ASSESSMENT REPORT 2020

PHY415115 – PHYSICS

The paper was a little shorter and more straightforward than previous, with no evidence of candidates having insufficient time to do all they could. The distribution of marks in all criteria was skewed to the top end, hence the high cut-offs for an A. Even with these high cut-offs there were still many EA's. This probably reflects the shorter paper, giving capable candidates time to solve the more demanding questions and thus show their potential.

The response to the either/or questions was interesting in that quite a number of candidates answered both and, when both were marked, they scored the same mark or very close to. Was this a tactic that students used to maximise scoring opportunities, rather than failing to follow instructions? No or little advantage was gained by doing both questions, and candidates would have been better off using their time to complete and correct other questions.

The cut-offs for the exam used this year were (out of 34):

Criterion	A	B	C
5	28.5	23	10.5
6	28	22.5	10.5
7	28.5	21	10.5
8	28	22	10.5

The answers to the examination are included at the end of the comments on individual questions.

PART 1 – CRITERION 5

Question 1 (Either)

(a) Generally done well.

(b) Not answered well by most candidates. Part marks were awarded if a reasonable explanation was provided, even with an incorrect "Yes" response.

(c) Done well by most candidates.

Question 2 (Or)

(a) Generally done well.

(b) Generally done well.

(c) Varying responses here. Many candidates made the error of just finding the kinetic energy using a speed of 17.5ms-1, rather than the change in energy. Some candidates incorrectly calculated the change in kinetic energy as $\Delta E_k = \frac{1}{2}m(v-u)^2$, instead of $\Delta E_k = \frac{1}{2}m(v^2-u^2)$, and were awarded generous part marks.

Question 3

(a) Very few candidates achieved full marks for this question. Most candidates drew a vector diagram that allowed for the ADDITION of the momentum vectors, instead of SUBTRACTION, and this was awarded no marks. Part marks were awarded if the correct diagram was drawn, but without an (or an incorrect) arrow for the change in momentum vector.

(b) Most candidates correctly answered this question. Some found a scalar difference between the initial and final momentums, which was only awarded 0.5 marks.

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(c) This question was generally done well.

(d) Most candidates were able to find the direction easily. Describing the direction with respect to the initial momentum proved more of a challenge. The most successful candidates drew a diagram to indicate the direction (or referred to the diagram in part (a)). Specifying "to the horizontal" was a common occurrence, without reference to the initial momentum. Candidates who used south and east/west were awarded marks if they established that the initial momentum was eastward. Full marks were awarded for an appropriate response, with an error carried forward from part (a).

Question 4

(a) Relatively few candidates achieved full marks for this question. Many attempted using either an equation of straight-line motion, or an equation of uniform circular motion, neither of which are relevant in this case (even though the former will yield a correct answer). For full marks, candidates needed to use a conservation of energy approach.

(b) Most candidates achieved full marks for this question, with the majority of these using the direct approach detailed in the examiner's solutions. Some others successfully managed to work through a more convoluted approach using multiple equations of motion.

(c) Most candidates achieved full marks for this question. The majority of these candidates started with $s = ut$ and solved the problem directly, while there was evidence to suggest that others relied on the 'show that' nature of the question to find the path to a solution via either mathematical logic or a process of elimination.

(d) There was a broad range of responses to this question. Many candidates arrived at the correct answer by stepping through a logical argument. Others immediately saw that the equation for x is independent of g. For the candidates who did not properly understand the question, part marks were awarded for sensible statements about the effects of lower gravity in a simpler horizontal projection context.

Question 5

(a) Relatively few candidates achieved full marks for this question. Many attempted a ratio approach, but either failed to square the periods or failed to cube the radii. Others set up a ratio-based solution correctly, but failed in the execution of the calculations. A reasonable number of candidates attempted to solve the problem by finding the mass of the sun. This approach was awarded full marks when it succeeded, but most candidates who attempted this approach made multiple calculation errors.

(b) There was a broad range of responses to this question. A reasonable number of candidates correctly set $g = a_c$ and successfully solved for velocity. Most who attempted this approach succeeded. Another significant proportion of candidates attempted $v = \frac{2\pi r}{T}$ using Kepler's Law for the period. Those who attempted this approach frequently made calculation errors. Others attempted to use the period of orbit of Bennu around the Sun as the period of orbit of OSIRIS-REx around Bennu, indicating a failure to properly understand the context of the question.

(c) Most candidates approached this question correctly, but calculation errors were surprisingly common. The most frequent of these was a failure to square the radius of Bennu in the calculation of g, despite having included the square when writing the equation.

(d) (i) Candidates were generally successful in this question, although many arrived at $v = \frac{2\pi r}{T}$ via $\frac{v^2}{r} = \frac{4\pi^2 r}{T^2}$, which cost them time and resulted in many unnecessary calculation errors.

(ii) Very few candidates achieved full marks for this question. A large number incorrectly argued that the apparent acceleration due to gravity would exceed the gravitational field strength, due to the 'additional' centripetal force present at the equator. Part marks were awarded for sensible statements about the centripetal, normal and gravitational forces, even if the candidate did not reach the correct conclusion. Part marks were also awarded for correct calculation of the centripetal force and/or acceleration.

Question 6

(a) This question was not done well. Candidates were clearly confused with the only "two forces" being required. Half marks were awarded for three drawn force vectors (weight, normal and friction), but only IF the vectors were drawn to demonstrate equilibrium.

(b) This question was generally done well. A number of candidates interchanged the answers for (i) and (ii), resulting in part marks being awarded.

(c) There was large variance in responses here. Many candidates described the resulting motion, but did not perform a calculation, as specified in the question, thus achieving part marks. Full marks were awarded for describing the motion as accelerating down the slope due to the weight component parallel to the slope now being more than the frictional force, AND a calculation of the resulting acceleration. Errors were carried forward from part (b)(ii).

PART 2 – CRITERION 6

Question 7 (Either)

(a) This question was mostly done well, although some omitted to include the direction.

(b) Most students could calculate these values correctly. Some forgot to include the negative charges or calculated the charge incorrectly.

(c) No marks were awarded for no / yes alone; responses needed justification in terms of integer multiples of elementary charge. 0.5 was given for some reference to the charge of an electron.

Question 8 (Or)

(a) For full marks, students needed to identify that the plate was negative and justify this by referring to the magnetic force being to the right and the electric force to the left. A number of students thought the plate was positive in order to repel the positive charges on a circular path; this showed a fundamental misunderstanding of the mass spectrometer.

(b) Done well.

(c) Done well.

(d) Mostly done well, although some students used a charge of 1 instead of 1.6×10^{-19} C and earned half marks.

Question 9

(a) Generally done well.

(b) For full marks, students needed to state that P was negative and justify in terms of the fact that the force on a positive charge was downwards / current downwards. Some students stated current was down but therefore concluded that P was positive; this is confusing the direction of current flow from positive to negative in an external circuit with what is going on in a source of EMF. These students earned half marks. Justifications that simply referred to RHR without mentioning that current / positive charge is downwards earned 1.5./2 Some students referenced the LHR instead of the RHR and hence gave an incorrect answer. The markers do not recommend use of the LHR for this reason.

(c) This was poorly answered. Many students did not realise that an eddy current is circular, and fewer drew the correct position and direction of the eddy current(s).

(d) Many students earned partial credit for some mention of Lenz's law and the induced current 'opposing the motion' but did not explain it in full. Full explanations needed to refer to the induced current creating a magnetic field, which creates a magnetic force that opposes the motion. Alternative explanations that earned full marks included explanations in terms of conservation of energy.

Question 10

(a) This was generally done well as directions were ignored in this question, although some students tried to add the two fields using the Pythagorean Theorem rather than recognizing that these fields are linear.

(b) Done well.

(c) Full marks were awarded for answers using $F = BI\Delta l$ and the field strength calculated in part (a). However, the majority of students used the parallel wires equation and received part marks.

(d) Mostly done well.

Question 11

(a) Many students used the wrong radius in this question and received part marks.

(b) As with part (a), many students again used the wrong radius and received part marks.

(c) A range of radii were accepted, as the question was worded 'near the dome' so any value close to 0.15 m (including 0.2 m) was accepted. A common error was to forget to square the radius, but otherwise done well.

(d) This question was confusing for many students. Full marks were awarded when students explained that the field strength increased due to charge separation in the main dome. However, many students instead explained why a spark occurs due to a potential different (regardless of the breakdown field strength); these students received part marks.

(e) Few students received full marks on this question, although most could show the general shape of the field. Common errors included:

- not including the charge distribution
- not showing the increased field strength between the main dome and the small sphere
- not showing the field lines on the other side of the main dome
- poorly drawn and unclear diagrams.

Question 12

(a) This question was generally done well, although some used the wrong radius or did not convert the radius to metres.

(b) Done well.

(c) Mostly done well, although some students found the area in km^2 and others incorrectly divided the area by the current range rather than the other way around.

PART 3 – CRITERION 7

Question 13 (Either)

All parts were very well answered.

Question 14 (Or)

This question was found to be the more difficult of the choices and the common errors were:

- the use of the velocity of sound rather than c in part (a)
- drawing multiple waves in the antenna in part (b)
- not realising the lack of diffraction would cause shadows in the city and limit coverage in part (d).

Question 15

Parts (a), (b) and (c) were very well answered. The rest of the question was a discriminator, with it being either well answered or answered very poorly. Those students who understood the relationship given in part (c), and how it could be displayed graphically, excelled in the latter part of this question. There are multiple ways of completing parts (d) to (f), some much more complex than others. Drawing a $T \sim f^2$ graph, having a gradient of μ, was the easiest way and chosen by quite a few candidates.

Question 16

(a) Poorly answered, with few candidates realising the 3rd, 4th and 5th harmonics were given, so the instrument was open as an even harmonic was present.

Both (b) and (c) were well done, but error carried forward had to be applied on a regular basis.

Question 17

This question confused a high proportion of the candidates, although there were some excellent answers.

Parts (a) and (b) of this question were poorly done as many did not understand the movement of points x and y.

Part (c) required a realisation and statement that sound had only one direction of particle movement and as such could not be polarised.

Question 18

This question was surprisingly well done considering the complexity of the diagram. Part (d) was poor, as there were two reasons for the faintness of the e-ray and most candidates just gave one.

PART 4 – CRITERION 8

Question 19 (Either)

(a) Generally well done. Marks were lost for not including the type of force, or that the charges were responsible for the unbalanced force. Many students suggested the electron would be repelled by the nucleus, or gain energy as it passed.

(b) Very well done. Points were lost for a path that suggested a repelling force.

(c) Very well done. The most common error was failing to match the energy of the electrons with the correct value of Planck's constant.

(d) Moderately well done. Successful students recognised that the wavelength corresponded to an electron giving up all of its kinetic energy, which is unlikely unless it collides with a nucleus.

Question 20 (Or)

(a) Both parts were very well done.

(b) Well done. Common mistakes were drawing a horizontal line between the 0 and 1 excitation level, rather than finding a difference between energy levels that corresponds to the answer, or stating that transition did not exist.

(c) Well done. Common wrong answers were 5 eV, 0 eV and 0.11 eV.

(d) Well done. Successful students recognised that the voltage corresponded to an electron energy of 40 eV, which clearly exceeds the ionisation energy of 10.4 eV on the diagram.

Question 21

(a) Many forgot to convert 52 kg to grams.

(b) Many failed to convert half-life values to seconds, therefore did not calculate the actual activity, a quantity that is measured in Becquerel ie decays s^{-1}.

(c) A poorly done section, with many students failing to use the alpha decay half-life. The resulting answer was therefore 0.717% rather than 3.86%.

Question 22

(a) Well done by students.

(b) Well done by students.

(c) Mostly well done but a number gave the product as $_{8}O$, rather than $^{13}_{8}O$, while others forgot the neutrino and/or added "energy" to the equation.

(d) Either well done or students completely missed the answer.

Question 23

(a) Well done.

(b) Generally well done.

(c) Poorly done. Some used a mechanical reasoning based on P = Fv, which cannot be applied here. Most who started by finding the momentum of a single photon $p = h/\lambda$ then multiplied by the value obtained in part (b) correctly, but failed to include the fact that the momentum change is doubled by reflection.

(d) Many interesting explanations were given, a number of which were relevant.

Question 24

(a) Poorly done. A lot of students did not fully read or understand the question, and these students wrote down excess and unnecessary information about "Black Bodies" – much of it wrong. Understanding of "Black Bodies" is clearly an issue across the cohort.

(b) Very well done. Simply reading the value off the information sheet was enough.

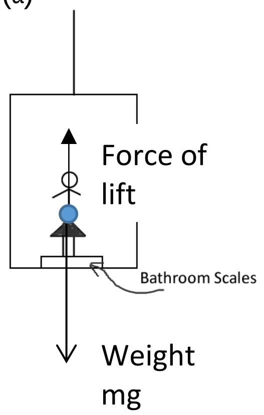
(c) Very well done. A simple substitution. Students are encouraged to leave the temperature in Kelvin, as 2.73K was converted to 272.23°C a significantly large number of times.

SOLUTIONS

PART 1

Question 1

(a)



(b) Incorrect - weight does not change but remains at 65.4 x 9.81 N = 641 N

(c) F_{net} = weight down + lift floor up

= 641 down + 62.0 x 9.81 up N

= 32.8 N down

= ma (Newton's Second Law)

a = 32.8/62.0 ms^{-2} down

= 0.530 ms^{-2} down

Question 2

(a) m = $\rho V = 1.23 \times r \times \pi \times r^2 \times h = 3.09 \times 10^5$ kg

(b) $E_k = ½ mv^2 = 0.5 \times 3.09 \times 10^5 \times 18.0^2 = 50.1$ MJ

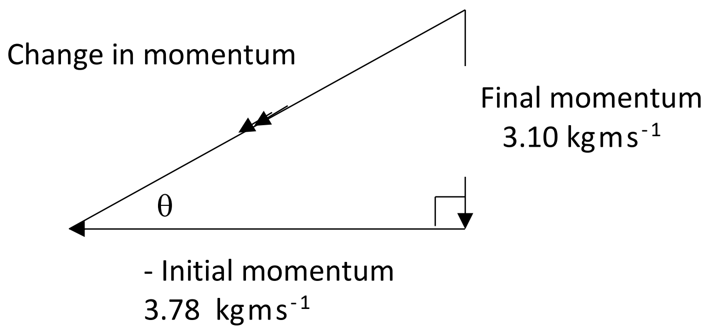
(c) Power = $\Delta E_k /t = (0.5 \times 3.09 \times 10^5 \times 18.0^2 - 0.5 \times 3.09 \times 10^5 \times 17.5^2) /1$

= (50.1 – 47.3) MW

= 2.8 MW

Question 3

(a)



(b) Magnitude is given by Pythag Thm

$$\Delta p = \sqrt{3.78^2 + 3.10^2} = 4.89 \text{ kgms}^{-1}$$

(c) Force = $\Delta p / t = 4.89 / 10^{-3} = 4.89 \times 10^3$ N

(d) Direction tan θ = 3.10 /3.78 gives the angle at 39.3^0 to the original direction or deflected 140.6^0 right.

Question 4

(a) E_p lost = E_k gained Height = radius, r, of arc thus mgr = ½ mv^2 gives desired $v = \sqrt{2gr}$

(b) Vertically s = ½ at^2 This becomes h = ½ gt^2 leading to desired $t = \sqrt{\frac{2h}{g}}$

(c) Distance x in forward direction x = vt

Substitute (a) and (b) gives $x = \sqrt{2gr} x \sqrt{\frac{2h}{g}}$ leading to $x = 2\sqrt{rh}$

(d) Same distance as final equation for x is independent of the gravitational acceleration.

Question 5

(a) Using Kepler's Third Law

$$T_B = T_E \left(\frac{r_B}{r_E}\right)^{\frac{3}{2}} = 365\left(\frac{1.68}{1.50}\right)^{1.5} = 432 \text{ days}$$

(b) Use $g = \frac{GM}{r^2} = \frac{v^2}{r}$ gives $v = \sqrt{\frac{GM}{r}} = 0.0187$ ms^{-1}

(c) Gravitational Field Strength $g = \frac{GM}{r^2} = \frac{6.67x10^{-11}x\ 7.32\ x\ 10^{10}}{245^2} = 8.13\ x\ 10^{-5}$ Nkg^{-1}

(d) (i) $v = \frac{2pr}{T} = \frac{2px245}{4.30x3600} = 0.0994$ ms^{-1}

(ii) The apparent acceleration due to gravity would appear less as the object's spin on the equator places it closer to being in orbit.

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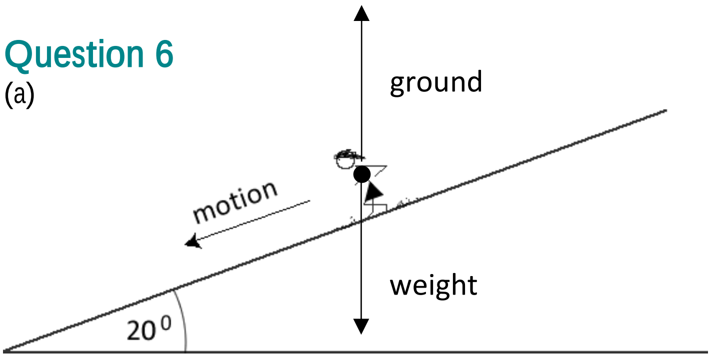
Question 6

(a)



(b) (i) Normal force = mg cos 20^0 = 553 N at right angles to surface upwards

(ii) Frictional force = mg sin 20^0 = 201 N backwards up slope

(c) In this situation F_{un} = 201 N downhill +100 N uphill = 101 N downhill = ma
Person accelerates at

$$a = 101/60\ ms^{-2} \text{ downhill}$$
$$= 1.68\ ms^{-2} \text{ downhill}$$

PART 2

Question 7

(a) Ball is stationary thus electric force = weight = 5.59×10^{-15} N

(b)

Ball	Potential Difference V	Electric Field Strength NC^{-1}	Charge on Ball C
1	+76.2 V	19100 up	$+2.93 \times 10^{-19}$
2	-72.1 V	18000 down	-3.1×10^{-19}
3	-140.8 V	3520 down	-1.59×10^{-19}

(c) Approximately ±1,2 multipliers of 1.6×10^{-19} C therefore reasonable evidence of elementary charge.

Question 8

(a) Magnetic force is to the right so electric force must be to the left. Left plate A must be negative

(b) E = V/d = 75 / 5 x10^{-3} = 1.5 x 10^4 NC^{-1}

(c) In a velocity filter v = E/B = 1.5 x 10^4 / 0.150 = 10^5 ms^{-1}

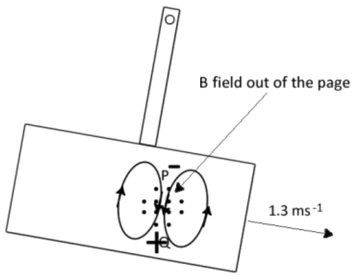
(d) $$m = \frac{rqB}{v} = \frac{0.245 \text{ x } 1.60 \text{ x}10^{-19} \text{x } 0.150}{10^5} = 5.88 \text{ x } 10^{-26} \text{ kg}$$

Question 9

(a) EMF = vlB = 1.30 x 0.02 x 0.25 = 0.0065 V = 6.5 mV

(b) By Right Hand Rule, Q is positive so P is negative

(c)



(d) A current is generated in the magnetic field due to the separation of charge. The direction of the current in the field will be down so by F = IlB and RHR, a force AGAINST the motion will exist bringing the plate to a halt.

Alternatively, energy is lost as ohmic heating in the plate so this will be taken from the potential and kinetic energies bringing the plate to a halt.

Question 10

(a) At X, B_P = 2 x 10^{-7} I/r = 5.00 x 10^{-5} T INTO the page while B_Q = 1.00 x 10^{-4} T OUT OF the page
B_{Total} = 5.00 x 10^{-5} T OUT OF the page

(b) Out of the page from (a)

(c) F =IlB thus F/l = IB = 5.00 x 10^{-5} x 6.00 = 3.00 x 10^{-4} Nm^{-1}

(d) By RHRule it will be towards wire Q

Question 11

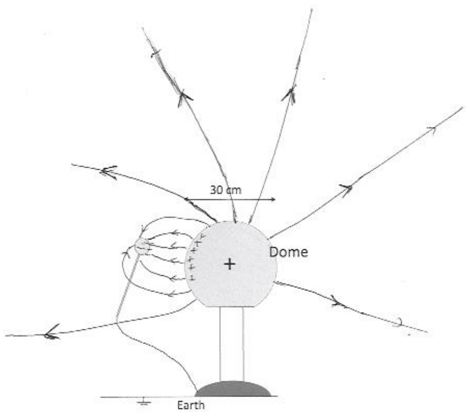
(a) Approximately $E = V/d$, so $V = Ed = 3 \times 10^6 \times 0.05$ volts $= 1.5 \times 10^5$ volts

(b) From the given equation $Q = Vr / k_E = 1.5 \times 10^5 \times 0.15 / 9 \times 10^9 = 2.5 \times 10^{-6}$ C = 2.5 μC

(c) $E = k_E Q / r^2 = 9 \times 10^9 \times 2.5 \times 10^{-6} / (0.15)^2 = 1 \times 10^6$ N C^{-1}

(d) Field Strength increases between domes due to negative charge being attracted onto the secondary ball by the positive on the main dome. The presence of more charge increases the field strength particularly between the plates.

(e)



Question 12

(a) $$Q = \frac{Er^2}{k_E} = \frac{200\,(6.4 \times 10^6)^2}{9 \times 10^9} = 9.10 \times 10^5 \text{ C}$$

(b) $V = Ed = 200 \times 10^5 = 2 \times 10^7$ V

(c) $I / A = 2000 / 4 \times 3.142 \times (6.4 \times 10^6)^2 = 3.89 \times 10^{-12}$ A, current per unit area = 3.89 pA

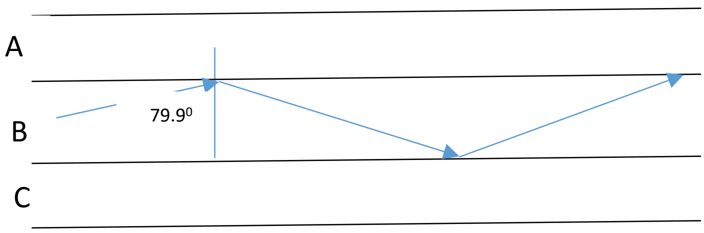
PART 3

Question 13

(a) Snell's Law $\frac{\sin q_A}{\sin q_B} = \frac{v_A}{v_B}$ gives $\frac{\sin 30^0}{\sin q_B} = \frac{1540}{1516}$ gives $q_B = 29.5^0$

(b) Critical angle between B and A 1540 $\sin\theta_{crit} = 1516$ gives $\theta_{crit} = 79.9^0$

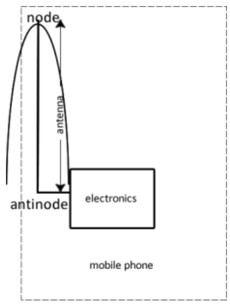
(c) Sound can be fully internally reflected along the channel B as both A and C have higher velocity speeds of sound hence lower relative refractive indices.



Question 14

(a) Using $\lambda = c/f$ (i) 4G $\lambda = 0.143$ m (ii) 5G $\lambda = 0.0115$ m = 11.5 mm

(b)

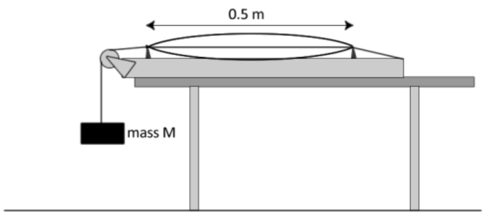


(c) Typical length would be ¼ of the wavelength = about 3 mm

(d) Very small wavelength therefore unlikely to diffract very much so line of sight transmission. Need many transmitter stations.

Question 15

(a)



(b) Double the length of the wire so λ = 1m.

(c)

Two relevant equations $v = / f$ and $v = \sqrt{\frac{T}{m}}$

As $/ = 1m$, $v = f = \sqrt{\frac{T}{m}}$

(d) Two possible ways of completing this:

(i) Either using f^2 as a vertical axis

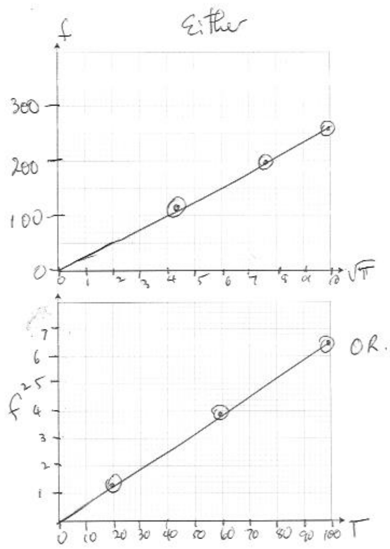
Or

(ii) $\sqrt{T}$ as an horizontal axis

(d)

Mass kg	2	6	10
Tension N	19.6	58.9	98.1
Either $\sqrt{T}$	4.43	7.67	9.90
Frequency Hz	114	198	256
Or f^2	1.30×10^4	3.92×10^4	6.55×10^4

(e) Either



(f) Either $f \sim \sqrt{T}$ graph. Slope = 256 /9.90 = 25.9 = $\frac{1}{\sqrt{m}}$ gives μ = 0.0015 kgm^{-1}

Or $f^2 \sim T$ graph. Slope = 6.55×10^4 / 98 = 668, μ = 1/ slope = 0.0015 kgm^{-1}

Question 16

(a) The resonances are successive integer multiples of 88 Hz; 88 x 3 = 264 Hz , 88 x 4 = 352 Hz, 88 x 5 = 440 Hz therefore the pipe is acting as an OPEN pipe.

(b) From the above 88 Hz.

(c) In an open pipe, the length = ½ wavelength at the fundamental. Taking the speed of sound as 344 ms^{-1}, wavelength = 344 / 88 = 3.91 m gives the pipe length of 1.95 m.

Question 17

(a) Component point X – the movement resembles the longitudinal motion of a molecule in moving as a pure single frequency sound wave.

(b) Component point Y – the motion resembles the transverse wave motion of either the electric field or magnetic field of an electromagnetic wave.

(c) The wave generated by X – as it is longitudinal it cannot be polarized by some blocking mechanism at right angles to the wave direction.

Question 18

(a) (i) $\frac{\sin q_i}{\sin q_R} = \frac{n_R}{n_i}$ gives $\frac{\sin 22^0}{\sin q_R} = 1.486$ gives $q_R = 14.6^0$

(ii) $\frac{\sin q_i}{\sin q_R} = \frac{n_R}{n_i}$ gives $\frac{\sin 22^0}{\sin q_R} = 1.658$ gives $q_R = 13.1^0$

(b) $\frac{\sin q_i}{\sin q_R} = \frac{n_R}{n_i}$ gives $\frac{\sin q_c}{\sin 90^0} = \frac{1.55}{1.658}$ gives $q_c = 69.2^0$

(c) $\frac{\sin q_i}{\sin q_R} = \frac{n_R}{n_i}$ gives $\frac{\sin 76.94^0}{\sin q_R} = \frac{1.55}{1.486}$ gives $\sin q_R = 0.934$ so $q_R = 69.1^0$ This is a real refraction so some e-ray will pass into the junction.

(d) The resulting light passing through will be dim as all the o-ray light is lost and, because the light onto the glue junction is at a high angle of incidence, light will lost in reflection on the junction. Some light will also be lost at the surface of the crystal.

PART 4

Question 19

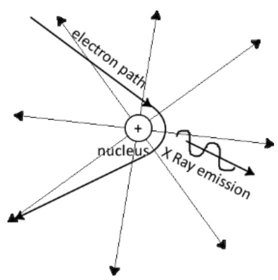
(a) Extremely strong attraction between the positive nucleus and the negative electron. Coulomb's Law in place giving a value at a distance of say 10 fm, a force of about

$$F_E = \frac{9x10^9\,xZx(1.6x10^{-19})^2}{(10^{-14})^2}$$ where Z = atomic number of nucleus. Assume Z= 1

gives F ~ 2N so acceleration a ~ 10^{30} m s^{-2}

The very high mass of the nucleus means that it will remain essentially in place so the electron will be forced to change direction strongly when close to the nucleus.

(b)



(c) (i)

E_p lost = photon energy gained qV = hc / λ

$1.60 \times 10^{-19} \times 5 \times 10^4 = 6.63 \times 10^{-34} \times 3 \times 10^3 / \lambda$

Gives $\lambda = 2.48 \times 10^{-11}$ m

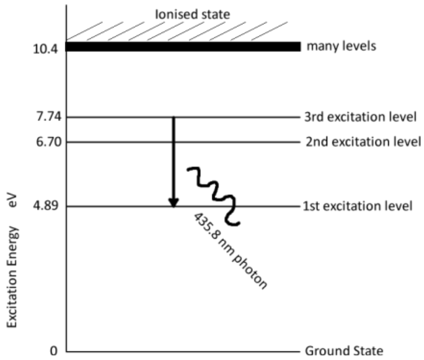
(ii) Most electrons will pass at greater distances than very close to the nucleus so have less acceleration. This will lead to lower energy photons.

Question 20

(a) Photon energy in eV = hc / λ, h = 4.14 x 10^{-15} eVs

(i) Substituting λ = 435.8 nm gives E = 2.85 eV
(ii) Substituting λ = 546.0 nm gives E = 2.27 eV

(b)



(c) The only emission would be a 4.89 eV photon.

(d) Highly ionised as ionisation is reached with electrons of energy 10.4 eV. 40 eV electrons will clearly eject atomic electrons from the atom structure.

Question 21

(a) $\frac{N}{N_A} = \frac{m}{M}$ where m = 52000 g and M = 235 g mol^{-1}

This gives N = 1.33 x 10^{26} atoms

(b) A = λ N = 0.693 x N / $T_{1/2}$ = 0.693 x 1.33 x 10^{26} / 3.5 x 10^{17} x 365 x 24 x 3600
= 8.35 Bq

(c) A = λ N = 0.693 x N / $T_{1/2}$ = 0.693 x 1.33 x 10^{26} / 7 x 10^{8} x 365 x 24 x 3600
= 4.17 x 10^{9} Bq

(d) Present percentage = original percentage x $e^{-\lambda t}$

So Original percentage = $0.717e^{\frac{0.693x1.7x10^9}{7x10^8}} = 0.717e^{1.683} = 0.717x5.38$ = 3.86%

Question 22

(a) Mass difference = mass of products – mass of reactants
= (13.00574 +1.00867) – 14.00307 = 0.01134 u

(b) The mass of the products EXCEEDS the mass of the reactant by 0.01134 u so the equivalent mass as energy must be put in in the form of a photon.

Energy needed minimally = 0.01134 x 931 MeV = 10.56 MeV = minimum photon energy

(c) $^{13}_{7}N \rightarrow ^{13}_{6}C + ^{0}_{1}e + ^{0}_{0}n$

(d) Minimum energy of a gamma photon = mass energy of an electron
= 0.000549 x 931 MeV
= 0.511 MeV

Question 23

(a) $E = hc / \lambda = 6.63 \times 10^{-34} \times 3 \times 10^{8} / 450 \times 10^{-9} = 4.42 \times 10^{-19}$ J

(b) Power = Energy change / time
Taking one second of time Total energy = 1.70×10^{3} J= n x energy of one photon
$n = 1.70 \times 10^{3} / 4.42 \times 10^{-19}$
$= 3.85 \times 10^{21}$ photons
Approximately 4×10^{21} photons each second

(c) Force = change of momentum / time
= 2 x momentum of all photons in one second of light as 100% reflectance
Momentum of one photon = $h / \lambda = 6.63 \times 10^{-34} / 450 \times 10^{-9} = 1.47 \times 10^{-27}$ kgms^{-1}

Force = $2 \times 1.47 \times 10^{-27} \times 3.85 \times 10^{21}$ N = 1.13×10^{-5} N

(d) Over several months the time could be long enough to significantly change the momentum of the spacecraft. (2 months is approximately 5.2×10^{6} s so change in momentum could be about 60 kgms^{-1})

Question 24

(a) A perfect "black body" both absorbs and emits ALL wavelengths of electromagnetic radiation a 100% efficiency.

(b) The Microwave part of the spectrum

(c) Using $\lambda_p T = 2.90 \times 10^{-3}$ then $T = 2.90 \times 10^{-3} / 1.063 \times 10^{-3} = 2.73$ K

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