Part A.
marks

Total : **15**

1. **D**	2. **A**	3. **D**	4. **B**	5. **A**
6. **C**	7. **D**	8. **B**	9. **C**	10. **A**
11. **A**	12. **B**	13. **C**	14. **D**	15. **C**

Part B.
marks

Total : **60**

16. (a) MARKING GUIDELINES (2 marks)

Criteria	Marks
Indicates or use Newton's Gravitation equation, OR_{ff} states gravity inversely proportional to square of radius and directly proportional to mass, AND_{ff} states Planet B will have greatest surface gravity.	2
Refers to mass related to gravitational acceleration OR_{ff} suggestion of Newton's gravitation equation be employed for answer.	1

Specimen Answer:

The surface gravity of a planet is directly proportional to the mass of the planet and inversely proportional to the square of the radius of the planet. Since planet B has a much smaller radius, and only slightly smaller mass, it would have the largest surface gravity.

16. (b) MARKING GUIDELINES (2 marks)

Criteria	Marks
Shows relationship between centripetal and gravitational force and substitutes correct values into the equation and successfully calculates value.	2
Uses centripetal force but does not directly relate to gravitational force. Shows some attempt to substitute in values.	1

Specimen Answer:

It is the gravitational force due to N-Chig that creates the centripetal force holding planet B in its orbit. Using the data on the radius of orbit, the mass of B, and the orbital speed, the centripetal force, equivalent to the gravitational force, can be calculated.

$F_g = F_c = \frac{mv^2}{r}$, substituting in values, $F_g = \frac{2.87 \times 10^{26} \times (55.8 \times 10^3)^2}{1.5 \times 10^{11}}$

$\therefore$ Gravitational force = $\underline{5.96 \times 10^{24}\ N}$ towards N-Chig.

17. (a) MARKING GUIDELINES (2 marks)

Criteria	Marks
States maximum force on rocket can be determined using graph and known mass of the rocket. Clearly indicates gravity opposing thrust and states maximum acceleration = (F_{max} – (m_R g)) divided by mass of rocket.	2
States maximum force read from graph, will be divided by known mass of rocket to yield maximum acceleration OR_{ff} states F=ma and infers maximum F_{max} obtained from graph.	1

Specimen Answer :

Considering the graph shows the force produced by the rocket engine over time, and gravity continually opposes the motion of the rocket propelled vertically up, by reading the maximum force from the graph (19 N) and then subtracting the weight force of the rocket (m_R g), the nett force that will act up can be determined. Applying F=ma, by dividing this nett force by the known mass of the rocket, the result will yield the theoretical maximum acceleration of the rocket.

17. (b) MARKING GUIDELINES (3 marks)

Criteria	Marks
Suggests area under graph, with consideration of opposition force due to gravity over the time the fuel burnt, allows the resultant impulse, from the engine to the rocket, to be calculated AND_{ff} states or shows, that this impulse is equivalent to the mass of the rocket x its change in velocity. Infers that through correct use of information from the graph, a knowledge of mass, gravity, and the time the fuel burns, the students are able to predict the maximum velocity of their rocket.	3
Suggests that information from the graph allows the impulse, from the engine to the rocket, to be calculated, and states or infers, this is equivalent to the (mass x the change in velocity) of the rocket. Relates this to use of known mass of the rocket, and gravity, to allow students to calculate maximum velocity of rocket.	2
Suggests that information from the graph, known mass of the rocket, and gravity, can be used to calculate maximum velocity of rocket.	1

Specimen Answer :

The area under a force vs time graph is equivalent to the impulse that the engine will provide to propel the rocket. Remembering that gravity continually acts down, the force due to gravity will reduce the thrust from the engine by (m_Rg) over the time the burning fuel is creating an upward thrust. This means the students can calculate the resultant impulse as; the AREA under the curve, minus the product of (m_Rg) and the time (Δt) the engine provided thrust (6.75s from graph). Since Impulse is the change in momentum, i.e. FΔt = mΔv, then considering the rocket begins at rest, then Δv, the change in velocity of the rocket, is equivalent to the top speed, and can be calculated using the information from the graph, gravitational acceleration, and the known mass for the rocket.

18. (a) MARKING GUIDELINES (2 marks)

Criteria	Marks
Correctly outlines the three relativistic changes that would be apparent	2
Outlines ONE change correctly.	1

Specimen Answer:

If possible to make observations, the observer on Earth would notice, clocks on the spacecraft would run more slowly than on those on Earth, the length of the spacecraft would appear to have contracted, and the mass of the spacecraft would appear to have increased.

18. (b) MARKING GUIDELINES (2 marks)

Criteria	Marks
Clearly explains sensor is moving with spacecraft and as such will always send the same mass back to be read by the observer on Earth.	2
Suggests the mass will remain more or less constant	1

Specimen Answer:

Considering the sensor is onboard, it will always be travelling at the same speed as the spacecraft. This means, considering little mass is lost in propelling the spacecraft, that the reading of the mass received from the spacecraft, should remain more or less the same over the entire mission.

18. (c) MARKING GUIDELINES (2 marks)

Criteria	Marks
Clearly outlines; need to significantly reduce speed (kinetic energy) AND, the requirement for re-entry into the Earth's atmosphere at the correct angle.	2
Outlines at least one consideration correctly	1

Specimen Answer:

Considering the spacecraft must enter the atmosphere and then come to rest on the surface, the spacecraft must reduce its velocity significantly and then ensure that it enters the Earth's atmosphere at the correct angle of re-entry.

19. MARKING GUIDELINES (5 marks)

Criteria	Marks
Clear, concise answer describing the aether as medium proposed by classical wave theory to acts as a medium for light to travel through free space, clearly stating proposal that it occupied all free space (vaccum) and the remarkable properties it must have. Discusses, Michelson and Morely experiment, explaining reasoning, as an attempt, using sensitive apparatus, to measure an aether wind, but still with a "null" result after many trials, AND, Einstein's role in the final suggestion of the constancy f the speed of light and that there was absolutely no need for the aether..	5
Describes aether as medium proposed by classical wave theory to acts as a medium for light to travel through free space, with some reference to properties, clearly stating proposal that it occupied all free space (vaccum), mentions Michelson and Morely experiment, attempt to measure aether wind with null result and Einstein's role in the final suggestion that there was absolutely no need for the aether..	3 - 4
Describes aether, with some reference to medium for light occupying all free space (vaccum), mentions Michelson and Morely experiment and Einstein.	2 - 3
Indicates aether proposed as medium to transmit light	1

Specimen Answer:

The "aether" was a medium proposed by wave theorists to acts as a medium for the transmission of light waves through free space (vacuum). According to classical wave theory, a medium was required for the vibrations of wave energy to be transferred. The aether had to have remarkable properties, described as a massless, all pervading medium occupying all free space, while still allowing the planets to move through it with no friction. Maxwell had incorporated an aether as part of his analysis of electromagnetic waves and with the verification of the existence of electromagnetic waves by Hertz, Michelson and Morely began serious attempts to try and measure the so called "aether wind" that should be present because of the relative motion of the Earth through the aether. Their experiment, incorporating an extremely sensitive interferometer, was performed many times in many locations but produced a null result, i.e. it could not provide any evidence of the aether. The problem of the aether was finally resolved by Einstein when he produced his Special theory of relativity, suggesting the constancy of the speed of light, and that there was absolutely no need for an aether to allow light to travel through a vacuum.

20. (a) MARKING GUIDELINES (2 marks)

Criteria	Marks
Correct answer with equation and correct substitution shown.	2
Correct substitution and calculation without using correct SI units (eg 6 x 10^{-5} N)	1

Specimen Answer:

The Force acting can be calculated using Ampere's law, i.e.

$$F = k_{mag}\frac{I_1 I_2}{r}\Delta l = \frac{2\times10^{-7}\times 5\times 5\times 3}{5\times10^{-2}} = 3\times10^{-4}\ N.$$

20. (b) MARKING GUIDELINES (3 marks)

Criteria	Marks
Refers to the current direction and correctly describes how interaction of the magnetic fields around the wires determines the direction of the force on the wires and resultant movement.	3
Refers to the current direction and interaction of magnetic fields around the wires leading to the movement.	2
Refers only to the current direction as causing movement.	1

Specimen Answer:

When the switch was closed, the currents flowing in the wires must have been in the same direction, as the magnetic fields they produced interacted to result in a magnetic field that was less intense between the wires than it was on the other sides of the wires.

This interaction resulted in a magnetic force moving the wires together.

21. MARKING GUIDELINES (4 marks)

Criteria	Marks
Refers to a number of energy losses, eg. In transmission lines (as below), in transformers etc. Supports answer with detail on relationship between, R and I^2 with energy loss. Includes reference to reducing losses – eg. high voltage, low current transmission, reduced to safer voltage by transformers close to consumer.	4
Also includes reference to reducing losses – eg. high voltage low current transmission.	3
Very good verbal description of one type only &/or supported with equations eg $P = I^2R$	2
Verbal description of one type of loss only; eg along transmission lines	1

Specimen Answer:

The losses of energy in transmission of the electrical energy occurs wherever there is a resistance to the flow of charge. The power losses can be calculated from $P = RI^2$,

where R is the resistance of the component, and I^2 is the square of the current flowing.

The energy from the power station is transmitted through the transmission wires with very high voltages, allowing smaller currents to transfer the required energy. This high voltage is then stepped down by transformers to allow the consume a supply at high current but a safer low voltage. The transmission wires are large diameter and low resistance to minimise losses. Energy is also lost in transformers, as the eddy currents produced in the material making up the transformer, produce heating and associated energy losses. Modern transformer materials minimise the size of the induced eddy currents to again reduce losses associated with transmission of electrical power to consumers.

22. (a) MARKING GUIDELINES (2 marks)

Criteria	Marks
Correctly describes difference in number of loops in primary and secondary coils and the changes in voltage for both step-up and step-down transformer	2
Correctly describes changes in voltage for both step-up and step-down transformer	1

Specimen Answer:

A step-up transformer has more loops in the primary coil compared to the secondary coil resulting in it producing a higher voltage at the secondary coil compared to the supply to the primary coil, while a step-down transformer has less loops in the primary coil compared to the secondary coil and produces a lower voltage at the secondary coil compared to the supply to the primary coil.

22. (b) MARKING GUIDELINES (2 marks)

Criteria	Marks
Refers to magnetic linkage of coils, the need for AC supply to the primary coil and indicates the change of magnetic flux induces an emf in the loops of the secondary coil. Mentions voltages related to the number of loops in primary coil compared to secondary.	2
Refers to magnetic core (yoke) passing through the coils and the need for AC to the primary coil.	1

Specimen Answer:

The primary and secondary coils are linked (yoked) by a magnetic core that passes through both coils. When an AC source is supplied to the primary coil, the changing magnetic field produced by the AC, is carried by the magnetic core through the loops of the secondary coil. This changing magnetic field induces an emf in the loops of the secondary coil, producing a voltage available from the secondary coil, based on the voltage of the AC supply to the primary, and the ratio of the number of loops in the primary coil compared to the secondary.

22. (c) MARKING GUIDELINES (2 marks)

Criteria	Marks

Describes a positive impact on society, e.g. People are better informed because access to electricity has improved mass communication, OR, ability to supply electricity at array of voltages while providing for energy losses to be reduced.	2
Describes a positive impact for individuals e.g. more people have access to electricity.	1

Specimen Answer:

The development of the transformer has enabled modern power stations to be created whereby, they can now be much larger and in remote locations, and then use a transformer to transfer the electrical energy they generate at very high voltage, to minimise energy losses, and then, using other transformers, the voltage can be stepped down, to supply the various needs of industry and domestic consumers. This ready supply of electrical energy with the use of transformers, has allowed modern technological society to develop, while at the same time, increasing the efficiency in the use by society of valuable energy resources.

23. MARKING GUIDELINES (5 marks)

Criteria	Marks
Good description of a suitable procedure to demonstrate AC induction motor including clear, concise explanation of principles involved.	5
Good description of a suitable procedure to demonstrate AC induction motor including basic explanation of principles involved.	4
Good description of a suitable procedure to demonstrate AC induction motor but, with weak explanation of principles involved, OR, Good description of demonstration of other than an AC induction motor, with appropriate explanation of the principles for the AC motor described.	3
Weak description of a demonstration of AC induction motor, OR// sound description of other than AC induction motor, AND, Lacking any real explanation of principles involved	1 - 2

Specimen Answer:

In the induction motor, a rotating magnetic field in the stator, induces eddy currents in the rotor. The magnetic field associated with these eddy currents produce a force of attraction between the rotor and stator which causes the rotor to "follow" the rotating magnetic field of the stator - the rotor spins. To demonstrate this, a disc of alfoil was suspended above a rotating magnet (on top of a Magnetic stirrer hotplate). Eddy currents were induced in the aluminium foil as the magnet was spinning. The direction of the current in the foil was such that the magnetic field associated with the current, produced a force of attraction, providing a drag on the spinning magnet. (Lenz's Law) This drag caused the foil to "follow" the magnet, and start spinning too. Reversing the direction of the spinning magnet caused the foil to slow down, stop spinning and begin spinning in the opposite direction.

24. (a) MARKING GUIDELINES (2 marks)

Criteria	Marks
Suggests that voltage between the anode and cathode allows expected kinetic energy to be determined and from known values, the velocity can be calculated. Outlines relationship that students would use, i.e. $\Delta V. q = \_ m v^2$.	2
States known voltage between anode and cathode allows velocity to be calculated but lacks detail on how to actually determine velocity.	1

Specimen Answer:

The students would be applying an understanding of the energy gained by the electron in moving through a known potential difference, i.e. $\Delta E = \Delta V q$. Since the electrons are released from the thermionic filament in the evacuated tube with no excess kinetic energy, due to the potential difference between the cathode and anode, the gain in energy, ΔE, will be all be realised as kinetic energy, as the electron accelerates to the anode, i.e. $\Delta V q = \_mv^2$, where v is the velocity of the electrons produced in the beam of cathode rays. The students would be able to rearrange the equation and, using the known voltage of 5 kV and the known value for the mass and charge of an electron, be able to calculate the predicted velocity of the beam of electrons in the cathode rays used in their experiment.

24. (b) MARKING GUIDELINES (3 marks)

Criteria	Marks
States relationship of magnetic force and the centripetal force it produces, indicating the mathematical relationship, including a clear description of how relationship can be used to determine B produced by student's magnet.	3
Relates magnetic force to centripetal force and shows mathematical relationship but weak description of how relationship can be used to determine B.	2

Relates magnetic force to centripetal force but fails to clearly show how relationships can be used to determine B.	1

Specimen Answer:
The students reasoning is that, as the beam of cathode rays passes through the magnetic field created by their magnet, the electrons will experience a magnetic force that acts perpendicular to their velocity. This centripetal force is maintained while the electrons travel through the region of magnetic field. Since the magnetic force for a moving charge is given by F = Bqv, and a centripetal force causes a curving path according to $F_c = mv^2/r$. The students can then combine this to produce, $Bqv = mv^2/r$, or $B = mv/qr$. Using the calculated velocity of the electrons in the beam, and from the experimental measurement, using the value they have determined for the radius of the curving path of the electrons as they past through the magnetic field, the students can then use the known mass and charge of the electron, and substitute all the values into the equation shown, to calculate the experimental result for the strength of the magnetic field produced by their magnet.

Q24 (c) on the NEXT page.

24. (c) MARKING GUIDELINES (3 marks)

Criteria	Marks
Refers to varying high voltage supply and collecting data for each of the different velocities that can be produced, stating that by collecting more data, a graph can be drawn, and then, using the line of best fit to determine an experimental result for the magnetic field strength, produces a more reliable answer.	3
Refers to possibility of varying high voltage supply and collecting data for each of the different velocities that can be produced, stating that by collecting more data to determine magnetic field strength, produces a more reliable answer.	2
Suggests students could repeat the measurement several times	1

Specimen Answer:
The students have used just one set of data to obtain their experimental result for the magnetic field strength. Considering the high voltage power supply had several settings, the students could repeat the trial using each of the available high voltages.

By using the equation, $v = \sqrt{\frac{2Vq}{m}}$, the students can determine the velocity for each voltage.

By measuring the deflection of the cathode ray for each different voltage, and using the same technique as previously, they can determine the radius of the curving path for the different velocities produced by each voltage.

Considering the theory yields, $B = \frac{mv}{qr}$, if the students were then to graph the result of the velocity of the cathode rays versus the radius of their curved path in the magnetic field, they could then use the line of best fit from the graph, and the known charge and mass of an electron, to determine a more reliable result for the strength of the magnetic field produced by their magnet,

i.e., $B_{exp} = \text{Slope of line on graph} \times \frac{m_e}{q_e}$

25. (a) MARKING GUIDELINES (2 marks)

Criteria	Marks
Names Heinrich Hertz including an accurate description of his observation	2
Names Heinrich Hertz but fails to offer suitable description of his observation	1

Specimen Answer:
It was Heinrich Hertz who first observed the photoelectric effect while performing his famous experiment where he verified the existence of electromagnetic radiation. He noticed that when the light produced by the spark of his transmitter loop fell directly onto the receiving loop, that the sparking at the receiver was stronger, (more easily produced). He noted that something to do with the light falling on the receiver was allowing the charge to be released more easily but he did not investigate further.

25. (b) MARKING GUIDELINES (3 marks)

Criteria	Marks
Clearly explains zero point of lines on kinetic energy axis is the threshold frequency, and related by Planck's constant to the work function to remove	3

electrons from the metals. AND, explains how slope of lines can be used to determine Planck's constant.	
States threshold frequency for metal X is lower than threshold frequency for metal Y indicating lower work function to remove electrons from X with explanation directly referring to zero point of lines on kinetic energy axis. AND, states slope of lines can be used to determine Planck's constant.	2
States threshold frequency for metal X is lower than threshold frequency for metal Y with weak explanation.	1

Specimen Answer:
The graph produced by the scientists allows several important features of the photoelectric effect to be noted;

- the work function, ϕ, to remove an electron from the two metals can be determined from the threshold frequency, f_o, (the point where the photoelectron kinetic energy reaches zero, with $\phi = h f_o$, where h = Planck's constant). The results indicate that Metal **X** has a lower work function than Metal **Y**.
- the slope of the line shows that as the frequency of the light increased, the kinetic energy of the emitted photoelectrons increased in direct proportion. Considering Einstein's equation to explain the photoelectric effect, the slope of the line can be used to determine the value of Planck's constant. i.e. $E_k = hf - \phi$, therefore, $h = \dfrac{E_k + \phi}{f}$.

26. MARKING GUIDELINES (7 marks)

Criteria	Marks
Coherent answer that clearly describes the appropriate model used to explain how current flows for each example, including sufficient detail on the mechanism of charge transfer for each type. Comments on ability of charges to move, how they move, and the related energy losses. A comparison between the three types is clearly evident.	7
Good description of the models used to describe flow of charge through each type of conductor, with some detail on all three types, and making a genuine attempt to show how the types are similar and different.	5-6
Good coverage of at least two of the models for the three forms of conductor with some effort to compare the mechanism of current flow between the three types.	4
Good coverage of at least one of the models for the three forms of conductor with some effort to compare the current flow between at least two of the three types.	3
Weak attempt with only reference to resistance of three forms of conductor and no real comparison of how charge moves.	1-2

Specimen Answer:
The models used to explain a current flowing in all forms of conductor involves the movement of charge through a crystal lattice of nuclei, but the mechanisms described by the models, to explain how the charge moves, varies for the three forms of conductor being discussed.

In a metallic conductor at room temperature, the accepted model describes the structure as, " a close-pack crystal lattice of metal nuclei immersed in a sea of electrons". Because of the close-pack structure, the valence electrons are directly available to the conduction band and, when an electric field is applied across the metals, many valence electrons are easily mobilised into the conduction band and begin to move, becoming involved in collisions with nuclei as they drift through the lattice. In this way many electrons are able to drift through the lattice to carry a current while their interactions with the nuclei leads to them losing electrical energy and the conductor rising in temperature.

In a doped semiconductor, small amounts of impurities added to pure silicon, give rise to, in the case of a p-type, a crystal lattice with some vacant positions (holes) remaining for some silicon atoms electrons, or, in the case of a n-type, extra electrons that cannot be successfully bound in the crystal lattice. When an electric field is applied to the doped semiconductor, in the case of the p-type, the presence of the holes allows a valence electron to take the place of the hole, promoting the hole into the conduction band. In this way the holes drift as a positive flow from atom to atom through the crystal lattice. In the case of an n-type, the applied electric field can provide sufficient energy for the unbound electrons in the lattice to be raised into the conduction band. In this way the electrons can pass from atom to atom as a negative flow through the crystal lattice. Because of the limited number of charges that are easily mobilised, doped semiconductors have a very high resistance compared to metallic conductors and lose electrical energy in heating atoms as the charge passes through the lattice.

The model generally used to describe the way current flows in a superconductor below its critical temperature is the BCS model. In this theory, quantum effects that occur below the critical temperature, allow the electrons that move in the current in the superconductor, to behave very differently than conduction electrons in metallic conductors and semiconductors at room temperature. In this model, the electrons come together to form Cooper pairs, which are able to interact with the nuclei, such that they can travel through the crystal lattice of the superconductor with negligible resistance. In this way the superconductor, unlike metallic conductors and semiconductors at room temperature, can carry large currents, with the Cooper pairs carrying the charge, experiencing no energy losses. This negligible resistance remains possible while the superconductor remains below its critical temperature, providing the size of the current does not become too large, with the magnetic field created by too large a current, causing the superconductive property to be lost.