Physics 2018 PHY4   Solutions

Part 1

Question 1

(a) The force required on the classical bow becomes greater and greater meaning it will be hard to hold steady when at maximum pull. In contrast, the compound bow has a lower pullback force at 0.6m so while it is harder to pull back at first, it becomes easy to hold in the position to aim.

(b) (i) Work Done = area under the graph = ½ x 300 x 0.6 J = 90 J

(ii) Work Done = area under the graph

= ½ x 200 x 0.2 + 0.3 x 200 + 50 x 0.1 + ½ x 150 x 0.1

= 92.5 J

(c) The system is 60% efficient therefore 60% of 92.5 J = 55.5 J

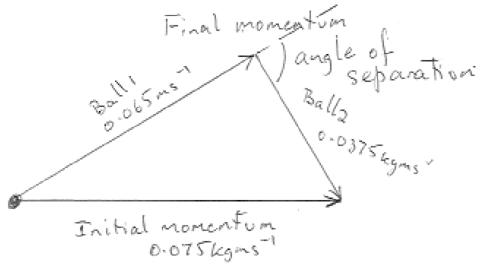
This becomes $E_k = ½ mv^2$

$v^2 = 55.5 \times 2 / 0.018 = 6170$

Final Speed $v = 78.5\ ms^{-1}$

Question 2

(a)



(b) Kinetic energy before the collision = ½ x 0.15 x $(0.5)^2$ = 0.0188 J

After the collision

Total Kinetic Energy = ½ x 0.15 x $(0.433)^2$ + ½ x 0.15 x $(0.25)^2$

= 0.0141 + 0.00469 J

= 0.0188 J

Therefore is elastic by definition of E_k conserved

(c) In the momentum diagram above, using the cos rule

$$(0.075)^2 = (0.065)^2 + (0.0375)^2 - 2x(0.065)x(0.0375)\cos\theta$$

$$\cos\theta = \frac{(0.065)^2 + (0.0375)^2 - (0.075)^2}{2x(0.065)x(0.0375)} = 0$$

$$\theta = 90^0$$

Angle of separation = 90^0

Question 3

(a) Horizontal component $v_H = v \cos\theta = \underline{55.4 \text{ ms}^{-1}}$

Vertical component $v_v = v \sin\theta = \underline{155.2 \text{ ms}^{-1}}$

(b) At the greatest height, $v_v = 0$. Using

$$2as = v^2 - u^2$$

$$-19.6s = 0 - 155.2^2$$

$$s = 1180m$$

Greatest Height = $\underline{1180 \text{ m}}$

(c) At a height of 66m using $2as = v^2 - u^2$ the speed $v = \pm 151 ms^{-1}$ therefore v = -151 ms^{-1} as it is going down.

Calculate the time using v = u + at, where (a = -9.81 ms^{-2}) gives t = 31.2 s

Using the horizontal component of velocity, range s_H = 55.4 x 31.2 = $\underline{1730 \text{ m}}$

Question 4

(a) Final $E_k = \frac{1}{2} mv^2 = 800 \times (150/3.6)^2 = \underline{1.39 \text{ MJ}}$

(b) Acceleration = v/t = (150/3.6)/15 = 2.78 ms^{-2} , $s = \frac{1}{2} at^2 = \frac{1}{2} \times 2.78 \times 225 = 313$ m

Therefore height gained = 313 sin 5^0 = 27.2 m

E_p gained = 1600 x 9.81 x 27.2 J = $\underline{0.427 \text{ MJ}}$

(c) Total Energy = 1.39 + 0.427 MJ = 1.82 MJ

Total Energy developed by engine = P x t = 200 x 15 kJ = 3 MJ

Loss of Energy = $\underline{1.18 \text{ MJ}}$

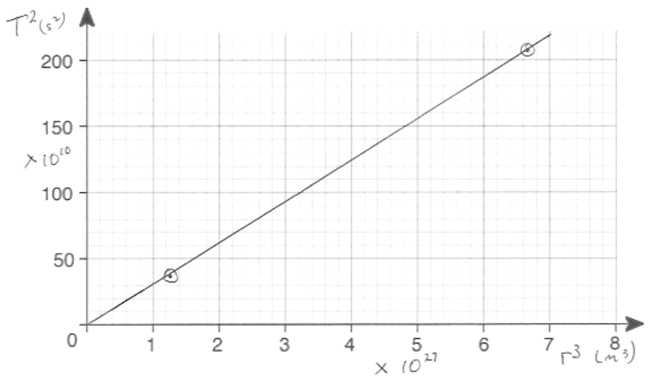
Question 5

(a) Ganymede $r^3 = 1.23 \times 10^{27} \text{ m}^3$ $T^2 = 38.2 \times 10^{10} \text{ s}^2$

Callisto $r^3 = 6.24 \times 10^{27} \text{ m}^3$ $T^2 = 207.3 \times 10^{10} \text{ s}^2$

(b) Yes - relevant formula has no y intercept $T^2 = 4\pi^2 r^3/GM$

(c)



(d) Slope = $185 \times 10^{10}/6 \times 10^{27}$ = $\underline{3.08 \times 10^{-16} \text{ units } (s^2m^{-3})}$

(e) Slope = $4\pi^2/GM$ thus $M = 4\pi^2/3.08 \times 10^{-16}$ kg = $\underline{6.11 \times 10^{26} \text{ kg}}$

Question 6

(a) For a sphere g = GM/r^2 = $6.67 \times 10^{-11} \times 9.39 \times 10^{20}/ (4.73 \times 10^5)^2$ = $\underline{0.296 \text{ Nkg}^{-1}}$

(b) $v = 2\pi r/T = \underline{91.0 \text{ ms}^{-1}}$

(c) $a_c = v^2/r = \underline{0.0175 \text{ ms}^{-2}}$

(d) Feel less of the gravitational field strength. Due to your spin on the equator, you are partly in orbit so you are closer to weightless.

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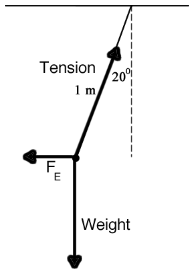
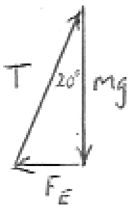
Part 2

Question 7

(a)



(b) From the force diagram,



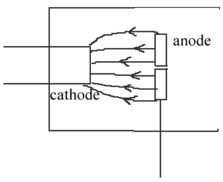
F_E = mg tan 20^0 = 9.81 x 5 x 10^{-6} tan 20^0 = <u>1.79 x 10^{-5} N towards Van D G Generator</u>

(c) Using the definition of E = F_E /q = 1.79 x 10^{-5} / 5 x 10^{-9} = <u>3580 NC^{-1} away from Van D G</u> Generator as the charge q is negative

(d) E = kQ/r^2 3580 = 9 x 10^9 x Q/2.2^2 gives <u>Q = +1.93 x 10^{-6} C</u>

Question 8

(a)



(b) E = V/d = 10^4 /5 x 10^{-3} = <u>2 x 10^6 Vm^{-1} (NC^{-1}) left</u>

(c) The field is contained within the gap so once through the hole, the field no longer has an effect on the electrons. (The forces due to the charges on cathode and anode essentially cancel each other once through the hole in the plates.)

(d) The force on the electrons by the magnetic field is DOWN by RHR so the electric force is UP.

The top plate is positive so the <u>electric field direction is DOWN.</u>

(e) The electric and magnetic fields act as a velocity filter.

Speed of the electrons v = E/B = 3 x 10^5 /5.06 x 10^{-3} = <u>5.93 x 10^7 ms^{-1}</u>

(f) E_p lost = E_K gained, thus qV = ½ mv^2 q = 1.60 x 10^{-19} C, m = 9.11 x 10^{-31} kg, V = 10^4 volts

Gives <u>v = 5.93 x 10^7 ms^{-1}</u>

Question 9

(a) (i) v_{perp} = v sinθ = 3 x 10^6 sin30^0 = <u>1.5 x 10^6 ms^{-1}</u>

(ii) v_{para} = v cosθ = 3 x 10^6 cos30^0 = <u>2.60 x 10^6 ms^{-1}</u>

(b) v = dist/time thus $t = s/v = 2.0 \times 10^8 / 2.60 \times 10^6$ = <u>77s</u>

(c) $r = mv\sin\theta / qB = 1.67 \times 10^{-27} \times 1.5 \times 10^6 / 1.6 \times 10^{-19} \times 10^{-3}$ = <u>15.6 m</u>

Question 10

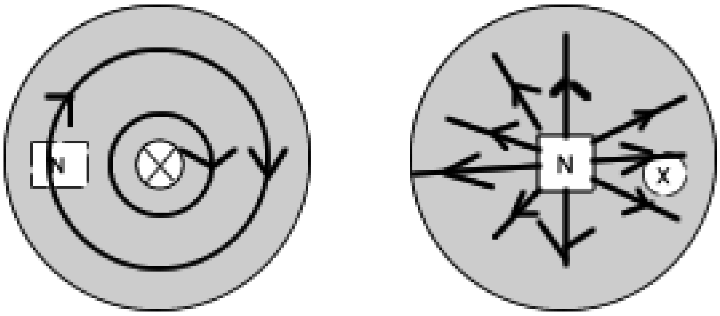
(a) A is <u>positive</u> by RH Rule

(b) EMF = $vlB = 5 \times 0.05 \times 0.2$ = <u>0.05 V</u>

(c) Force applied to current $F = IlB = 0.1 \times 0.05 \times 0.2 = 10^{-3}$ N upwards, so by Newton's Third Law force applied to disc = <u>10^{-3} N downwards</u>

Question 11

(a)

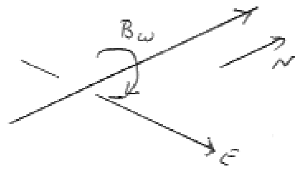


(b) <u>Rotate clockwise</u>

(c) <u>Rotate clockwise</u>

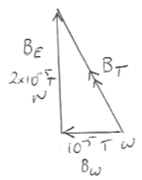
Question 12

(a) $B = kI/r = 2 \times 10^{-7} \times 5/0.1$ = <u>10^{-5} T West</u>



(b) Using vector diagram,

$\tan\theta = 2 \times 10^{-5}/10^{-5} = 2$ thus $\theta = 63.4^0$ so compass points <u>W63.4^{0}N or N26.6^{0}W</u>



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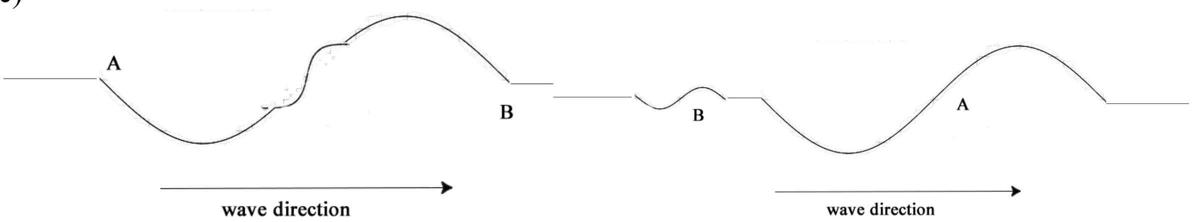
Part 3

Question 13

(a) speed of wave A, $v = 1.24\sqrt{\lambda} = 1.24\sqrt{40} = 7.84\ ms^{-1}$

(b) speed of wave B, $v = 1.24\sqrt{\lambda} = 1.24\sqrt{10} = 3.92\ ms^{-1}$

(c)



Question 14

(a) Fundamental wavelength $\lambda = 2l$ $\quad l$ = length of string

$\lambda = 2 \times 0.325$ m = <u>0.65 m</u>

(b) Calculate $v = \lambda f = 0.65 \times 660\ ms^{-1}$ = $\underline{429\ ms^{-1}}$

$v = \sqrt{\dfrac{T}{\mu}}$ hence $429 = \sqrt{\dfrac{T}{0.420x10^{-3}}}$ gives $\underline{T = 77.3N}$

(c) $f_1 - f_2 = \pm f_B$ hence $660 - f_2 = \pm 10$

Thus f_2 = 650 or 670 Hz. Increasing T retunes the string therefore it was "flat" at 650 Hz.

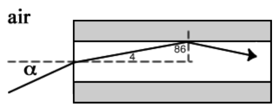
Question 15

(a) (i) Speed in glass $v = c / n = 3.00 \times 10^8 / 1.4475 = \underline{2.07 \times 10^8\ ms^{-1}}$

(ii) t = dist /speed = $1.60 \times 10^7 / 2.07 \times 10^8$ = <u>0.00772 s</u> between Sydney and New York

(b) $\sin\theta_c = \dfrac{n_2}{n_1} = \dfrac{1.4440}{1.4475} = 0.9976$ gives $\underline{\theta_c = 86.0^0}$

(c) At the air / glass boundary at the front of the fibre, the refracted angle after entry will be $90^0 - 86.0^0 = 4^0$

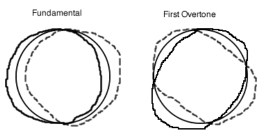


Using Snell's Law $\sin\alpha = 1.4475 \sin 4^0 = 0.1010$ gives $\underline{\alpha = 5.80^0}$

Question 16

(a) "Resonate" means to vibrate in response to a matching imposed vibration.

(b)



(c) Wavelength of first overtone = ½ wavelength of the fundamental wavelength as two waves fit the same circumference. Thus frequency of first overtone = 2 x 200 Hz = <u>400 Hz</u>

(d) The circumference of the rim $s = 2\pi r = 2 \times \pi \times 0.03 = 0.188$ m $= \lambda$

$v = \lambda f = 0.188 \times 200 =$ <u>37.7 ms^{-1}</u>

Question 17

(a) When Path Difference = 0 single central antinodal line

When Path Difference = 10cm two antinodal lines on each side of centre

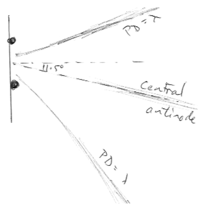
For the next antinodal lines, PD = 20cm > 15cm the separation of the sources

Therefore only <u>3 antinodal lines</u>

(b) From the diagram $\sin\theta = 3/15 = 0.2$, <u>$\theta = 11.5^0$</u>

(c) Time delay = s/c = $0.03/3 \times 10^8$ = <u>10^{-10} s</u>

(d)



(e) more interference from other sources will make the antinodal lines narrower

Question 18

(a) Longer wavelengths diffract more than shorter so <u>200m more likely</u> to curve around the Earth's surface than 1m

(b) Reflections from the ionosphere are much more likely to reach Sydney as less reliant on diffraction and angle of reflection will be large giving a strong signal with little refraction.

(c) <u>Horizontal Polarisation will be stronger</u> as the other component will tend to refract. Reflection from the surface of the layer will be like light reflecting from the surface of glass or water.

Physics 2018 PHY4 Solutions

Part 4

Question 19

(a) (i) $\lambda_p = 0.00290 / T$ = $\underline{7.25 \times 10^{-8}\ \text{m}}$ <u>Bluish colour</u>

(ii) For it to be dim, it would have to be physically small so emitting less light.

(b) It would mean large quantities of ionised hydrogen is present.

(c) $\lambda_\alpha = 656$ nm

Photon energy $E = hc/\lambda = 4.14 \times 10^{-15} \times 3 \times 10^{8} / 6.56 \times 10^{-7} = 1.89$ eV

This corresponds to the transition between <u>n = 3 to n = 2</u>.

Question 20

(a) Using $E_{kmax} = hf - W$

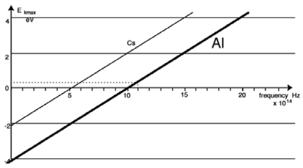
Extrapolating to the vertical axis gives Work Function = <u>2.1 eV</u>

(b) Either from the zero on the horizontal axis f_0 about 5.2×10^{14} Hz giving the wavelength as $3 \times 10^{8} / 5.2 \times 10^{14} = 5.77 \times 10^{-7}$ m or 580 nm

OR from the work function $W = hf_0 = hc/\lambda$, $\lambda = 4.14 \times 10^{-15} \times 3 \times 10^{8} / 2.1 = 590$ nm

As the answer depends on estimation from the graph, the wavelength is about <u>560 – 590 nm</u>

(c)



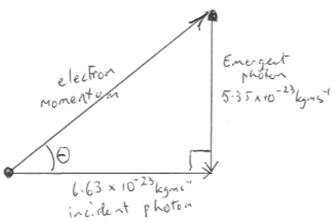
(d) $\lambda = 273$ nm so $f = c/\lambda = 11 \times 10^{-14}$ Hz

From the graph approx. <u>E_{kmax} = 0.2eV</u>

Question 21

(a) $p = h/\lambda = 6.63 \times 10^{-34}/10^{-11} = \underline{6.63 \times 10^{-23}\ \text{kgms}^{-1}}$

(b)



(c) Using Pythagoras's Theorem as it is a right angle triangle

$$mv = 10^{-23}\sqrt{6.63^2 + 5.35^2} = 8.52x10^{-23}\ \text{kgms}^{-1}$$

As $m = 9.11 \times 10^{-31}$ kg, $\underline{v = 9.35 \times 10^{7}\ \text{ms}^{-1}}$

Angle of emergent electron θ = artan 5.35/6.63 = $\underline{38.9^0}$

Question 22

(a) $4{}_1^1p \rightarrow {}_2^4He + 2{}_{-1}^{0}e + 2{}_0^0\bar{v}$

(b) mass difference = mass of protons – (mass of helium nucleus + electrons)

Mass of protons = 4 x 1.00727 = 4.02908 u

Mass of He plus two electrons = 4.002604 + 2 x 0.000549 = 4.003702 u

Mass difference = 4.02908 – 4.00370 = 0.02538 u = 23.6 MeV

(If students ignore the mass of the two electrons solution = 24.7 MeV)

(c) Area of a sphere around Earth = $4\pi r^2 = 4\pi (1.50 \times 10^{11})^2 = 2.83 \times 10^{23}$ m^2

Total energy emitted in one second = energy on 1 m^2 on Earth x area of sphere

$= 1.36 \times 10^3 \times 2.83 \times 10^{23}$ J

$= 3.85 \times 10^{26}$ J

(d) $E = mc^2$ thus $m = E/c^2 = 3.85 \times 10^{26} / 9 \times 10^{16} = 4.27 \times 10^9$ kgs^{-1}

(e) nuclear reactions each second = energy per second / energy of one reaction

If 23.6 MeV $= 3.85 \times 10^{26} / 23.6 \times 10^6 \times 1.6 \times 10^{-19} = 1.02 \times 10^{38}$ reactions

If 24.7 MeV nuclear reactions each second = 9.74×10^{37}

Question 23

(a) Potential energy loss by the electron gives the maximum Xray photon energy

$qV = hc/\lambda_{min}$ Thus $\lambda_{min} = hc/qV = 4.97 \times 10^{-11}$ m = 0.497 pm

(b) Acceleration of the electron passing the nucleus – braking radiation or Bremsstrahlung

(c) Inner electrons being displaced from the atom and new electrons falling in releasing photons with particular wavelengths – Line spectra

Question 24

(a) mass of K-40 = 400 x 0.01 /100 mg = 4×10^{-5} g = 4×10^{-8} kg

(b) $A = \lambda N$ but $N = mN_A/M$,

$N = 4 \times 10^{-5} \times 6.02 \times 10^{23} / 40 = 6.02 \times 10^{17}$ atoms

Thus $A = 0.693 \times 6.02 \times 10^{17} / 1.39 \times 10^9 \times 365 \times 24 \times 3600 = 9.52$ Bq

(c) $^{40}_{19}K \rightarrow ^{40}_{20}Ca + ^{0}_{-1}e + ^{0}_{0}\bar{v}$

(d)

- 24 counts per minute is approximately 1 count every 2 seconds.
- A Geiger counter cannot capture all the emissions from a banana as these emissions are in every direction
- 9 Bq is 9 every second in random directions
- Some absorption of electrons by banana

MIGHT possibly be some slight increase in count rate if banana placed close to Geiger Tube