

**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)**

1. State the direction in which the current will be flowing – North or South.

(1 mark)

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

(3 marks)

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

**Question 2 (4 marks)**

Given that there is sufficient frictional force, calculate the minimum force of friction that would cause the box to rotate forwards.

|  |  |
| --- | --- |
| The box will rotate forward about point P (see diagram); as it begins to rotate, moments about P sum to zero. |  |
|  | 2 marks |
|  | 1 mark |
|  | 1 mark |

**Question 3 (5 marks)**

An object launched vertically upwards from the surface of the Earth would reach a much lower maximum height than if it was launched in the same way on Portia. By calculating and comparing the gravitational field strength on the surface of each body – and by using relevant equations of motion – explain why this is the case.

|  |  |
| --- | --- |
|  | 1 mark |
|  | 1 mark |
|  | 1 mark |
|  | 1 mark |
| ‘h’ is inversely proportional to ‘g’; hence, the projectile on Portia will reach a maximum height that is times higher than on the Earth. | 1 mark |

**Question 4 (4 marks)**

Explain how this sound in Coil 2 is produced.

|  |  |
| --- | --- |
| The alternating magnetic field in Coil 1 passes through Coil 2 causing a change in flux in this coil. | 1 mark |
| An alternating current is induced in Coil 2 that, according to Lenz’s law, opposes the alternating magnetic field produced by Coil 1. | 1 mark |
| Due to the closed circuit, an alternating current is produced in Coil 2 and the loudspeaker. | 1 mark |
| This current will alternate with a frequency of 400 Hz - hence, a 400 Hz sound is produced. | 1 mark |

**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 |
| ∆E = E3 – E1 > E3 – E2. | 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)**

1. Calculate the maximum EMF (εmax) produced by the generator.

(2 marks)

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

1. Calculate the transmission RMS voltage in the power lines.

(2 marks)

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

1. The transmission lines to the nearby town are about 20 km long. Explain how the power and voltage delivered to the town compare with the output power and voltage at the generator.

(3 marks)

|  |  |
| --- | --- |
| The power delivered to the transformer at the town centre is given by:  where RT is the resistance in the transmission lines. | 1 mark |
| The voltage delivered to the transformer at the town centre is given by:  where RT is the resistance in the transmission lines. | 1 mark |
| Hence, the power delivered will be less than 5.00 x 102 kW; and the voltage delivered will be less than 8.25 x 104 V. | 1 mark |

**Question 7 (5 marks)**

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

A Minh sees the light from Delta first.

B Minh sees the light from Liam first.

C Minh sees the light from both simultaneously, because both are at equal distances from her when they light the matches.

D Minh sees the light from both simultaneously, because special relativity requires that light travels at the same speed in all frames of reference.

(1 marks)

|  |  |
| --- | --- |
| A | 1 mark |

1. Minh 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)

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

**Question 8 (5 marks)**

Explain how this braking system works and how the speed of the climber can be varied.

|  |  |
| --- | --- |
| 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)**

1. 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): | 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 |

1. 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, Fc=W. | 1 mark |
| This is achieved when the minimum circular speed (v) at the top of the circle is given by: | 1 mark |

**Question 10 (6 marks)**

1. State the type of charge on each particle.

(1 mark)

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

1. Which path represents the particle with the largest charge? Explain.

(2 marks)

|  |  |
| --- | --- |
| The radius of the path is given by the expression: | 1 mark |
| Hence, path 1 represents the path for the particle with the largest charge. | 1 mark |

1. 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 the expression in part (a), a constant decrease in speed ‘v’ would result in a constant decrease in radius ‘r’. | 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).

|  |  |
| --- | --- |
|  | 1 mark |
| ie, | 1 mark |
|  | 1 mark |
|  | 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)**

1. 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 |
| ∑F = 0; 19.4 + WK = 42.9 | 1 mark |
| WK = 42.9 – 19.4 = 23.5 N down | 1 mark |
| Hence: | 1 mark |

1. 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.  Horizontal component of the TENSION = 25 x cos 51° = 15.7 N left | 1 mark |
| Hence, ∑Fh = Fc = 53.0 + 15.7 = 68.7 N | 1 mark |
|  | 1 mark |
|  | 1 mark |

**Question 13 (15 marks)**

1. Using formulae from the Formulae and Data Booklet, show that the relationship between the threshold voltage (V0) and the maximum wavelength (λ) for an LED is given by:

(2 marks)

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

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

|  |  |  |  |
| --- | --- | --- | --- |
| **LED colour** | **Vo (V)** | **λ (nm)** | **1/λ (x 106 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** |

1. Complete the table by filling in the missing value in the ‘1/λ’ column.

(1 mark)

|  |  |
| --- | --- |
| 1. 1.44 | 1 mark |

1. On the graph paper provided on the next page, plot a graph of ‘Vo’ against ‘1/λ’. Place ‘1/λ’ on the horizontal axis. Draw a line of best fit for the data.

(4 marks)

Vo (V)

1/λ (x 106 m-1)

1. Calculate the slope of your line of best fit. Include units in your answer.

(4 marks)

|  |  |
| --- | --- |
| Picks two points from the graph: (1.6 x 106, 2.00) and (0.40 x 106, 0.50) | 1 mark |
|  | 1 mark |
|  | 1 mark |
| Vm | 1 mark |

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

(4 marks)

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

**Question 14 (15 marks)**

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

(4 marks)

|  |  |
| --- | --- |
|  | 1 mark |
|  | 1 mark |
|  | 1 mark |
|  | 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)

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

(e) Explain what would happen to the dark and light fringe patterns on the optical screen if the speed of the electrons was decreased.

(3 marks)

|  |  |
| --- | --- |
| Decreasing the electrons’ speed increases their de Broglie wavelength. | 1 mark |
| Hence, the distance between dark fringes will increase. | 1 mark |
| There will be less dark fringes on the optical screen. | 1 mark |

**Question 15 (17 marks)**

1. 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 |

T

HINGE

FP

42.0°

WO

WD

6.50 m

11.5 m

16.0 m

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

(4 marks)

|  |  |
| --- | --- |
| Take moments about the hinge; ∑M = 0; ∑MC = ∑MA. |  |
|  | 2 marks |
|  | 1 mark |
|  | 1. mark |

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

(5 marks)

|  |  |
| --- | --- |
| ∑F = 0 |  |
|  | 1 mark |
|  | 1 mark |
|  | 1 mark |
|  | 1 mark |
|  | 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: | 1 mark |
|  | 1 mark |
|  | 1 mark |
|  | 1 mark |

**Question 16 (19 marks)**

1. Using the orbital data for our Sun, show that the mass of the Milky Way is about 100 billion (1011) solar masses (1 solar mass = mass of Sun).

(5 marks)

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

1. (i) Using formulae from the Formulae and Data Booklet, derive an expression that shows a stars orbital speed (v) with an orbital radius (r) as it orbits the Milky Way’s centre of mass (M).

(3 marks)

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

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

(2 marks)

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

(iii) 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)

v

r

|  |  |
| --- | --- |
| The graph indicates an inverse relationship between ‘r’ and ‘v’. | 1 mark |
| The graph indicates a hyperbola shape. | 1 mark |

1. Astronomers are able to confirm that stars in an orbital radius smaller than that of our Sun are orbiting around the centre of the galaxy by observing the red- and blue-shifted light emitted by these stars. Explain this observation.

(4 marks)

|  |  |
| --- | --- |
| Stars orbiting around the galactic centre with a smaller orbital radius than the Sun will have a higher orbital speed ‘v’ and smaller orbital period (T). | 1 mark |
| Hence, there will be times when these stars appear to be travelling towards the Earth and their light will be blue-shifted. | 1 mark |
| There will also be times when these stars appear to be travelling away from the Earth and their light will be red-shifted. | 1 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 mark |

1. Explain why the observed orbital speeds, being higher than expected, suggest the presence of dark matter in the Milky Way.

(3 marks)

|  |  |
| --- | --- |
|  |  |
| ‘r’ is fixed for each satellite | 1 mark |
| Hence, if ‘v’ is higher than expected, the mass ‘m’ of the galaxy outside the Sun’s orbit must be higher than suggested by luminous matter. | 1 mark |
| Therefore, invisible matter that is exerting a gravitational effect must be present. | 1 mark |

**Question 17 (15 marks)**

1. Calculate the velocity of Spaceship B as measured by Spaceship A.

(4 marks)

|  |  |  |
| --- | --- | --- |
| ELEMENT | DESCRIPTION |  |
| uses consistent sign convention | v = -0.600c; u = 0.850c |  |
| correctly identifies frames of reference | Looking for u’ | 1 mark |
| correct equation selected |  | 1 mark |
| enters correct values and directions |  | 1 mark |
| correct answer | 0.960c | 1 mark |

1. A light is turned on in Spaceship A for 1.20 s. Calculate how long the light appeared to be turned as measured in Spaceship B.

(3 marks)

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

1. Spaceship B fires a rocket with a velocity of 0.550c with respect to itself in the direction of Spaceship A. Calculate the velocity of the rocket as measured by the observer on Earth.

(4 marks)

|  |  |  |
| --- | --- | --- |
| ELEMENT | DESCRIPTION |  |
| uses consistent sign convention | All velocities are positive |  |
| correctly identifies frames of reference | Looking for u | 1 mark |
| selects correct equation. |  | 1 mark |
| enters correct values and directions |  | 1 mark |
| correct answer | 0.954c | 1 mark |

1. Calculate the velocity of the rocket as measured by Spaceship A.

(4 marks)

|  |  |  |
| --- | --- | --- |
| ELEMENT | DESCRIPTION |  |
| uses consistent sign convention | All velocities are positive |  |
| correctly identifies frames of reference | Looking for u | 1 mark |
| correct equation selected |  | 1 mark |
| enters correct values and directions |  | 1 mark |
| correct answer | 0.988c | 1 mark |

**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 18 (18 marks)**

1. 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 |

1. “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.”
2. 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 |

1. Let the time taken for the football to travel from the ground **to maximum height be ‘tUP’**.

Let the time taken for the football to travel from maximum height **to the ground be ‘tDOWN’**.

**When air resistance is ignored,** these two values are the same (ie – tUP = tDOWN).

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)

|  |  |
| --- | --- |
| tUP < tDOWN | 1 mark |
| On the way up: ∑a = g + aresistance | 1 mark |
| On the way down: ∑a = g - aresistance | 1 mark |

1. 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:

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:

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

(4 marks)

|  |  |
| --- | --- |
|  | 1 mark |
|  | 1 mark |
|  | 1 mark |
|  | 1. mark |

1. 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)

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

1. 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)

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

**Question 19 (18 marks)**

1. Using data from your Formulae and Data Booklet, calculate the mass of a muon in kilograms (kg).

(3 marks)

|  |  |
| --- | --- |
| From Formulae and Data Booklet, mass of muon: mµ = 105.7 MeV/c2 | 1 mark |
|  | 1 mark |
|  | 1 mark |

1. In addition to the more familiar forces of gravity and electromagnetism (which is responsible for electricity and magnetism), the strong and weak forces govern the behaviour of sub-atomic particles; ie – neutrons and protons - which both consist of three quarks.
2. In the table below, state the structure of a proton and a neutron (ie – the three quarks). In addition, show how the structure of each of these nucleons determines their charge.

(4 marks)

|  |  |  |
| --- | --- | --- |
| **NUCLEON** | **QUARK STRUCTURE** | **CHARGE** |
| **PROTON** | (up up down) uud |  |
| **NEUTRON** | (up down down) udd |  |

|  |  |
| --- | --- |
| PROTON = (up up down) uud | 1 mark |
| NEUTRON = (up down down) udd | 1 mark |
| PROTON CHARGE = | 1 mark |
| NEUTRON CHARGE = | 1 mark |

(ii) Describe the role of the strong force in the formation of the nucleons – protons and neutrons. Name the boson responsible for the mediation of this force in the nucleus.

(3 marks)

|  |  |
| --- | --- |
| The strong force acts between quarks to bind them in groups of three. | 1 mark |
| These three quarks form the nucleons. | 1 mark |
| The mediating boson is known as the gluon. | 1. mark |

(iii) A weak force interaction is shown below. One particle is missing.

Use Conservation laws to determine the following properties for the unknown particle.

(3 marks)

|  |  |
| --- | --- |
| Baryon Number | 0 |
| Lepton Number | -1 |
| Electric Charge | 0 |
| Symbol and Name | Anti-electron neutrino, |

|  |  |
| --- | --- |
| Both baryon and lepton number are correct. | 1 mark |
| Electric charge correct. | 1 mark |
| Symbol and name correct. | 1. mark |

(iv) In reality, gravity does not play a very significant role in governing the behaviour of sub-atomic particles. Explain.

(2 marks)

|  |  |
| --- | --- |
| In comparison to the other fundamental forces, gravity is by far the weakest of the four. | 1 mark |
| Hence, its influence over the behaviour of sub-atomic particles is much lower than the other forces in comparison. | 1 mark |

1. Some Physicists are beginning to think that the observed expansion of the Universe speeding up could be attributed to a ‘fifth fundamental force’. Explain how the increasingly rapid expansion of the Universe could be caused by contrasting the possible properties of this fifth fundamental force with the fundamental force of gravity.

(3 marks)

|  |  |
| --- | --- |
| This force would have to be a repulsive force between matter. | 1 mark |
| This force would have to increase in strength as the distance between matter increases. | 1 mark |
| This would account for the measured increase in the rate of expansion as universe expands. | 1 mark |