**1.**

a) Discharge tubes at different pressures were set up and connected to a high voltage; this high voltage was generated using an induction coil. They were connected one by one and the visible striation patterns in the tubes were observed and recorded.

b) At the highest pressure, faint streamers were seen extending from the cathode to the anode. As the pressure was lowered, bands of light and darkness known as striations patterns begin to develop. Accompanying these striations originating from the cathode was a dark region adjacent to the anode known as Faraday’s dark space. As the pressure was lowered the size of the dark space increased and the striations became smaller and more defined. Eventually, at the lowest pressure there were no striations, simply a glow through the discharge tube.

**2.**

As soon as it leaves the generator it is stepped up to approximately 150 000 kV, it is then transported to society at this high voltage. As it gets closer to society, a substation steps down the voltage to around 1200V, this is often used in industry. Further substations nearer to domestic consumption step down this to 240V, this is provided to homes. Within the homes, various appliances are fitted with the relevant transformer needed.

**3.**

Student A’s claim that a small resistance will create larger eddy current and greater resistive heating is incorrect. The eddy currents created are proportional to the change in flux, therefore both pans will have the same amount of eddy currents generated in them. It is the resistance within the pan that determines how much of this energy is converted to heat (P=I2R). Therefore, Student B’s claim is valid as the large resistance will result in more of the eddy currents dissipating their energy in the form of heat.

**4.**

a) Mercury and Zinc, NbAlO and ?

b) All superconductors exhibit a property known as the Meissner Effect, which states that a superconductor will prevent penetration from external magnetic flux. This means that a permanent magnet will not be allowed to pass its magnetic field through the superconductor. This is achieved through circular currents generated on the surface of the superconductor; the electrons within this current are free to move as the element is in a superconducting state. The direction of the current is such that the superconductor induces effective magnetic poles that repel the permanent magnet. This upward electrostatic force of repulsion is exactly the same in magnitude of the downward weight force, this results in a net force of zero and subsequently a stationary levitating magnet.

**5.**

a) An inertial frame is one that is non-accelerating where as a non-inertial frame of reference is accelerating.

b) The Earth by itself can be considered a closed system; we consider it as the (impossible) absolute frame of reference. Our motion is recorded relative to the Earth making it an inertial frame of reference. This is mainly to simplify this complex concept.

**6.**

Einstein believed the science should be removed from social and political forces, that it should be universal and of benefit to all. This was reflected in his political activism as during the war he actively campaigned for peace, signing various treaties which was against the norm for scientists. Planck had a hugely conflicting view that science should be of the benefit of a specific social class or country, that it was very much attached to social and political forces. Planck’s stance echoes through his activity during the war, actively supporting and working for the Nazi doctrine. Even though the tumultuous global conditions had a huge influence on their perspectives, both scientists held very personal and subjective views of the role science held.

**7.**

a) During the initial stage of escaping the Earth’s gravity, the astronauts experience significant positive g-forces while accelerating away from Earth. In order to approach the desired escape velocity and successfully propel themselves, the spacecraft is provided a huge thrust. Furthermore, mass is continually lost as fuel is expended, this results in a large acceleration [Newton’s Second Law] and subsequently large g-forces [g-force = 1 + a/g]. These high g-forces have various effects on the health of the astronauts as it restricts blood flow creating loss of vision and consciousness with nausea. Significant training along with reclined seats are necessary to minimise these effects. Similarly, when re-entering Earth the spacecraft has to undergo massive and rapid deceleration resulting in high negative g-forces.

b) The rocket and its fuel can be considered a closed system, applying the Law of Conservation of Momentum shows us that INITIAL: mrocketvrocket + mgasvgas = FINAL: mrocketvrocket + mgasvgas . As the initial momentum at takeoff is zero, mrocketvrocket = -mgasvgas. Any change in momentum of the rocket is equal in magnitude to the change in momentum of the gas, the change in momentum can be expressed as Impulse = Force x Time. Since both the rocket and gas have equal impulse and it is a specified time frame, the force on each must be equal. Rockets are designed so that this force is constant, therefore as the mass of the rocket decreases (as fuel is lost) the acceleration has to increase as F is constant [a=F/m]. Therefore the acceleration is inversely proportional to the mass in the rocket.

**8.**

a) F= GMm/r2 , therefore the factors that can affect the magnitude of the force is the mass of the object and its distance from the centre of the Earth.

b) Satellite missions involve placing them in a circular orbit around the Earth, the centripetal force holding it in orbit is gravity. Using Newtons Law of Universal Gravitation, factors such as required orbital velocity can be determined for a specific orbital radius, this is done by equating Newtons Law to mv2/r.

**9.**

a) When a probe approaches a larger body, the gravitational interaction between the two results in an elastic collision. This inelastic collision results in the probe gaining kinetic energy (velocity) as well as angular momentum; this causes it to accelerate around the planet without expending any fuel. As the collision is elastic the planet loses the same amount of kinetic energy and angular momentum but experiences no effect as it is a minor change to an object of such large mass.

b) ?

**10.**

a) The vacuum is important to the cathode tube as it creates and maintains a low gas pressure, this is important as high gas pressures prevent the cathode rays from travelling from the cathode to the anode due to frequent collisions with gas molecules. The high voltage is necessary to provide the work/energy for the electron to escape the metal cathode and travel to the anode.

b) CRT relies on cathode rays to produce images on a screen; it requires three electron guns for each of the three primary colours. These electron guns consist of a heated cathode as well as focusing and accelerating anodes, this is needed to collimate the electrons into a fast beam. Once it leaves the electron gun, the cathode rays are deflected by either magnetic or electric fields, depending on the input signal (ie. TV signal). This allows the various colours to be directed into different areas of the screen, upon striking the screen it converts its kinetic energy to visible light which we see due to the phosphorescent nature of the screen.

**11.**

a,b) The field lines exit from the positive point charge and enter the negative point charge. Other field lines in the opposite direction also exist on both, lines radiating out for positive and lines inward for negative.

**12.**

a) Electron-hole conduction applies to specifically to semiconductors. In a semiconductor, the valence electrons are covalently bonded into a fixed lattice. If an electron were to escape this lattice, it would leave a region of electron deficiency, this hole can be considered as positive. Electrons are electrostatically drawn to this hole, upon occupying it they leave behind a hole in their former position. In this way, electrons and holes are able to move through the lattice in opposite directions, acting as two separate charge carriers in the conduction of electricity.

b) Silicon conducts well at high temperatures where as germanium loses conductivity. Both materials can be obtained in high purity. However, silicon is more abundant and subsequently cheaper. Therefore, even though silicon is a slightly poorer conductor, its the better choice for semiconductors.

c) Students stood in a line each carrying a yellow tennis ball, one student was chosen at random and the yellow tennis ball was taken away and replaced with a black tennis ball. The students were then asked to move the black tennis ball from end to end, with the rule that no student could simultaneously hold two tennis balls. In this model, the yellow tennis balls (electrons) would move in the opposite direction to the black tennis ball (hole), continually interchanging positions.

**13.**

a) A 5 cm by 5 cm grid was placed up against a wall, a ball was then thrown in a parabolic motion from one side to another, it was timed with a stopwatch. A stroboscopic light along with a fast motion camera was used to capture the motion of the ball at various points. Using the grid in the background, the maximum height and range could be determined. Using the appropriate equations and combining the time of flight measurements, the initial velocity of the ball was calculated.

b) A car that is turning around a corner experiences a centripetal force due to friction between the tyre and the ground. A satellite in stable orbit experiences a centripetal force due to earth’s gravitational field. An object tied to the end of a string experiences a centripetal force due to the tension in the string.

c) Tsiolokvsky is considered the father of Russian aeronautics. The range of contributions he made include developing a multistage rocket, he pioneered the concept of discarding the extra weight as fuel was consumed. He also identified the necessity of pressurised and liquefied oxygen for the combustion reaction to take place. All his various contributions could not be placed into practical application during his lifetime due to the political turmoil in Soviet Russia. However, his written works guided the success of the Soviet space program making his contribution none the less important.

**14.**

a) The main features of a DC motor are:

- stator: provides a permanent magnetic field for the coils to interact with

- rotor: carries the cols of current which experiences a force due to the motor effect, moving charge in magnetic field

- armature: the rotor is wound around the armature, the force the coils experience provide torque to the armature, this spinning motion is then used

- iron core: strengthens the magnetic field due to its ferromagnetic nature

- commutator and brushes: reverses the direction of the current every half turn to ensure the torque is in one direction

b) An AC induction motor requires no external contact (commutator/brushes) as the rotor carries induced current. Furthermore, the stator is multiple phase and connected to AC in order to generate an apparent rotating magnetic field.

c) The end of an aluminium can was cut out and attached to an axle from which it was free to spin. A permanent magnet was then placed above it and rotated in a circular motion, the can then began to spin in the same direction due to the induced eddy currents and effective magnetic poles. This is similar to the operation of an induction motor, in which the three phase stator creates a rotating magnetic field. This constantly changing magnetic field induces an EMF as well as current in the coils of the rotor. This generates effective magnetic poles in the coil which is attracted to the magnetic field that keeps moving away from it, in this way it is dragged behind it due to the electrostatic attraction creating constant rotation.

d) DC Motors [Advantages] easy to operate of battery power [Disadvantages] mechanical contact requires constant replacing, brush. AC Motors [Advantages] requires no commutator and brush, less maintenance, most appliances use AC, cheap to build [Disadvantages] can’t run on DC

**15.**

Max Planck hypothesised that atoms exists in specific quantised energy states, in order to move from one state to another blackbody radiation of frequency proportional to the energy difference is released (E=hf), therefore when heated the various transitions and corresponding radiation emitted can be exhibited as a blackbody curve. Certain transitions from one quantised state to another are more mathematically probable than others, this creates a peak wavelength of higher intensity on the graph. The other phenomenon Planck’s hypothesis was able to explain was the UV catastrophe, in order to create such short wavelengths an extremely large energy transition needs to take place; atoms don’t have such high energy states resulting in it never taking place.

**16.**

In order to successfully space travel, the spacecraft needs to be travelling at relativistic speeds in order to cover the large distances in reasonable time frames. To reach these high velocities, the spaceship needs to be significantly accelerated; this requires large amounts of fuel. This gives the spacecraft an initial large mass which becomes substantially dilated as the spacecraft approaches high velocities [Lorentz transformation]. According to Newton’s 2nd Law [a=F/m], a constantly increasing force is required to accelerate the spacecraft and offset the mass gain, this is difficult to provide. Time dilation has no implications for the astronauts on board as they experience proper time, however the length of the mission from Earth will feel extremely long. They do achieve the benefits of length contraction as the space ship is moving frame of reference, this reduces the amount of travel time. Therefore, special relativity has various implications for space travel due to the relativistic speeds at which the spacecraft travels.

**17.**

a) Bragg’s experiment involved sending collimated X-rays into a crystal structure in order to determine the spacing of the crystal using Braggs Law [nλ=2dsinθ]. This was achieved by measuring the angle of deflection caused by their diffraction. It required a source of X-rays, screens to collimate the X-rays and a photographic screen to observe the interference pattern caused by their diffraction. The constancy of maxima and minima in the interference pattern led them to conclude that the atoms are uniformly spaced in the crystal lattice. Though initially observed in ionic substances, this was soon discovered to hold true in metals. It was discovered that this lattice was made up of cations meaning that the electrons were delocalised and free to carry charge.

**18.**

The student’s claim is invalid as in order to maintain an orbit at a specific radius, the satellite needs to be travelling at the appropriate velocity, which is derived in the equation. However, this equation only holds for uniform circular motion, any loss in velocity will cause the satellite to break its circular path nullifying the above equation. This loss in kinetic energy will cause the satellite to fall towards Earth as it doesn’t have enough energy to overcome Earth’s gravitational attraction [vescape>vorbital]. Provided it doesn’t continue to lose kinetic energy it might form a stable orbit at a lower radius.