ARC. Answers /2002

Physics Trial Worked Solutions

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

16 A mass was attached to a piece of string. The string was fed through a piece of inflexible tubing. The other end of the string was attached to another mass. The tube was held vertical so that the first mass could be swung in an orbit. A paper clip was attached 1 cm below the tube when the radius of the orbit was 25 cm. The tube was manipulated in such a way that the paper clip remained at a constant height in order that the force was constant. The time taken for 20 revolutions was determined and the velocity of the orbiting mass calculated. The experiment was repeated but with a radius of 50 cm and half the mass below the tube. The velocities were compared and one would expect the trial with the smaller radius to have the larger velocity.

17 The terminals supply a potential difference to the coil of wire in the motor which in the presence of the magnetic field induces a force on the coil of wire. The orientation of the current is such that the wire on one side of the coil is forced down whilst the wire on the other side of the coil is forced up. The result is that a torque acts on the

coil so that it will rotate around the axle. As the coil completes a half cycle, the direction of the current must be reversed in order that the torque continues to act in the same direction. The split ring commutator does this by ensuring that the current always enters on the left side of the axle and leaves on the right side. As the commutator spins around, the current continually chnages its direction every half cycle. Thus the torque acts in a continuous direction.

18 Eddy currents are produced in metal with a constantly changing magnetic flux according to Lenz's Law. By slicing the iron core into sheets and thinly laminating each, the magnetic field is still extremely strong however the eddy currents are minimised as electrons cannot travel through the laminated sheets.

19 The introduction of generators has allowed electricity to be generated efficiently and easily so that it is available for not only the workplace but also th home. The development in the workplace has allowed electromagnets to be utilised in machinery resulting in much faster and efficient production. It has decreased pollution in cities also as the energy can be generated outside of the city. In the home, elctricity has meant that information can be communicated more quickly and efficently. People are much more comfortable due to heating and cooling from appliances and food is kept for longer in the refrigerator.

20 $F = LkI_1I_2/d$
$F = 1.2 \times 2 \times 10^{-7} \times 2 \times 3/0.04$
$F = 3.6 \times 10^{-5}$ N repulsion

21 AC induction motors employ an apparently rotating magnetic field. This induces a current to move in the rods in the squirrel cage. The current in the magnetic field creates a force that causes the rods to rotate around an axle.

22 $u_h = u\cos\theta$
$u_h = 38\cos 57$
$u_h = 20.7$

$t = s/u_h$

$t = 59/20.7$

$t = 2.85$ s

$u_v = u\sin\theta$

$u_v = 38\sin 57$

$u_v = 31.8$

$s = ut + \frac{1}{2}at^2$

$s = 31.8 \times 2.85 - \frac{1}{2} \times 9.8 \times 2.85^2$

$s = -29$

height of cliff = ~~29~~ 51 m

23 Extended space travel is not primarily due to the problem of achieving a high enough velocity. Due to the fact that combustible fuels is how current space vehicles are propelled, simply increasing the amount of fuel does not achieve the high velocity so desired. This is because the fuel adds to the mass and therefore the acceleration of the space vehicle is greatly decreased. Increasing the amount of fuel carried will increase the maximum velocity of the vehicle however it will not be significant. No viable alternatives have been found to repalce the combustible fuel vehicle. Therefore it will take far too long for current vehicles to achieve any great distance.

24 $t_e = 6.8/0.9$

$t_e = 7.6$

$t_{0e} = t_e(1-v^2/c^2)^{½}$

$t_{0e} = 7.6(1-0.9^2)^{½}$

$t_{0e} = 3.3$

$t_s = 6.8/0.4$

$t_s = 17$

$t_{0s} = t_s(1-v^2/c^2)^{½}$

$t_{0s} = 17(1-0.4^2)^{½}$

$t_{0s} = 15.6$

$\Delta t = 15.6 - 3.3$

$\Delta t = 12.3$ years

25 The Michelson-Morley experiment yielded an unexpected result; that the motion of the Earth did not increase the velocity of light through the aether. Einstein suggested that the velocity of light is constant and is not dependent upon the motion of the source of light or the observer. Rather it is length and time that are relative. This was a complete change from Newtonian physics which stated that length and time were constant and velocity was relative.

26 A step-up transformer increases the potential difference in a circuit.

27 It had been observed that electrons will not travel from the cathode to the anode in certain situations but when a UV light shone upon them, they did bridge the gap. Einstein explained that because the light travelled in photons, a photon of low frequency emr would not give the electrons enough energy to escape the cathode to the anode. A photon of high frequency emr had enough energy that it would yeild enough KE with the electric field to bridge the gap. The intensity of the light was largely irrelevant. Even intense low frequency emr would not yield enough energy because it is the energy of the individual photon rather than the total energy of the emr.

This has been utilised in the solar cell. EMR enables the electrons to cross the junction in the diode and cause electrons to flow around the circuit.

28 There is an np junction in the solar cell. Electrons have travelled across the junction from the negatively doped semiconductor to the positively doped semiconductor to fill the holes. There is a slight conregation of electrons around the junction on the p-side and a congregation of holes around the junction on the n-side. This prevents any more electrons from travelling from the n-side to the p-side. When light falls on the solar panel, the electrons are given enough kinetic energy to travel across the

junction. When they do this, electrons migrate through the p-semiconductor and flow around the circuit back to the n-semiconductor, thus creating a current.

29 YBCO is a superconductor. When it is cooled to an extremely low temperature the crystal lattice is very still. The electroins form into pairs called cooper pairs and pass unimpeded through the superconductor as they do not strike any atoms in the crystall lattice. Rather the electrons tunnel through the lattice as the electrons slightly draw the atoms near to themselves.

30 Germanium was used as a semiconductor in early transistors as it was able to be refined to a suitable purity. Purity is important as if there are other elements in the semiconductor then they will be unintentionally doping the semiconductor and thus will no longer possess its properties which make it useful.

31 The oscilloscope allows the potential difference in a circuit to be mapped against time and has alos led to increased ability to communicate through the use of television.

32a Seismic tomography builds up information about the composition and internal structure of the Earth by showing the velocities of seismic waves in the mantle and the core.

32b A gravity meter consists of a large known mass, suspended by a very sensitive spring. The distance that the spring is extended is dependent upon the weight force and is therefore an indirect method of measuring the acceleration due to gravity at that point. Corrections must be maded for the latitude (taking into account the elliptical nature of the Earth, the altitude due to the topography and the mass of the rock lying between the ellipsoid and the gravimeter. When this is done, an archaeologist would be interested to note slight lower values for g. This could indicate a pocket of air due to some ancient buried building.

32c The outer core is thought to be fluid because it does not transmit S-waves and because of the way the Earth responds to the gravitational attraction of the Sun and the Moon. The inner core is thought to be solid because very large earthquakes cause the Earth to oscillate in a way that is only possible if it has a solid inner core. Also, a seismic wave which travels to and from the inner core as a P-wave but traverses the inner core as an S-wave has been recorded. And when a phase is reflected off the inner core, the amplitude of the phase suggests that it has a finite rigidity and is therefore solid.

32d Above 500°C all permanent magnetism in magnetite is destroyed. At 700°C, magnetite will crystallize. As it begins to crystallize, permanent magnets are set up in the magnetite crystals that are in line with the magnetic field of the Earth. This shows the orientation of the magnetic field of the Earth at the time the magnetite crystallized. Magnetite on the oceanic crust shows a constantly changing magnetic field indicating that the magnetic field of the Earth has changed with time. The further away from the mid oceanic ridge, the older the magnetite. The magnetite can also be dated radiometrically. Thus ages of particular magnetite samples have been established and these can be used to determine the age of rocks on the ocean floor.

32e Geophysicists have been able to monitor the adherence of nations to nuclear test ban treaties by analyzing the seismic waves which are given off by nuclear explosions. They can determine whether a nuclear explosion has taken place or an earthquake has occurred in conjunction with satellite photographs by analyzing any heat given off.

32f It was discovered that the asthenosphere which is a low velocity region is exceedingly weak and has fluid, viscous like properties. The lithosphere however is quite rigid and strong and can form sheets which can slide sideways over the asthenosphere. It was also discovered that the old oceanic crust is constantly being destroyed and new oceanic crust is constantly being created. These two facts helped

convince scientists (along with paleontological and geological evidence) that the Earth contains tectonic plates which move over the asthenosphere.

33a X-Rays are produced when a electrons decelerate as they reach the anode in a cathode ray tube. As they decelerate, they lose energy and give off this energy as X-rays. To produce a conventional X-ray image, the patient is bombarded with X-rays. Some of these X-rays are transmitted, some is absorbed and some is scattered. Some of the absorption is dependent upon the proton number, Z, so different tissue types will result in different amounts of X-rays being transmitted and therefore an image can be created that focusses on a particular tissue type, for example bones. The image is produced on photographic film or a fluorescent screen by the amount of X-rays that strike the film. In a CAT scan, X-rays are used however, the X-rays focus on a section of the patient. Many of these are taken and the image is built up from all of these sections by a computer. As a result, a 3D picture can be produced. A CAT scan would be superior when examining soft tissue such as a breast as it can detect small differences in the intensity of the X-rays transmitted.

33b A proton in the carbon-11 will decay into a neutron, a positron and a neutrino. When the positron encounters an electron, 2 gamma rays will be produced that travel in opposite directions. These gamma rays strike a gamma ray detector which is placed around the patient. The C-11 will have congregated in a certain section of the brain. Given that the gamma rays travel in opposite directions, a computer can measure how long each gamma ray took to strike the detector and therefore determine its position in the brain. The computer can then build up an image of where the C-11 has congregated.

33c The frequency of a wave will be different when it is moving to when it stationary. This is due to the changing velocity of the source of the wave. With an ultrasonic wave, the transmitter of the wave will emit a certain ultrasonic frequency. A portion of the wave will be reflected by the blood in the vein. It will have a different frequency because of the velocity of the source of the wave, that is the reflection

from the blood. The frequency of the reflected wave can be picked up by a separate transducer. A large difference between the transmitted frequency and the reflected frequency will indicate that the blood is travelling more quickly than when there is a small difference. A graph of velocity of blood vs position along the diameter of the vessel will yield a parabolic curve with the apex at the centre of the blood vessel. A variation in this graph will indicate a blockage such as a blood clot.

33d Hydrogen nuclei will spin. Because they are charged, when they are in a magnetic field they will precess around the magnetic field lines at a frequency similar to that of radio waves. If pulses of a radio wave are applied with the same frequency then another rotating magnetic field is set up which causes the axis of precession to alter. At the end of the pulse the axis of precession realigns itself with the magnetic field lines of the original magnetic field. Electromagnetic radiation is given off by the nuclei as this happens which is detected and the information analysed by a computer to build up a diagram of the location of hydrogen nuclei. Because there is a different amount of hydrogen nuclei in white matter and grey matter in the brain, the two types of matter can be distinguished.

34a Firstly, much of the emr emitted by stars will be absorbed by the atmosphere of the Earth. Therefore, the viewing of stars from the Earth is very much limited to visible light and radio waves. Secondly, the turbulence of the air results in the path of the emr deviating from a straight line. This means that the resolution is limited to 0.5 arcseconds at best. This is not as big a problem for radio waves who have a longer wavelength, however the resolution for radio waves is not good because of the long wavelength (the longer the wavelength, the poorer the resolution for a given size dish diameter). Interferometry utilizes many telescopes over a large area, and adding the information electronically. The result is similar to having a dish with a diameter the distance apart the telescopes are. A very good resolution can therefore be obtained, overcoming the problems of the long wavelength.

34b $d = 1/p$

$d = 1/0.01043$

$d = 95.88$ pc

34c When emr from the fusion reactions in the core is incident upon the atoms in the outer portion of the star, emr of specific frequencies is absorbed as the electrons are excited and jump up energy levels. The frequency is fixed as the amount of energy it can absorb and jump energy levels is fixed. The result is that when viewing the absorption spectra of stars, certain wavelengths are darkened because they have been absorbed by the electrons in the atoms. Each atom has characteristic wavelengths that can be absorbed by the electrons. The absorption spectra can therefore show which atoms are present in the star.

34d $d = 10^{1+(3.78-7.92)/-5}$

$d = 67.3$ pc

34e A V-colour value will yield the brightness of a star. A B-colour value will also yield the brightness of a star however this colour value is more sensistive to the blue end of the spectrum. Therefore a star that is blue in colour will have a B-value which is

slightly more negative than the V-colour value and a star that is red in colour will have a B-value which is slightly more positive than then V-colour value. So if the colour index (B-V) is negative then it is a blue star and if it is positive then it is a red star. Of course the spectrum of stars lies in between these extremes. This is useful because the colour of the star reveals the temperature of the star.

34f $d = 3.0 \times 10^{12}$

$m_1 + m_2 = 4\pi^2 r^3/GT^2$

$m_1 + m_2 = 4\pi^2 \times (3 \times 10^{12})^3/(6.67 \times 10^{-11} \times (18300 \times 60 \times 60 \times 24)^2)$

$m_1 + m_2 = 6.39 \times 10^{30}$ kg

34g The star has multilayered shells in which burning of different elements is taking place. When the forces from nuclear fusion is no longer sufficient to counter the weight force, the star will collapse under its own weight. The gases come rushing to the centre of the star. When the gases meet in the centre the energy creates a violent explosion called a supernova results, blowing away the material that formed the gases in the shells leaving an extremely dense core. The density is so great that the protons and electrons are forced together forming neutrons. The result is a neutron star that is extremely low in diameter but extremely high in density.

35a Bohr made three postulates. The first stated that electrons exist in stationary states in which they are stable. Any permanent change in their motion involves a complete change from one state to another.His second postulate stated that no radiation is emitted from an atom when the electrons are in their stationary state. Rather the radiation is absorbed when the electron moves to a higher state and is emitted when it moves to a lower state. This radiation has the frequency $f = \Delta E/h$. His third postulate was that an electron in a stationary state has an angular momentum that is $nh/2\pi$

The hydrogen emission spectrum consists of specif wavelentghs. These wavelengths correspond with the frequencies of the photons that are emitted when electrons travel from the higher energy states down to the lowest energy state.

35b $\lambda = h/mv$

$\lambda = 6.63 \times 10^{-34}/(9.11 \times 10^{-31} \times 4 \times 10^{5})$

$\lambda = 1.82 \times 10^{-9}$

$k = 4.00 \times 10^{-7} / 1.82 \times 10^{-9}$

$k = 220$

35c Davisson and Germer fired an electron beam onto nickel crystals which were wider than the electron beam. They observed diffraction patterns which are a phenomenon of waves and not particles.

35d A cathode fires electrons through an anode, accelerated by the electric field. The beam of electrons if coussed by either a magnetic or electric field onto the object being viewed. The electrons travel through the object. Using further electric or magnetic fields, the image is focussed onto a photographic plate or fluorescent screen. The degree to which an image can be resolved is determined by the wavelength of that which is creating the image. Given that the wavelength of the electrons is much smaller than visible light the resolution is much better and hence the image can be magnified to a much greater extent and still be in focus.

35e Thorium-201 is digested by the patient. As it is digested, it will move to the heart. As the Thorium emits gamma rays, they are picked up by a detector which using a computer builds an image of the heart. The image can then be studied to see if there is coronary heart disease or damaged muscle.

35f The uranium in the fuel rods splits apart. When it does so, there is a loss of mass from the reactants to the products. This mass has been converted into electromagnetic energy. This radiation causes the water to heat up and turn into steam. The heat turns into kinetic energy as the steam moves due to the pressure it is under. This drives a turbine which when interacting with a magnetic field will produce a current in the wire around the turbine.

35g 7 beta particles will also be produced.

Total mass of reactants = 236.0526 amu

Total mass of products = 235.7330 amu

Decrease is mass = 0.3196 amu

Energy = 0.3196 x 931.5

Energy = 297.7 MeV

36a An integrated circuit containing vavles would be far too large and heavy to be of much use as a military guidance system for aircraft and missiles. An integrated circuit with a silicon chip was more lightweight and much more compact and was invented for the miltary guidance systems. It impacted upon electonics by making electronic devices more durable and reliable because there were less connections between components, electronic devices became smaller and faster as there was less distance for the signals to travel and the cost of appliances was lowered as the integrated circuits could be produced at a cheaper cost.

36bi $R_v = (2200 \times 12 - 6 \times 2200)/6 - 650$

$R_v = 1.55\ k\Omega$

36bii The variable resistor accesses some of the potential difference so that only a certain amount is available for the output voltage. By varying the resistance in the variable resistor, the amount available is varied also.

When the variable resistor has an infinite resistance the output voltage would be zero.

When the variable resistor has no resistance, the output voltage would be $2.20/2.85 \times 12 = 9.26$ V.

36c With a light dependent resistor, the greater the amount of illumination, the lower the resistance. In a camera, the light dependent resistor would be exposed to the surrounding light. It could be a part of a potential divider. When there is a great deal of light, the resistance would be low. The potential divider could be arranged so that with the light dependent resistor in parallel with the output voltage, low light would result in a high output voltage and consequently the flash mechanism could be triggered. It would also adjust the aperture and shutter speed accordingly.

36d Light emitting diodes are pn junction semiconductors. Because of their difference in concentrations, electrons diffuse from the negative side to the positive side and holes from the positive side to the negative side. The result is a double layer of charge at the junction with the p-side negative and the n-side positive. When a potential difference is applied that is forward biased (that is, the potential difference will cause electrons to continue to travel from the n-side to the p-side), the electrons will fall into holes, losing energy and emit the energy as light).

36e

Gate 1	
Input	Output
0	1
1	0

Gate 2	
Input	Output
0	1
1	0

Gate 3		
Input A	Input B	Output
0	0	0
0	1	0
1	0	0
1	1	1

Gate 4		
Input A	Input B	Output
0	0	0
0	1	0
1	0	0
1	1	1

Gate 5		
Input A	Input B	Output
0	0	0
0	1	1
1	0	1
1	1	0

36f An inverting amplifier will result in a decrease in the output when there is a positive increase in the input and the output signal is also inverted (that is the outpuyt is negative when the input is positive). A non-inverting amplifier will result in an increase in the output when there is a positive increase in the input.