2022 Physics Exam – suggested solutions

1

(a)

$$v_H = 8.96\cos 28.0 = 7.91 \text{ ms}^{-1}$$
$$v_V = 8.96\sin 28.0 = 4.21 \text{ ms}^{-1}$$

(b)

$$\text{At max. height } v = 0$$
$$v = v_o + at \rightarrow t = \frac{v - v_o}{a}$$
$$t = \frac{0 - 4.21}{-9.80} = 0.430 \text{ s}$$

(c)

$$t = 2 \times 0.430 = 0.860 \text{ s}$$
$$d = v_H t = 7.91 \times 0.860 = 6.80 \text{ m}$$

2

(a)

$$F = G\frac{m_1 m_2}{r^2}$$
$$F = 6.67\times10^{-11}\,\frac{7.77\times10^{30}\times5.04\times10^{30}}{(9.79\times10^{13})^2} = 2.73\times10^{23} \text{ N}$$

(b)

Gravitational forces are equal in magnitude and act on different objects. The forces are also opposite in direction (both attractive).

3

(a)i)

$$F = \frac{1}{4\pi\varepsilon_0}\frac{q_1 q_2}{r^2}$$
$$F = 9.00\times10^{9}\,\frac{1.60\times10^{-19}\times1.60\times10^{-19}}{(2.00\times10^{-15})^2} = 57.6 \text{ N}$$

(a)ii)

Photon

(b)

uud

Quark charges add to $+e\left(\frac{2}{3}+\frac{2}{3}-\frac{1}{3}\right)$

4

(a)

$r = 6.37\times10^{6} + 20200\times10^{3} = 2.66\times10^{7}\ \text{m}$

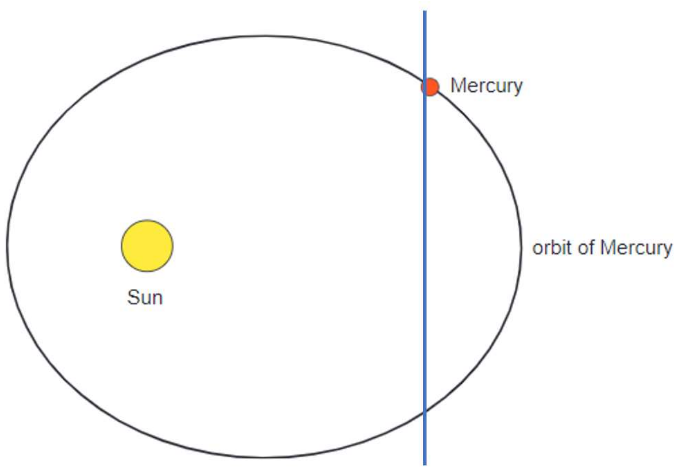
$$v=\sqrt{\frac{6.67\times10^{-11}\times5.97\times10^{24}}{2.66\times10^{7}}}=3.87\times10^{3}\ \text{ms}^{-1}$$

(b)

$$T=\frac{2\pi r}{v}=\frac{2\pi\times2.66\times10^{7}}{3.87\times10^{3}}=4.32\times10^{4}\ \text{s}$$

5

(a)



[This diagram is not drawn to scale.]

Anywhere to the left of the line on the orbit.

(b)

Equal areas are swept in equal times. Therefore, the lengths travelled along the orbit closer to the Sun is greater than further away to keep the areas equal. Since the distance travelled occurs in the same time interval the speed must increase.

6

(a)

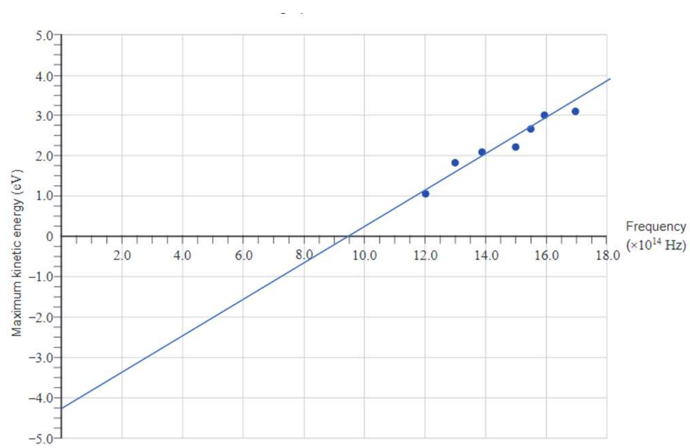
$$v = f\lambda \rightarrow \lambda = \frac{v}{f} = \frac{3.00\times10^{8}}{206\times10^{6}} = 1.46 \text{ m}$$

(b)

Oscillating or accelerating electrons produced an oscillating electric field. This oscillating electric field produces an oscillating magnetic field, which in turn produces an oscillating electric field. Therefore, a self-propagating wave is produced.

7

(a)



(b)i)

4.2 eV

(b)ii)

9.5×10^{14} Hz

(c)

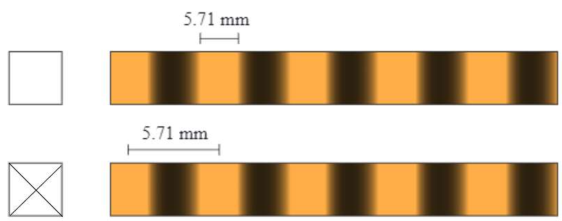
Electrons are energetically bound to the surface by a quantity called the work function. Therefore, to liberate an electron, a photon needs a minimum energy. Since $E = hf$, the photon must have a minimum (threshold) frequency.

8

(a)i)

$$\Delta y = \frac{\lambda L}{d} = \frac{589\times10^{-9}\times1.57}{1.62\times10^{-4}} = 5.71\times10^{-3}\ \text{m}$$

(a)ii)



(b)

Waves of light from both slits are incident on the screen. If the path difference between the waves is an integer multiple of the wavelength of the light then constructive interference occurs and a bright fringe is observed.

(c)

$$m\lambda = d\sin\theta \rightarrow \theta = \sin^{-1}\left(\frac{m\lambda}{d}\right)$$

$$\theta = \sin^{-1}\left(\frac{2\times589\times10^{-9}}{1.00\times10^{-5}}\right) = 6.77^{\circ}$$

9

(a)

The magnetic field causes charged particles to undergo circular motion, so that the particles may cross the electric field multiple times to increase the energy of the particles.

(b)

$$T = \frac{2\pi m}{qB} \rightarrow B = \frac{2\pi m}{qT}$$

$$B = \frac{2\pi\times1.67\times10^{-27}}{1.60\times10^{-19}\times4.68\times10^{-8}} = 1.40\ \text{T}$$

(c)

$$500\times15.0\times10^{3} = 7.50\times10^{6}\ \text{eV}$$

(d)

Increasing the potential difference increases the kinetic energy and therefore speed of the protons. This results in a greater radius of the circular path ($r \propto v$) and therefore the proton crosses the electric field fewer times.

10

(a)

$$F = qvB = 1.60\times10^{-19}\times4.30\times10^{7}\times3.50\times10^{-5}$$
$$F = 2.41\times10^{-16}\ \text{N}$$

(b)

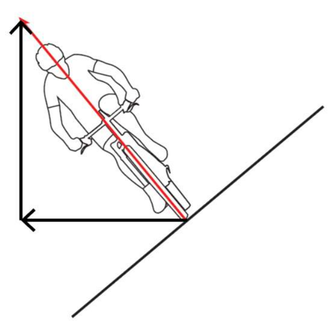
$$r = \frac{mv}{qB} = \frac{9.11\times10^{-31}\times4.30\times10^{7}}{1.60\times10^{-19}\times3.50\times10^{-5}} = 6.995 \rightarrow 7.00\ \text{m}$$

(c)

$$p = \frac{h}{\lambda} \rightarrow mv = \frac{h}{\lambda} \rightarrow \lambda = \frac{h}{mv}$$
$$\lambda = \frac{6.63\times10^{-34}}{9.11\times10^{-31}\times4.30\times10^{7}} = 1.69\times10^{-11}\ \text{m}$$

11

(a)



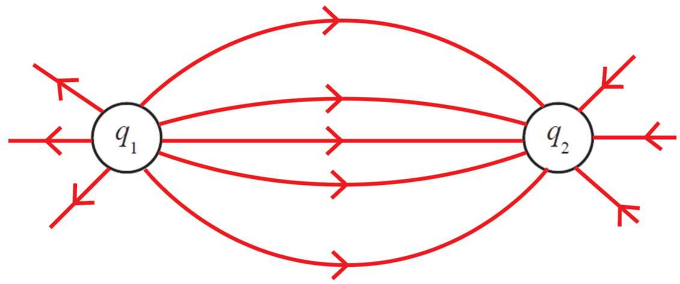
Source: adapted from © Michal Sanca | Shutterstock.com

(b) 12°

The reliance on friction is greater for smaller angles as there is a smaller horizontal component of the normal force contributing to centripetal acceleration.

12

(a)



(b)i)

$$E = \frac{1}{4\pi\varepsilon_o}\frac{q_2}{r^2}$$

$$E = 9.00\times10^{9}\,\frac{3.00\times10^{-6}}{0.240^{2}} = 4.69\times10^{5}\ \mathrm{NC^{-1}}$$

(b)ii)

$$E = \frac{1}{4\pi\varepsilon_o}\frac{q_2}{r^2}$$

$$E = 9.00\times10^{9}\,\frac{3.00\times10^{-6}}{0.120^{2}} = 1.88\times10^{6}\ \mathrm{NC^{-1}}\ \text{left}$$

$$\Sigma E = 1.88\times10^{6} - 4.69\times10^{5} = 1.41\times10^{6}\,\mathrm{NC^{-1}}\ \text{left}$$

13

(a)

Particle	*Charge* (e)	*Baryon number*	*Muonic lepton number*
K^-	-1	0	0
μ^-	-1	0	+1
$\overline{\nu}_\mu$	0	0	-1

(b)

The decay is possible. The baryon number, charge, and lepton numbers are all conserved.

(c)

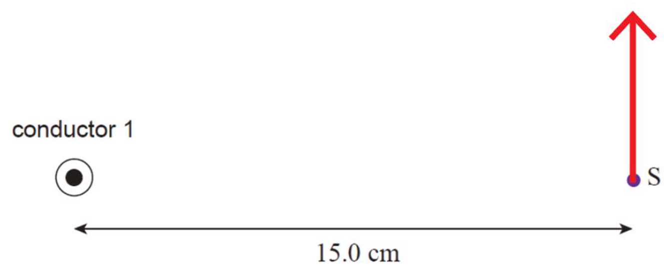
Students should state that collaboration involves the sharing of data and/or findings. The response should also focus on how collaboration involves groups working together.

Possible points include:

- Share data for analysis and verification
- Each group could repeat the experiment using the other group's method
- Each method could be analysed for flaws
- The findings and raw data could be submitted for peer review

14

(a)i)



(a)ii)

$$B = \frac{\mu_o}{2\pi}\frac{I}{r} = 2.0\times10^{-7}\frac{1.40}{0.15} = 1.87\times10^{-6}\ T$$

(b)

If B = 0 then the magnetic fields must be equal in magnitude.

$$B_1 = B_2$$

$$\frac{\mu_o}{2\pi}\frac{I_1}{r_1} = \frac{\mu_o}{2\pi}\frac{I_2}{r_2} \rightarrow \frac{I_1}{r_1} = \frac{I_2}{r_2} \rightarrow I_2 = I_1\frac{r_2}{r_1}$$

$$I_2 = 1.40\frac{0.10}{0.15} = 0.93\ \text{A}$$

15

(a)

$$\frac{F_1}{F_2}=\frac{\frac{1}{4\pi\varepsilon_o}\frac{q_e q_p}{r_1^2}}{\frac{1}{4\pi\varepsilon_o}\frac{q_e q_p}{r_2^2}}=\frac{r_2^2}{r_1^2}$$

$$\frac{F_1}{F_2}=\frac{r_2^2}{r_1^2}=\frac{(2.12\times10^{-10})^2}{(5.30\times10^{-11})^2}=16$$

(b)i)

$$E=13.60-3.40=10.2\text{ eV}$$

$$E=10.2\times1.60\times10^{-19}=1.63\times10^{-18}\text{ J}$$

$$E=hf\rightarrow f=\frac{E}{h}=\frac{1.63\times10^{-18}}{6.63\times10^{-34}}=2.46\times10^{15}\text{ Hz}$$

(b)ii)

UV

(c)

The photon can be absorbed. The energy of the photon corresponds to the energy difference between the n = 1 and n = 3 electron energy-levels.

16

(a)

Induced emf in the solenoid.

(b)

As the magnet falls through the solenoid then is a change in magnetic flux through the loops of the solenoid. From Faraday's law, an emf is induced in the loops of the solenoid as there is a change in magnetic flux.

(c)

If the height is increased then the magnetic moves at a higher speed as it passes through the solenoid. Therefore, the time taken for the magnet to pass through the solenoid decreases. Finally, the rate of change of magnetic flux through the solenoid increases and a greater emf is induced.

17

(a)i)

15×10^{18} Hz or 1.50×10^{19} Hz (a)ii)

$$f_{\max} = \frac{e\Delta V}{h} \to \Delta V = \frac{hf_{\max}}{e}$$
$$\Delta V = \frac{6.63\times10^{-34}\times1.50\times10^{19}}{1.60\times10^{-19}}$$
$$\Delta V = 6.2\times10^{4}\ \text{V}$$

(b)

The bone has a higher density than muscles. Therefore, more X-rays are absorbed (greater attenuation) by the bone.

18(a)i)

$$t = \gamma t_o \to \gamma = \frac{t}{t_o}$$
$$\gamma = \frac{252}{120} = 2.10$$

(a)ii)

$$\gamma = \frac{1}{\sqrt{1-\frac{v^2}{c^2}}} \Rightarrow \frac{1}{\gamma} = \sqrt{1-\frac{v^2}{c^2}}$$
$$\left(\frac{1}{\gamma}\right)^2 = 1-\frac{v^2}{c^2} \Rightarrow 1-\left(\frac{1}{\gamma}\right)^2 = \frac{v^2}{c^2}$$
$$v = \sqrt{1-\left(\frac{1}{\gamma}\right)^2}\,c$$
$$v = \sqrt{1-\left(\frac{1}{2.10}\right)^2}\,c = 0.88c$$

(b)

$$l = \frac{l_o}{\gamma}$$
$$l = \frac{6.65\times10^{10}}{2.10}$$
$$l = 3.17\times10^{10}\ \text{m}$$

19

(a)

Xenon ion gains energy: $W = \Delta E = q\Delta V$

This work is converted into kinetic energy, giving:

$$q\Delta V = \frac{1}{2}mv^2$$
$$v = \sqrt{\frac{2q\Delta V}{m}}$$

(b)i)

$$q\Delta V = \frac{1}{2}mv^2$$
$$v = \sqrt{\frac{2\times1.60\times10^{-19}\times1.50\times10^{3}}{2.18\times10^{-25}}} = 4.69\times10^{4}\ \text{ms}^{-1}$$
$$\Delta p = m\Delta v = 2.18\times10^{-25}\times4.69\times10^{4} = 1.02\times10^{-20}\ \text{kgms}^{-1}$$

(b)ii)

$$F = \frac{\Delta p}{\Delta t} \rightarrow F = ma = N\frac{\Delta p_{Xe}}{\Delta t}$$
$$a = \frac{N\Delta p_{Xe}}{m\Delta t}$$
$$a = \frac{6.10\times10^{12}\times1.02\times10^{-20}}{3100\times6.90\times10^{-7}} = 2.91\times10^{-5}\ \text{ms}^{-2}$$

20

The law of conservation of momentum states that:

$$\Sigma p = 0 \rightarrow \Delta p_A + \Delta p_B + \Delta p_C \rightarrow \Delta p_C = -(\Delta p_A + \Delta p_B)$$