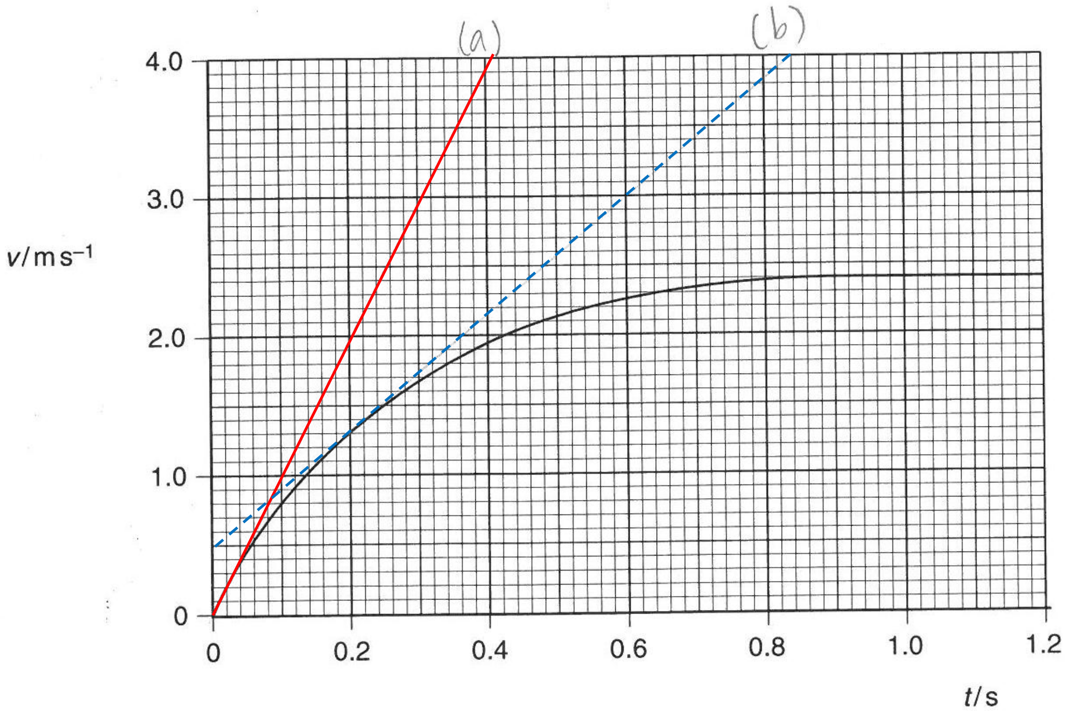
2012 H2 Physics A Level Paper 3

1

(a) Draw a tangent to the curve at t = 0 s. The gradient of this line is 9.81 m s^{-2}



(b) Gradient $= \dfrac{3.00 - 1.30}{0.60 - 0.20} = 4.25 \text{ m s}^{-1}$

(c) **(i)** Maximum resistive force occurs at terminal velocity.
Taking downwards as positive,
N2L
Weight - Resistive force = 0
Resistive force = Weight = 0.015 (9.81) = 0.147 N

(ii) Taking downwards as positive,
Weight - Resistive force = Net force
mg – Resistive force = ma
Resistive force = mg – ma = m(g – a) = 0.015 (9.81 – 4.25) = 0.083 N

(d) If resistive force F_R is proportional to speed v,
$F_R = kv$
At t = 0 s, v = 0 m s^{-1}, F_R = 0 N

At t = 0.2 s, v = 1.3 m s^{-1}, F_R = 0.083 N, $k = \dfrac{F_R}{v} = 0.064$

At t = 0.84 s, v = 2.4 m s^{-1}, F_R = 0.147 N (from c(i)), $k = \dfrac{F_R}{v} = 0.061$

Since the value of k is constant (to 1 s.f), the magnitude of the air resistance force is proportional to the speed of the ball.

2

(a) (Note, since this is a show question, working must be clearly explained. The use of
$F_C = F_G$ with no explanation of what the terms mean will result in marks being deducted.)

As planet is orbiting about the star,
Gravitational force by star on planet provides the centripetal force required for the planet's orbiting motion.

$$\frac{GMm}{x^2} = m\omega^2 x$$
$$GM = \omega^2 x^3 \quad \text{(shown)}$$

(b) (i) 49.9 Light Years = 49.0 x 3.0 x 10^8 x 365 x 24 x 60 x 60
= 4.64 x 10^{17} m
= 4.64 x 10^{14} km

(ii) From (a)

$$\omega^2 \propto \frac{1}{x^3} \quad \text{(Since } \omega = \frac{2\pi}{T}\text{)}$$
$$\frac{1}{T^2} \propto \frac{1}{x^3}$$
$$T^2 \propto x^3$$

Therefore the order of planets starting from the nearest to furthest. (Planet c, d, b, e)

(iii) Using $GM = \omega^2 x^3 = (\frac{2\pi}{T})^2 x^3$

For planet c

$$GM = (\frac{2\pi}{9.69 \times 24 \times 60 \times 60})^2 (1.35 \times 10^{10})^3$$
$$GM = 1.38575 \times 10^{20}$$
$$M = 2.07759 \times 10^{30} \text{ kg}$$

For planet e

$$GM = (\frac{2\pi}{4210 \times 24 \times 60 \times 60})^2 (7.83 \times 10^{11})^3$$
$$GM = 1.4324 \times 10^{20}$$
$$M = 2.1475 \times 10^{30} \text{ kg}$$

Average value of M = $\dfrac{2.07759 \times 10^{30} + 2.1475 \times 10^{30}}{2} = 2.11 \times 10^{30}$ kg

3 (a) $KE_{max} = \frac{1}{2} m x_0^2 w^2$

$75 \times 10^{-3} = \frac{1}{2}(0.590)(2.4 \times 10^{-2})^2 (2\pi f)^2$

$f = 3.34$ Hz

(b) Draw a horizontal line at $E_K = 40$ mJ (visually/relatively to suggest the whole curve shifted down). Therefore, Amplitude = 1.65 cm

4 (a)(i) The phase difference between light waves emitted from different sources(points of the light source) are constant.

(a)(ii) The vapour produces light through emission of photons on de-excitation of electrons in the atoms of the vapour. Since the process is random, the wave trains emitted are not coherent.

(b) Using $x = \lambda D/a$

From the diagram $5x = 10.4 \times 10^{-3}$ m

$x = 2.08 \times 10^{-3}$ m

Thus $2.08 \times 10^{-3} = (6.33 \times 10^{-9} \times 2.95)/a$

$a = 0.898$ mm

5 (a) At higher temperatures, the thermal energy possessed by the valence electrons is higher and more valence electrons can jump the forbidden band into the conduction band. They also leave behind holes in the valence band. When an electric field is applied, electrons in the conduction band can easily move into higher energy levels and holes in the valence band can also move in the opposite direction of the valence electrons. Although the increase in temperature also increases the lattice vibrations which increases resistance, its effect is less than the decrease in resistance due to the increase in the number of mobile charge carriers.

(b) The increase in temperature causes the lattice ions to vibrate with larger amplitude. Thus, the mobile electrons in the conduction band collide more frequently with the lattice ions, impeding current flow and increasing resistance. Although the increase in temperature also increases the number of mobile charge carriers a little (which decreases resistance a little), its effect is far less than that due to the increase in lattice vibrations.

6 (a) (i) Linear momentum of an object is the product of its mass and its velocity.

(ii) Force is the rate of change of momentum and it acts in the direction of the change in momentum.

(b) (i) The net momentum of a system remains constant provided no external <u>resultant</u> force acts on the system.

(ii) No. Since the net momentum is not zero initially, there must be a finite momentum at all times during the collision. If both trolleys were at rest simultaneously then the net momentum would be zero.

(c) (i) Given

$$KE_{\beta} = 0.74MeV = (0.74\times10^{6})(1.6\times10^{-19})$$
$$\frac{1}{2}m_e v^2 = 1.184\times10^{-13}$$
$$m_e^2 v^2 = 2(1.184\times10^{-13})(9.11\times10^{-31})$$
$$m_e v = \sqrt{2(1.184\times10^{-13})(9.11\times10^{-31})} = 4.64\times10^{-22}\ \text{kg m s}^{-1}$$

(ii) 1.

$$E_{photon} = \frac{hc}{\lambda}$$
$$(0.85\times10^{6})(1.6\times10^{-19}) = \frac{(6.63\times10^{-34})(3\times10^{8})}{\lambda}$$
$$\lambda = 1.46\times10^{-12}m$$

2.

$$p = \frac{h}{\lambda}$$
$$p = \frac{6.63\times10^{-34}}{1.46\times10^{-12}}$$
$$= 4.34\times10^{-22}\ \text{kg m s}^{-1}$$

(d) (i) As the initial net momentum of the system before the decay is zero, by the principle of conservation of linear momentum, the final net momentum of the system should also be zero. Nucleus Y has zero momentum after decay and since the magnitude of the momentum of both the β-particle and the γ-ray photon are almost the same as seen in the above calculations the β-particle and γ-ray photon should move off in approximately opposite directions.

(ii) The initial net momentum is zero and it needs to be conserved in all directions. Since nucleus Y has no momentum vertically, the vertical component of β-particle's momentum and the vertical component of γ-ray photon should be equal and in opposite directions, $p_{\beta}\sin\theta = p_{\gamma}\sin\phi$, where p_β is the momentum of β-particle and p_γ is the momentum of γ-ray photon.

7(a) (i) A field of force refers to a region in space where a body experiences a force when placed in it.

(ii) The electric field strength at a point in an electric field is defined as the electric force per unit positive charge acting on a small stationary test charge placed at that point.

(iii) If the test particle is not stationary, the force acting on the test particle may be due to the presence of a magnetic field instead of due to the electric field only.

b(i) It is the potential gradient at the point or it is the rate of change of potential V with respect to the distance r. (Note: if an equation form is given as an answer, i.e $E=-\frac{dV}{dr}$, the terms V and r must be defined.)

(ii)1. At x = 25.0cm, the potential gradient is negative, hence the field strength acts in the positive direction, which means in the A to B direction.

2. At x = 35.0cm, the potential gradient is zero

$$E = -\frac{dV}{dr} = 0$$

Force on electron = q E = 0

3. For static charge in a conductor, the electric field strength must be zero within the conductor. Since $E=-\frac{dV}{dr}$, there will be no change in potential and hence potential is constant for distance between x=0 and x=9.0 cm.

(c)(i) Data from graph:

x	V	Vx
0.14	550	77
0.19	420	79.8
0.21	390	81.9

Since the product of Vx is not constant, the student is incorrect

(ii) The expression Vx = constant $\Rightarrow V \propto \frac{1}{x}$ only applies to a single isolated charge and in this instance, there are two charged spheres, hence leading to the conclusion in **(i)** that the expression is not valid.

d(i) By conservation of energy,

Total initial EPE + KE = Total Final EPE + KE

$0 + 0 = qV + \frac{1}{2} m v^2$

$0 = -1.6 \times 10^{-19} (295) + \frac{1}{2} (9.11 \times 10^{-31}) v^2$

$v = 1.02 \times 10^{7}\ ms^{-1}$

(ii) The electron will accelerate towards the charges and cross the line joining the two centres of the sphere at x = 35 cm. After crossing the line, the electron will decelerate.

8

(a) **(i)** Nuclear decay is *spontaneous* because it occurs without any external stimulus.No external factors affect the rate or likelihood of nuclear decay.

(ii) Although the probability of decay per unit time is constant, it is impossible to predict when a particular radioactive nucleus will decay

(b) **(i)** $A = \frac{\Delta N}{\Delta t}$

(ii) Probability = $\frac{\Delta N}{N}$

(iii) $A = \lambda N \Rightarrow \lambda = \frac{A}{N} = \frac{\Delta N / \Delta t}{N}$

(c) **(i)** ${}^{90}_{38}Sr \rightarrow {}^{90}_{39}Y + {}^{0}_{-1}e$

${}^{90}_{39}Y \rightarrow {}^{90}_{40}Zr + {}^{0}_{-1}e$

(ii) $\lambda = \frac{\ln 2}{t_{\frac{1}{2}}} = \frac{\ln 2}{65 \times 60 \times 60} = 2.96 \times 10^{-6}\ \text{s}^{-1}$

(d) $N = N_0 e^{-\lambda t}$

$$\frac{N}{N_0} = e^{-\lambda t}$$

$$= e^{-\frac{\ln 2}{t_{\frac{1}{2}}} t}$$

$$= e^{-\frac{\ln 2}{28} 50}$$

$$= 0.290$$

(e) Due to the much shorter half-life of yttrium as compared to strontium, when the strontium decays to form yttrium, the yttrium would decay to zirconium in a much shorter time as compared to the time taken for strontium to decay to yttrium. Since the yttrium rapidly decays to zirconium, the amount of zirconium is almost equal to the number of strontium nuclei that have decayed.

(f) When the electrons (Beta particles) hit onto the lead shield, the beta particles experience a deceleration (or braking). The loss in kinetic energy of the beta particles results in the emission of photons which have the energy equal to the loss in KE experienced by the beta particles. Some of the photons emitted are in the range of X-rays.