 = 4.33 x1020 Hz

**Question 8 (5 marks)**

A volley ball is served by hitting it at 12.8 m s-1 at 25.00 above the horizontal. The server made contact with the volleyball when it was 2.35 m above the ground. Find the horizontal range of

the volleyball serve. Air resistance can be ignored.

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Find time in air\*\*        Solving the quadratic,    \*\*May also use approaches such as or using followed by to determine time in air | 1-3 |
| Find horizontal range | 1-2 |
| **Total** | **5** |

**Alternatively:**

**v2 = u2 + 2as**

**= 12.8sin 25 + 2(-9.8)(-2.35)**

**v = -8.68ms-1**

**v = u + at**

**-8.68 = 12.8cos25 – 9.8t**

**t = 1.438s**

**Question 9 (4 marks)**

A boy pulls his 12.0 kg red cart up an incline of 15.00. While the cart moves up the incline, the friction between the wheels and the ground is 150 N and the boy pulls at 205 N along the incline. Calculate the acceleration of the cart.

15.00

mg sin15

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Weight parallel to incline    MANY MISSED THIS! | 1 |
| Adds forces    -1 if missing | 1-2 |
| Calculates acceleration | 1 |
| **Total** | **4** |

**Question 10 (5 marks)**

Electric cars utilise regenerative braking. By referring to both Faraday’s law and Lenz’s law,

explain the physical principles that help to recharge the battery and assist with slowing the

car down.

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Correctly refers to Faraday’s law inducing an emf in the coil due to rotation in a field  “While braking, the rotating coil experiences a change in flux which induces an emf, causing the motor to also behave like a generator (Faraday’s law)” | 1-2 |
| States the induced emf recharges the battery  “The emf drives a current and recharges the battery” | 1 |
| Correctly refers to Lenz’s law applying a force against motion, assisting with braking  “Lenz’s law describes that the direction of the induced current will be such that it creates a resistive force against the motion of the coil, helping to slow the car down” | 1-2 |
| **Total** | **5** |

NOT BACK EMF OR EDDY CURRENTS!

**Question 11 (6 marks)**

A single charged sodium ion (Na+) is moving at 1250 m s-1 within a 0.866 T magnetic field as shown below. The sodium ion has a 3.82×10-26 kg mass.

X X X X X X

X X X X X X

X X X X X X

X X X X X X

V

1. In the diagram above, draw the path the sodium ion follows. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Draws a circle (accept partial curve, taking ion outside field shown) | 1 |
| Circular path is counter clockwise (taking ion above its position shown in diagram) | 1 |
| **Total** | **2** |

1. Calculate the wavelength of the sodium ion. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
|  | 1-2 |
| **Total** | **2** |

1. Calculate the radius of the ion’s movement. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
|  | 1-2 |
| **Total** | **2** |

**End of Section One**

|  |  |
| --- | --- |
| **Section Two: Problem-solving** | **(90 Marks)** |

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**Question 12 (12 marks)**

Rovers have been sent to Mars to obtain samples from the planet’s surface. One such rover is approaching the surface of Mars at 25.0 m s-1 at an altitude of 300 m. The internal components of the rover require that the rover contacts the surface at no greater than 0.850 m s-1 to remain intact. To achieve this, a parachute is opened at this altitude to reduce the speed of the 1050 kg rover.

These details may be used to help answer the following questions:

* Mass of Mars: 6.42 × 1023 kg
* Radius of Mars: 3.38 × 106 m

1. Find the gravitational field strength at the surface of Mars. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
|  | 1 |
|  | 1-2 |
| **Total** | **3** |

1. Show by calculation that the work done by the parachute to ensure the rover makes contact with the surface at a safe speed is approximately 1.50 MJ. You may assume the gravitational field strength is constant between the ground and the 300 m altitude. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
|  | 1 |
|  | 1 |
| - 1mark if missing | 1-2 |
| **Total** | **4** |

1. Hence calculate the average air resistance acting against the parachute from the 300 m altitude until the rover makes contact with the ground. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
|  | 1 |
|  | 1 |
| **Total** | **2** |

1. Was the assumption made in part (b) reasonable? Justify your response. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Yes “No” = zero marks regardless of reasoning | 1 |
| States gravitational field strength won’t change very much  “The gravitational field strength only changes minimally between the surface and an altitude of 300 m” | 1 |
| Justifies by comparing distances (with or without exact numbers)  “This is because the altitude is insignificant compared to the radius/distance from the centre of mass of Mars.” | 1 |
| **Total** | **3** |

**Question 13 (11 marks)**

Beta decay is the ejection of an electron from the nucleus of a radioisotope. The beta particle (electron) speed can vary, but for this question, assume they are ejected at 0.990c.

1. Calculate the energy of the beta particle. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
|  | 1 |
|  | 1-2 |
| **Total** | **3** |

1. Two beta particles are ejected towards each other from two nuclei that are at rest relative to each other.

Calculate the speed of one beta particle as measured from the reference frame of the other. Give your answer to **6 significant figures and in terms of c**. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| (quoting either addition formula is fine, but will influence which values should be used in next step) | 1 |
| \*  (positive or negative answer is fine as depends on which particle students solve for).    \*Students who do not apply correct sign to values may end up with “zero velocity” due to numerator equating to 0. | 1-2 |
| **Total** | **3** |

1. Calculate the magnitude of the momentum of a beta particle as measured from the reference frame of the nucleus. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
|  | 1 |
|  | 1-2 |
| **Total** | **3** |

**-1 if me is wrong**

1. Calculate the quantity of mass lost by the nucleus due to the beta decay event.

(2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Uses energy of beta, from part a, converting to an equivalent mass value | 1-2 |
| **Total** | **2** |

**Can also use m =**

**Question 14 (13 marks)**

To help students’ visualise the workings of a generator, a demonstration generator is built using the design shown in the diagram below.

Generator

Transformer

N

S

Circular coil

Slip ring

Generator coil number: 18

Generator coil radius: 0.0700 m

Magnetic flux density: 3.00 mT

The demonstration generator is not capable of a high voltage output. To increase the output voltage, the demonstration generator was connected to a transformer. The primary to secondary windings ratio was 1:53, resulting in an rms output voltage of the transformer of 2.36 V.

1. Explain in detail how the rotation of the generator coil results in the generation of a

sinusoidal current delivered to the transformer.

(5 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Rotation causes a change in flux within the coil  “As the coil rotates, the area of the coil perpendicular to the field lines of the magnets changes, therefore changing the amount of flux in the coil.” | 1-2 |
| Refers to Faraday’s law, resulting in emf  “The change in flux induces an emf in the coil” | 1 |
| Makes suitable connections between rotation of coil and slip rings resulting in an alternating current output  “The rotation of the coil results in an alternating current and the slip rings provide a frictionless contact that allows this current to pass this current from the generator to the transformer. | 1-2 |
| **Total** | **5** |

1. Calculate the maximum flux that can be encased by the generator coils. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| (-1 if A = 2) | 1 |
|  | 1 |
| **Total** | **2** |

1. Calculate the rms voltage output by the generator. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
|  | 1 |
|  | 1 |
| **Total** | **2** |

1. Calculate the frequency of the rotation of the generator coils. If you could not obtain an answer to part (c), you may use a value of 4.00×10-2 V. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Find peak voltage output | 1-2 |
| Find frequency  (taking from part (b), or calculating here)    (or 10.9 Hz if used assumed value) | 1  1 |
| **Total** | **4** |

**Question 15 (14 marks)**

Consider the energy level diagram below, with a single electron in the ground state.

n=1

n=2

n=3

n=4

n=∞

n=5

-12.8 eV

-5.30 eV

-3.28 eV

-2.55 eV

-1.85 eV

0 eV

1. Calculate how much energy is required to move from the ground state to the n=2 energy level. (1 mark)

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

1. On the energy level diagram, draw all the possible transitions an electron can make as it changes from the n=4 level to the n=2 level. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| All transitions shown, no extra. | 1 |
| **Total** | **1** |

1. Calculate the largest wavelength of all possible photons produced as an electron makes a transition between n=4 and n=2. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Uses smallest energy transition | 1 |
| Converts to joules | 1 |
| Calculates wavelength | 1-2 |
| **Total** | **4** |

1. An EMR source is used to promote an electron from the ground state to n=4. Which part of the electromagnetic spectrum does the EMR belong? Justify your answer with a calculation. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Finds energy difference | 1 |
| Converts to joules | 1 |
| Determines frequency (or wavelength)  , 𝝀 = 1.21 x 10-7 m | 1 |
| Matches frequency (or wavelength) to spectrum on formulae and data sheet  “Ultraviolet” | 1 |
| **Total** | **4** |

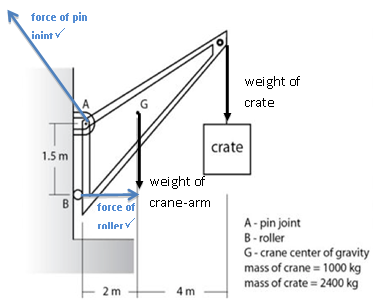
1. “To ensure the photons from the EMR source are able to excite electrons from the ground state to n=4, we should increase the frequency of the EMR source slightly”.

Comment on the suitability of this suggestion. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| States changing the frequency increases/changes the energy  “Increasing the frequency will increase the energy of the photons () | 1 |
| Describes the energy requirements for excitation of electrons by incident photons  “When photons are used to excite an electron, the photon energy must match the difference in energy between the levels exactly. Having more energy will result in the excitation not occurring at all. | 1-2 |
| Refers back to question  “Thus increasing the frequency of the EMR source is not a good idea” | 1 |
| **Total** | **4** |

No marks were awarded if accurate reasons were not provided and student stated that ‘it was not suitable’.No

**Question 16 (15 marks)**

In a mechanical workshop, a crane consists of a triangular crane-arm fixed to a wall by a pin joint at point A, as shown in the diagram at right. The crane-arm has a mass of 1000 kg centred at point G. The crane is being used to lift a heavy crate of mass 2400 kg, and has an adjustable roller at point B to help keep the vertical section of the crane-arm in place. Note that the roller only exerts a **horizontal force** on the crane-arm.

(a) On the diagram, draw in and label the other two forces acting on the crane-arm. **(2 marks)**

(b) Explain why the roller can only exert a horizontal force on the vertical section of the crane-arm. (2 marks)

**The roller is free to roll up and down the wall 1 mark**

**so if it exerted a vertical force on the crane-arm then the reaction force of the crane-arm on the roller would move the roller vertically. 1 mark**

**IF**

**Horizontal reaction force at the pin is balanced by the roller and vertical reaction force at pin is balanced by the weight of the crane arm and crate. 1 mark only**

**OR**

**Weight of the crate and arm provide clockwise torque and horizontal reaction force at B provides anti-clockwise torque. 1 mark only**

(c) Explain why the length of the cable attaching the crate to the crane-arm was not specified in the diagram. (2 marks)

**The length of the cable does not affect the calculation of clockwise torque produced by the weight of the crate 1 mark,**

**as the weight acts at a perpendicular distance of 6 m from the pivot at point A regardless of the length of the cable. 1 mark**

**IF** **‘Does not affect the calculation of torque only’ 1 mark only**

(d) Calculate the size of the horizontal force exerted by the roller on the crane-arm. (3 marks)

**Take the pivot at point A∑clockwise = ∑anticlockwise 1 mark**

**NB: should state where pivot is taken from, though no marks lost if left out.**

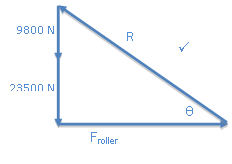
**(1000 kg)(9.8 m/s2)(2 m) + (2400 kg)(9.8 m/s2)(6 m) = (Froller)(1.5 m) 1 mark**

**19.6 kNm+ 141kNm = (Froller)(1.5 m)**

**Hence Froller= 161000 Nm / 1.5 m = 107 kN 1 mark**

(e) Calculate the magnitude and direction of the reaction force exerted by the pin joint at point A on the crane-arm. (4 marks)

**1 mark**

**Let R be the force of the pin joint on the crane-arm.**

**RH= Froller = 107 kN**

**RV = (1000 kg)(9.8 m/s2) + (2400 kg)(9.8 m/s2)**

**= 33.3 kN 1 mark**

**R2 = (33.3 kN)2 + (107 kN)2 R = 112 kN**

**1 mark**

**tanθ = 33.3 kN / 107 kNθ = 17.3° 1 mark**

(f) Explain how and why the size of the horizontal force exerted by the roller on the crane-armwould change if the roller was moved higher and closer to the pin joint at point A.

(2 marks)

**The roller must provide the same ACW torque= F x r as before, to maintain equilibrium 1 mark**

**but since the perpendicular distance r from the pivot would have decreased the horizontal force F exerted by the roller would have to increase in order to compensate for the reduced distance r. 1 mark**

**Question 17 (9 marks)**

An educational software package helps students understand electromagnetic principles by simulating a mini golf course. In this simulation, rather than hitting a ball into a hole with a putter, students must use electric charges to apply a force onto a charged golf ball to direct the ball towards the hole. Unlike real golf, there is no friction and the ball will not overshoot the hole because it is going too fast.

30.00

Hole

Ball

The charges and are located on the corners of the short edge of the putting area, equidistant from a golf ball. These charges share the same sign of charge as the golf ball, thus each repels the golf ball. Let the force acting on the golf ball due to charge be called and the force acting on the golf ball due to charge Charge is 260 nC and the golf ball has a 140 nC charge.

1. To putt the golf ball towards the hole, the ball must travel 30.00 above the horizontal line,

as indicated in the diagram. Show that the ratio of electric forces acting on the golf ball,

is approximately 3.73 for a successful putt. Include a vector diagram as part of your answer.

Note that the diagram above indicates that a line from charge A to the ball and a line from charge B to the ball are at right angles to each other. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Provides a labelled vector diagram showing understanding that two electrical forces combine to give net force in direction of hole | 1 |
|  | 1 |
| **Total** | **2** |

1. Hence, calculate the electric charge of . (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Uses Coloumb’s law to compare forces of both charges, reducing problem to the ratio of charges matching ratio of forces | 1-2 |
|  | 1 |
| **Total** | **3** |

1. Assume that the distance from each charge and to the golf ball is 5.00 cm. Calculate the strength of the electric field at the golf ball’s starting position due to the combined effect of charges and . (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Solves for either or (or both) | 1-2 |
| Uses trig rules (sin/cos/tan or Pythagoras) to solve for the net force  = 0.5058 N  OR | 1 |
| Solves for electric field strength | 1 |
| **Total** | **4** |

**Question 18 (16 marks)**

Young’s double slit experiment is used as evidence of the wave nature of light. The experiment requires a monochromatic light source, a blocking screen with a pair of thin, parallel slits and an observation screen.

Light

Blocking Screen

Observation Screen

When the light is turned on, the observation screen has a repeating pattern of bright and dim fringes. The theoretical relationship between the distance between bright fringes (), the separation of the slits () and the distance between the blocking screen and observation screen () is:

A 560 nm light was used and the distance between the fringes was recorded as the distance between the screens was increased. The results are given below.

|  |  |
| --- | --- |
| **(m)** | **(×10-3 m)** |
| 1.2 | 4.7 |
| 1.5 | 5.6 |
| 1.9 | 7.0 |
| 2.5 | 9.0 |
| 3.5 | 12.7 |

1. Explain the processes that occur that change the original light source into a pattern of

bright and dim fringes. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| States that diffraction occurs through slits  “As long as the wavelength of the light is similar in size to the width of a slit, the light diffracts through the slit.” | 1 |
| States two slits results in wave interfering on the far side of blocking screen  “The diffracted wave from both slits will spread out, cross paths and interfere with each other” | 1 |
| States the interference can be constructive (bright) or destructive (dim)  “When the interference is constructive, the light will produce a bright fringe, when destructive interference occurs, a dim fringe is the result. | 1 |
| **Total** | **3** |

1. Show that as long as , and are measured in metres, the formula for calculating the

width between the fringes will return a value in metres. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Shows dimensional analysis – showing how some units cancel to leave the final units as m | 1 |
| **Total** | **1** |

1. Draw a graph of against , with on the y-axis. Draw a line of best fit. Error bars

are not required. (5 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
|  | |
| Axes correct labels | 1 |
| Axes correct units | 1 |
| Appropriate scale  NOTE: some choice of scales made accurate plotting difficult | 1 |
| Accuracy of plotted points | 1 |
| Line of best fit | 1 |
| **Total** | **5** |

**Question 18** (continued)

1. Use the graph to calculate the gradient of the line of best fit. Show construction lines.

(3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Draws construction lines | 1 |
| If answer is 3.2 due to ignoring scale of values, only 1 mark | 1-2 |
| **Total** | **3** |

1. Use the gradient from part (d) and the provided equation to calculate the width between the slits in this experiment. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
|  | 1 |
|  | 1-2 |
| Answer to 2 sig figs: | 1 |
| **Total** | **4** |

**End of Section Two**

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

**Question 19 (17 marks)**

1. The “failed” Michelson-Morley experiment was the basis for one of Einstein’s postulates of special relativity.
2. Contrast what Michelson and Morley hoped to find in this experiment with the final outcome. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| States the intention of the experiment  “Michelson and Morley were attempting to find the velocity of the aether” | 1 |
| States the findings of the experiment  “The experiment showed the aether had no velocity; it was always stationary with the Earth.” OR the aether does not exist | 1 |
| **Total** | **2** |

**Question 19** (continued)

(ii) State the postulate this ‘failed’ experiment supports

(1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| States the 2nd postulate  “The speed of light is the same for all inertial frames of reference” | 1 |
| **Total** | **1** |

1. Assuming light does travel through an aether, show, via full working, that the time the longitudinal beam takes to move from the splitter to the mirror is .

(3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Starts from relationship between lengths | 1 |
| Suitable, clear mathematical steps | 1-2 |
| **Total** | **3** |

1. Assuming light travels through an aether, the anticipated **total** time it takes for the longitudinal beam to return to the splitter is **not** (twice the time it took to move

from splitter to mirror). Explain. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| States that reflected light moves with aether flow.  “When the beam reflects it will be going in the same direction as the aether flows”. | 1 |
| This will give the light a faster velocity as measured on Earth, with a speed c+v.” | 1 |
| Refers back to original question  “therefore the total time is smaller than | 1 |
| **Total** | **3** |

1. Physicists in the 1800s assumed light used the luminiferous aether as a medium. If this was true, explain how using a beam splitter and recombination of longitudinal and transverse beams would result in changes in light intensity. (5 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Describes that each beam has a different velocity due to relative motion through aether Beams at 90° to each other  “The velocity of the longitudinal beam flowing in the direction of the aether’s velocity will be adjusted by the aether. The transverse beam is not affected the same way, thus having a different velocity” | 1-2 |
| Describes how length and speed interact to affect time of beam – thus phase difference  “With the same distance, but different speeds, the time for each beam to return to the splitter will be different - This puts the beams out of phase (a phase difference)” | 1-2 |
| When beams are out of phase, intensity of combined light is reduced due to destructive interference | 1 |
| **Total** | **3** |

1. Even if the experiment was a “success”, the results were expected to change from one month to the next. Explain why. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| States the velocity of the aether is relative to Earth  “The experiment conducted on Earth would be moving through the aether with the Earth.” | 1 |
| States that Earth’s velocity is not constant  “As the Earth’s velocity changes as it orbits the Sun, the velocity through the aether would also be affected” | 1 |
| Refers back to question, connecting velocity through aether with results of experiment  “The experimental results will show the velocity of the aether based on the current velocity of the Earth around the Sun. | 1 |
| **Total** | **3** |

**Question 20 (19 marks)**

1. Discuss whether the following statements are physically sound for a two-body system consisting of the Earth and Moon:
2. “Both the Earth and the Moon experience the same magnitude of gravitational force”. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| States this statement is sound  “This statement is physically sound” | 1 |
| Provides suitable argument justifying the statement  “According to Newton’s 3rd Law, every action has an equal but opposite reaction. The same magnitude of gravitational force that the Earth pulls on the Moon will be applied to the Earth by the Moon” | 1-2 |
| **Total** | **3** |

1. “Both the Earth and Moon experience the same magnitude of centripetal acceleration.” (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| States this statement is **not** sound  “This statement is **not** physically sound” | 1 |
| Provides suitable argument that finds fault with the statement  “Despite both bodies having the same forces, they have different masses on which the force is applied. According to Newton’s 2nd law, acceleration is inversely proportional to mass”  OR  “Centripetal acceleration depends on radius and they have different orbital radius” - 1 mark only | 1-2 |
| **Total** | **3** |

1. By drawing gravitational forces for the two-body system shown below, explain why it is **not** possible to have the bodies in the position shown in the diagram. (3 mark)

+

Extra markings result in zero mark

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Draws two vectors, directed from centres of mass towards other body’s centre of mass. No penalty for mismatched size of vectors. | 1 |
| Describes need for net force to be directed towards centre which doesn’t occur here  “This is not possible as for circular motion as each body needs to have a net force acting towards the (bary)centre of the orbit. Here, the gravitational forces are not acting towards the centre of the orbit.” | 1-2 |
| **Total** | **3** |

**Question 20** (continued)

1. Calculate the distance from the centre of the Earth to the barycentre of the Earth

Moon system. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Uses | 1 |
|  | 1-2 |
| **Total** | **3** |

1. Knowledge of the barycentre location allows the speed at which the Earth is orbiting the barycentre to be determined.
2. Show that the velocity of the Earth with respect to the barycentre of the Earth-Moon system is . (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Equates centripetal force acting on Earth to gravitational force | 1 |
| Cancels Earth mass and rearranges for    Must have clear working | 1 |
| **Total** | **2** |

1. Hence, calculate the velocity of the Earth around the barycentre of the Earth-Moon system. If you could not obtain an answer to part (c), you may use 4.60 × 106 m.

(2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Uses correct and values from part c and formula and data sheet      Or if used data in question | 1-2 |
| **Total** | **2** |

1. Prove that if the two-body system is made of two bodies of identical mass, the barycentre is exactly equidistant from each body. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
|  | 1 |
|  | 1 |
| States that the calculated ‘r’ applies to both bodies (or also calculates )  “As and are indistinguishable/interchangeable, this is also the distance from the other body to the barycentre. Both bodies are from barycentre”  A proof cannot be just a single numerical example | 1 |
| **Total** | **3** |

**End of questions**