2014 SACE PHYSICS EXAM SOLUTIONS

QUESTION BOOKLET 1

1 As the wheel rotates the direction of motion of the reflectors changes.

This means that there is a change in velocity ($\Delta\vec{v}$) and hence an acceleration since $\vec{a} = \frac{\Delta\vec{v}}{\Delta t}$.

2 (a)

$$v_H = v\cos\theta = 43.4\cos 38 = 34.2 \quad ms^{-1}$$
$$v_v = v\sin\theta = 43.4\sin 38 = 26.7 \quad ms^{-1}$$

(b)

$$v = v_o + at \qquad \therefore \quad t = \frac{v - v_o}{a}$$

$$t = \frac{0 - 26.7}{-9.8} = 2.72 \quad s$$

$$Total \quad time \quad in \quad the \quad air = 2.72x2 = 5.44 \quad s$$

(c) $s = vt = 34.2x5.44 = 186 \quad m$

(d) Increasing the angle from 38^o up to 52^o will increase the range.

3 (a) $v = \sqrt{\frac{GM}{r}} \quad \therefore \quad M = \frac{v^2 r}{G} = \frac{(7.6x10^3)^2 x6.8x10^6}{6.67x10^{-11}} = 5.9x10^{24} kg$

(b) The centre of the satellite's orbit must coincide with the centre of the Earth otherwise the satellite's orbit won't be stable.

This is because the gravitational force must act towards the centre of the Earth and toward the centre of the orbit in order to provide the centripetal acceleration for uniform circular motion.

4 (a) Time for the laser to cross the water once

$$t_w = \frac{t_b - t_s}{2} = (\frac{2.36x10^{-4}}{2}) = 1.18x10^{-4} \quad s$$

$$depth = v_{laser \quad in \quad water} \; xt_w$$

$$= \quad 2.98x10^8 \quad x1.18x10^{-4}$$

$$= \quad 3.52x10^4 \quad m$$

(b) (i) Magellan travels over the poles scanning the surface below.

As Venus rotates beneath it, this allows the entire surface of Venus to be scanned.

(ii)

$$v = \frac{2\pi r}{T} = \sqrt{\frac{GM}{r}}$$

$$(\frac{2\pi r}{T})^2 = (\sqrt{\frac{GM}{r}})^2$$

$$\frac{4\pi^2 r^2}{T^2} = \frac{GM}{r} \qquad therefore \qquad r^3 = \frac{GMT^2}{4\pi^2}$$

(iii)

$$r = \sqrt[3]{\frac{GMT^2}{4\pi^2}} = \sqrt[3]{\frac{6.67x10^{-11} x4.87x10^{24} x(5.64x10^3)^2}{4\pi^2}} = 6.40x10^6 m$$

5 (a) One vector arrow drawn between the centre of any two of the black dots (puck A).

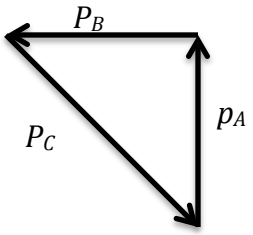
One vector arrow drawn between the centre of any two of the grey dots (puck B).

NB:This is because the mass of puck A and puck B is the same.

One vector arrow drawn between the centre of any three of the white dots (puck C).

NB:This is because the mass of puck C is twice that of puck A and puck B.

(b) A vector triangle that adds the three vectors.



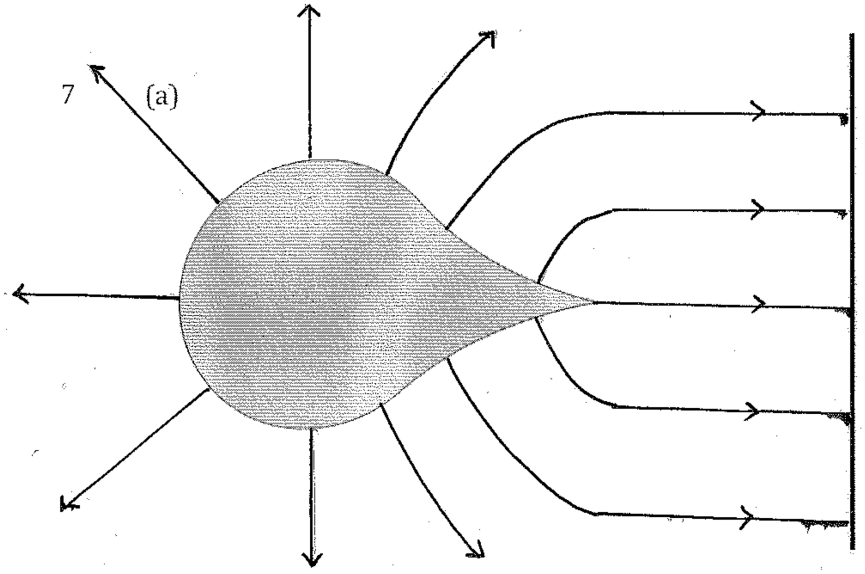
The vector triangle indicates that the total final momentum is zero.

The total initial momentum was zero.

Since the total initial and final momentum is equal (zero), momentum was conserved when the pucks were released.

6 $$E = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2} = \frac{9x10^9 x1.6x10^{-19}}{(5.29x10^{-11})^2} = 5.15x10^{-11} \quad NC^{-1}$$

7 (a)



(b) The positively charged electrode has a strong electric field surrounding it as it acts as a sharp point.

The strong electric field causes charges (negative) in the air to be attracted towards to electrode. The charges collide with neutral air molecules ionizing them (by knocking outer shell electrons out).

This creates positive ions that are repelled from the electrode.

8 The electric field between the long parallel plates is uniform.

This means that the electrons experience a constant force no matter where they are between the plates.

9 Using the right hand rule, the magnetic field at A due to conductor 1 is directed out of the page.

Since the total magnetic field at A is zero, the magnetic field at A due to conductor 2 must act into the page. Its magnitude will be the same as the magnetic field due to conductor 1 because the current flowing is the same.

This means that the current in conductor 2 must flow down the plane of the page.

10 (a) $$k = \frac{q^2B^2r^2}{2m} = \frac{(1.6x10^{-19})^2 x1.2^2 x0.32^2}{2x3.3x10^{-27}} = 5.7x10^{-13}J$$

(b) (i) The potential difference between the dees creates a uniform electric field. The electric field does work on the ions and they gain kinetic energy.

(ii) Increasing the potential difference creates a stronger electric field. More work is done every time the ions cross the gap. This means the ions gain more kinetic energy every time they cross the gap.

The ions therefore have a greater speed and trace a semicircular path of greater radius ($r = \frac{mv}{Bq}$).

The ions therefore cross the gap fewer times.

This means that overall the kinetic energy gained will be the same as gaining less energy per crossing of the gap but crossing the gap more times.

11 (a) (i) An arrow drawn at the top of the conductor pointing towards the top right hand corner of the page. E.g.

(ii)

$$F = BIl\sin\theta$$

$$\theta = \sin^{-1}(\frac{F}{BIl}) = \sin^{-1}(\frac{3.8x10^{-3}}{0.3x0.05x0.55}) = 27^o$$

(b) According to the equation $F = BIl\sin\theta$, the force on the conductor is directly proportional to the current.

A straight line through the origin should result. The line is straight but doesn't pass through the origin. This indicates that a systematic error is present.

12 (a) $F = qvB\sin\theta = 3.2x10^{-19}x4x10^{5}x0.14 = 1.8x10^{-14}N$

(b) The particles experience a constant magnetic force that acts at 90° to their velocity.

The magnitude of the velocity does not change but the direction does.

The magnetic force therefore provides the centripetal acceleration for uniform circular motion.

(c) (i) The magnetic force provides the centripetal acceleration for uniform circular motion.

$$F_{magnetic} = Bqv\sin\theta \qquad and \quad F = \frac{mv^2}{r}$$

$$\text{therefore} \quad Bqv\sin 90 = \frac{mv^2}{r} \qquad ie \quad r = \frac{mv}{Bq}$$

(ii) *Radius = half the diameter = 6.0 cm*

$$r = \frac{mv}{Bq}$$

$$m = \frac{rBq}{v} = \frac{0.06x0.14x3.2x10^{-19}}{4x10^{5}} = 6.7x10^{-27}kg$$

(iii) positive

13 (a) Horizontal

(b) City and country television stations are orientated at 90^{o} to one another. That is country signals are vertically plane polarised.

The antenna would be vertical in order to receive the vertically plane polarised country signals and not the horizontally plane polarised city signals.

14

$$d\sin\theta = m\lambda$$

$$d = \frac{m\lambda}{\sin\theta} = \frac{1x780x10^{-9}}{\sin 0.023} = 1.9x10^{-3}m$$

QUESTION BOOKLET 2

15 (a) 5.6 mm represents 4 fringe separations $4\,\Delta y$.

The average distance between adjacent fringes is therefore

5.6/4 = 1.4 mm

(b)

$$\Delta y = \frac{\lambda L}{d}$$

$$\lambda = \frac{d\Delta y}{L} = \frac{1.2x10^{-4}\,x1.4x10^{-3}}{0.3} = 5.6x10^{-7} \quad m$$

(c) Coherent light from the double slits travels different distances in arriving at A on the screen. This is called a the path difference.

The path difference is 2 wavelengths.

The light undergoes constructive interference to produce a bright band.

16 (a) $k_{max} = hf - W = 6.63x10^{-34}\,x1.9x10^{15} - (7.3x10^{-19}) = 5.3x10^{-19} \quad J$

(b) Increasing the intensity of the light increases the number of incident photons.

More electrons absorb the energy of one photon and are ejected.

The kinetic energy of the ejected electrons does not change. It is independent of the intensity of light.

17 (a) The potential difference does work on the electrons incident on the target metal. The electrons gain kinetic energy ($W = K = q\Delta V$).

If the electrons collide head on with the nucleus of the target atoms and all of their kinetic energy is transformed into an X-ray photon (law of conservation of energy) then the X-ray photon will have a maximum energy and hence frequency ($E = hf$).

If the potential difference across the tube is decreased, the incident electrons have less kinetic energy, so the X-ray photons have less energy and hence a lower frequency.

(b) Ionising radiation can break chemical bonds between atoms.

This can damage the cell so that it no longer performs its function or it can kill the cell.

18 (a) (i)

$$W = K = q\Delta V = \frac{1}{2}mv^2$$

$$v = \sqrt{\frac{2q\Delta V}{m}} = \sqrt{\frac{2x1.6x10^{-19}x10x10^3}{9.11x10^{-31}}} = 5.9x10^7 \quad ms^{-1}$$

(ii)

$$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{6.63x10^{-34}}{9.11x10^{-31}x5.9x10^7} = 1.2x10^{-11} \quad m$$

(b) Electron microscopes produce a much higher resolution.

Resolution is the ability to distinguish between two points that are very close together. Resolution is limited due to diffraction effects. Diffraction becomes noticeable if the separation of the point is comparable to the wavelength.

Traditional microscopes use light with a wavelength in the order of 10^{-7} m while electrons have a smaller wavelength in the order of 10^{-11}m. Therefore the two points can be closer (and hence the resolution is greater) if electrons with a smaller wavelength are used (ie before diffraction effects become noticeable).

19 (a) A vector arrow drawn from *n = 3* to *n = 2*.

(b) $E = hf = \frac{hc}{\lambda} = \frac{6.63x10^{-34}\,x3x10^{8}}{6.56x10^{-7}} = 3.03x10^{-19}\,J$

(c) $3.03x10^{-19}$ J = 1.89 eV

$\Delta E = E_3 - E_2 \qquad \therefore \quad E_2 = E_3 - \Delta E \quad = -1.51 - 1.89 = -3.40 \quad eV$

20 (a) A population inversion occurs when there are more atoms in an excited state (metastable state) than in the ground state.

In the helium-neon laser, the pump constitutes an electrical discharge.

The gain medium (neon gas) has a metastable state. Helium is added to facilitate a population inversion.

Electrons pass through the atoms of gas. The helium is easily promoted to its first excited state. This closely matches the energy gap between the ground state and the second excited state of neon.

Through physical collisions, the helium gas atoms promote the neon gas atoms to the second excited state. This is the metastable state for neon.

When this occurs in many atoms, a population inversion is said to have occurred.

(b) Spontaneous emission occurs when excited electrons return to a lower energy level automatically.

Stimulated emission occurs when a photon of energy corresponding to an electron transition from a higher-energy level to a lower-energy level is incident on an electron in the higher-energy level (metastable state). The electron is be stimulated/forced to make a transition to the lower energy level.

21 (a) Neutrino (b) Z: 28 A: 64

22 Using the law of conservation of momentum, the total initial momentum is zero (Pu was at rest) so the total final momentum must be zero.

This means that the uranium nucleus and the alpha particle must travel in opposite directions.

$$0 = m_U v_U + m_\alpha v_\alpha \qquad \therefore \qquad v_\alpha = -\frac{m_U v_U}{m_\alpha}$$

The uranium nucleus is approximately 60 times heavier than the alpha particle (240/4=60).

This means that the alpha particle's speed is 60 times larger

$$v_\alpha = -\frac{240 v_U}{4} = 60 v_U$$

23 (a) (i)

Mass of products $m\,^3_H + m\,^1_H = 5.008\text{x}10^{-27} + 1.673\text{x}10^{-27} = 6.681\text{x}10^{-27}$ kg

Mass of reactants $m\,^2_H + m_H = 2(3.344\text{x}10^{-27}) = 6.688\text{x}10^{-27}$ kg

$$\Delta m = \left| \; m_{products} - m_{\text{reactants}} \; \right| = 6.688x10^{-27} - 6.681x10^{-27} = 7x10^{-30} \quad kg$$

The products are lighter than the reactants - energy is released

(ii) $E = \Delta mc^2 = 7x10^{-30}\,x(3x10^8)^2 = 6.30x10^{-13}\,J$

(b) Likely decay – beta minus.

Tritium has excess neutrons. A neutron turns into a proton resulting in beta minus decay.

(c) Two half-lives have passed if ¼ the amount of tritium remains.

2 x 12.3 = 24.6 years have passed.

The claim that the wine was produced in 1970 is false (44 years ago). The wine was more likely to have been produced in 1990 (24 years ago).

24 (a) After alpha decay, the daughter nucleus is often left in one of a few excited states.

The nucleus decays to the ground state emitting gamma ray photon(s) of energy equal to the energy gap between the nuclear energy levels.

(b) $^{237}_{93}Np^{*} \rightarrow {}^{237}_{93}Np + \gamma$

25 (a) Complete the 5th column with the following numbers

1
2.5
5
7.8
10.6
13.4
16.2
19

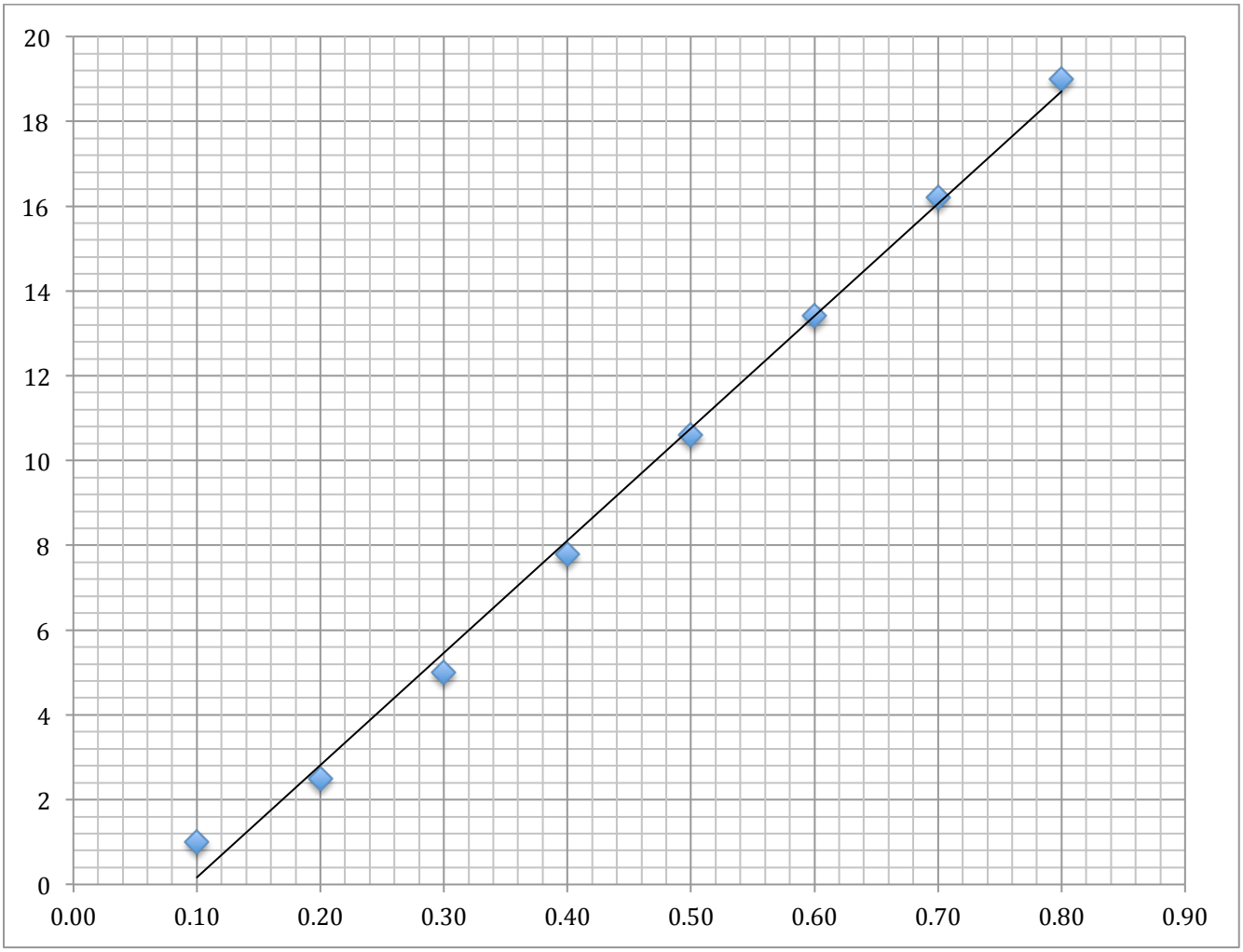
(b) The units are written next to each measurement. Units should be written at the top of each column.

The measurements for the average distance fallen should have a consistent number of significant figures.

(c)

Average distance fallen against time

Average distance fallen
cm



Time (s)

(d) $Gradient = \frac{rise}{run} = \frac{16}{0.7 - 0.09} = 26 \ \ cms^{-1} \ \ = 0.26 \ \ ms^{-1}$

(e) The units of the gradient indicate a distance per unit time and therefore a velocity (terminal).

(f) (i) The accepted/true value for the terminal speed is 0.25 ms^{-1}. The experimental value is close to this and is therefore accurate.

(ii) The plotted points lie close to the line of best fit. There is very little scatter. This means that the data is precise.

The table also indicates that repeated trials for the average distance fallen are close.

(g) A smaller area of cross section will result in less air resistance.

The smaller ball will take longer to reach terminal velocity.

The terminal velocity of the smaller ball will be greater.

QUESTION BOOKLET 3

26

Uranium reserves contain approximately 99% of the isotope uranium-238. Uranium-238 does not undergo induced fission. Less than one percent of uranium reserves contain the isotope uranium-235 which does undergo induced fission.

Enriched uranium is a sample of uranium in which the fraction of the isotope uranium-235 is increased.

When uranium-235 absorbs an incident neutron, it splits into two lighter, more stable nuclei and releases several neutrons and gamma radiation. The neutrons that are emitted after uranium-235 undergoes fission can go on and cause fission in other uranium-235 nuclei. This is called a chain reaction.

A chain reaction can only occur if the uranium is enriched. Enrichment ensures that there are enough uranium-235 nuclei available for the emitted neutrons to cause a continuous chain reaction.

One advantage of nuclear fission is that it releases approximately 200 MeV of energy per nucleus. Burning a fossil fuel such as coal only releases 2 – 3 eV per atom. Fission releases a lot more energy.

One disadvantage of nuclear fission is that the products are radioactive. This is because they have excess neutrons and will therefore undergo beta minus decay. Beta minus decay is a form of ionising radiation. It can break chemical bonds in the nucleus of a cell and or even kill the cell. As a consequence the products are difficult to handle and store. Radioactive is not a problem for fossil fuel power stations.

27

When light containing a range of frequencies is incident on the atoms of a gas, a line absorption spectrum is produced.

If the incident photons have a frequency and hence energy exactly equal to the energy gap between the energy levels of an atom, they can be absorbed by electrons. This will promote the electrons to a higher energy level. These photons will be removed from the range of frequencies incident on the atoms of gas while the other frequencies pass through the sample of gas. The 'missing' frequencies appear as dark lines on a continuous spectrum. The promoted electrons will return to lower energy levels and re-emit photons of light with the same frequency as the photons that were absorbed. However, these photons are scattered in all directions and are not observed.

A line absorption spectrum is unique to each atom. That is, the frequencies absorbed are different for different atoms because the energy levels are different in different atoms. To identify elements in a gas, the absorption spectrum of the gas is matched to the line absorption spectrum of a known element. If the position of the spectral lines is the same, the element must be present in the sample of gas.

A continuous spectrum contains all wavelength of light from red through to violet. If the temperature of the gas increases, the frequency of the emitted light increases (or wavelength deceases). This means that there is a shift in the spectrum. The spectrum will contain more violet light than red light (the wavelength of violet is shorter than the wavelength of red light). The frequency distribution graph shifts to the right as the temperature increases. It follows that the dominant colour for cooler objects is red and for hotter objects the dominant colour is blue/violet.

NB This effect is best illustrated by sketching the shift on a frequency distribution similar to the one given in the question.

In addition, if the object is at a higher temperature the frequency distribution shifts upwards. A higher temperature would produce brighter light. This means more photons are being emitted and the intensity increases.

NB This effect is best illustrated by sketching the shift on a frequency distribution similar to the one given in the question.