2022
VCE
Physics
Trial Examination

Suggested Answers

Kilbaha Education

Quality educational content

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MULTIPLE CHOICE ANSWER SUMMARY

1	**C**	**11**	**C**
2	**B**	**12**	**B**
3	**B**	**13**	**D**
4	**D**	**14**	**D**
5	**D**	**15**	**A**
6	**B**	**16**	**D**
7	**A**	**17**	**C**
8	**A**	**18**	**C**
9	**A**	**19**	**A**
10	**B**	**20**	**C**

Distribution: **A 5 B 5 C 5 D 5**

Section A – Multiple choice (1 mark each)

Question 1 C

$B = \sqrt{(0.03^2 + 0.045^2)} = \sqrt{2.925 \times 10^{-3}} = 0.054$ T

Study Design

- describe gravitation, magnetism and electricity using a field model
- investigate and apply theoretically and practically a vector field model to magnetic phenomena, including shapes and directions of fields produced by bar magnets, and by current-carrying wires, loops and solenoids

Web links

https://www.rpi.edu/dept/phys/SciIT/InformationStorage/faraday/magnetism_a.html#:~:text=A%20current%20traveling%20through%20a,direction%20of%20the%20magnetic%20field

https://web.ua.es/docivis/magnet/solenoid.html#:~:text=In%20physics%2C%20the%20term%20solenoid,can%20be%20used%20as%20electromagnets

https://gmw.com/technicalnotes/magnetic-field-vectors

Question 2 B

The Earth's field balances the downward field from Electromagnet Y. The only remaining component is that from Electromagnet Z which is directed west, direction B.
(Find the field direction with curled fingers, hold the front wire.)

Study Design

- investigate and compare theoretically and practically gravitational, magnetic and electric fields, including directions and shapes of fields, attractive and repulsive fields, and the existence of dipoles and monopoles
- investigate and apply theoretically and practically a vector field model to magnetic phenomena, including shapes and directions of fields produced by bar magnets, and by current-carrying wires, loops and solenoids
- investigate and analyse theoretically and practically the force on a current carrying conductor due to an external magnetic field, $F = nIlB$, where the directions of I and B are either perpendicular or parallel to each other

Web links

https://gmw.com/technicalnotes/magnetic-field-vectors

https://www.ngdc.noaa.gov/geomag/faqgeom.shtml#:~:text=The%20Earth's%20magnetic%20field%20intensity,magnetic%20north%20and%20true%20north

Question 3 B

mg = *Eqn* where *n* is the number of electron charges
$n = 7.2\times10^{-15} \times 9.8 / 4.0\times10^{4} / 1.6\times10^{-19} = 11.025 = 11$ charges Answer B

Study Design

- describe gravitation, magnetism and electricity using a field model
- investigate and compare theoretically and practically gravitational fields and electrical fields about a point mass or charge (positive or negative) with reference to:

—the direction of the field
—the shape of the field
—the use of the inverse square law to determine the magnitude of the field
—potential energy changes (qualitative) associated with a point mass or charge moving in the field

- analyse the use of an electric field to accelerate a charge, including:

—electric field and electric force concepts: $E = kQ/r^2$ and $F = kq_1\ q_2/r^2$
—potential energy changes in a uniform electric field: $W = qV$, $E = V/d$
—the magnitude of the force on a charged particle due to a uniform electric field: $F = qE$

Web links
https://www.youtube.com/watch?v=nwnjYERS66U

https://tutorpro.com.au/electric-magnetic-fields

Question 4 D

Answer D is the correct statement.
Note that while Answer A may be tempting, there are no magnets with a north pole only. Or south only magnets.

Study Design

- describe gravitation, magnetism and electricity using a field model
- investigate and apply theoretically and practically a vector field model to magnetic phenomena, including shapes and directions of fields produced by bar magnets, and by current-carrying wires, loops and solenoids

Web links
https://socratic.org/questions/why-are-magnets-dipoles

http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/solenoid.html

Question 5 D

Answer D
Sound has a speed determined by the medium, air, not the motion of the source or listener.
As the siren moves towards the listener, the wave lengths are shortened, so the frequency rises.
Similarly, the frequency drops as the siren departs.

Study Design

- explain qualitatively the Doppler effect

Web links
https://courses.lumenlearning.com/suny-osuniversityphysics/chapter/17-7-the-doppler-effect/#:~:text=What%20happens%20if%20the%20observer,lower%20than%20the%20source%20frequency

http://physics.bu.edu/~redner/211-sp06/class19/class19_doppler.html

https://www.physicsclassroom.com/class/sound/Lesson-3/The-Doppler-Effect-and-Shock-Waves

Question 6 B

The Heisenberg explanation offered here is the best explanation. The uncertainty explanations in the other answers offered are both wrong because the directions are incorrect. The uncertainty, in position and in momentum, are both in the same direction, sideways, the y-direction.
Coulomb forces are not forming this pattern.

Study Design

- interpret electron diffraction patterns as evidence for the wave-like nature of matter
- explain how diffraction from a single slit experiment can be used to illustrate Heisenberg's uncertainty principle

Web links
https://www.youtube.com/watch?v=iK2Fm4XmmZs

http://hyperphysics.phy-astr.gsu.edu/hbase/uncer.html

Question 7 A

The generator produces AC internally.
The commutators switch the AC every half cycle so that the half sine waves are all the same voltage polarity. The output voltage then is DC.

The motor is designed to run on DC
The DC motor needs commutators to switch the current each half cycle so that there is a constant rotational force.

Study Design

- investigate and analyse theoretically and practically the operation of simple DC motors consisting of one coil, containing a number of loops of wire, which is free to rotate about an axis in a uniform magnetic field and including the use of a split ring commutator
- explain the production of DC voltage in DC generators and AC voltage in alternators, including the use of split ring commutators and slip rings respectively.

Web links
https://www.youtube.com/watch?v=k7Sz8oT8ou0

https://scienceready.com.au/pages/generators

https://www.scienceflip.com.au/subjects/physics/electromagnetism/learn9/

Question 8 A

Answer A. This refers to the equal and opposite forces of the Third Law.
Answers B and C are wrong, apart from the directions of the accelerations, it is magnitudes of forces which are equal, not accelerations or changes in velocities.
Answer D is wrong. It refers to velocity changes. On the first the change is negative, on the second it is positive.

Now complete Question 9, Section A, in the VCE paper 2020.

Study Design

- investigate and apply theoretically and practically Newton's three laws of motion in situations where two or more coplanar forces act along a straight line and in two dimensions

Web links

https://www.physicsclassroom.com/class/momentum/Lesson-2/Momentum-Conservation-Principle#:~:text=The%20law%20of%20momentum%20conservation%20can%20be%20stated%20as%20follows,two%20objects%20after%20the%20collision

https://www.physicsclassroom.com/mmedia/momentum/trece.cfm

Question 9 A

.
While the $F_{\text{on the second trolley, by the first}}$ does work on the second trolley, there is no overall force on the system during the collision. Answer A

Study Design

- investigate and apply theoretically and practically the concept of work done by a constant force using:

—work done = constant force × distance moved in direction of net force
—work done = area under force-distance graph

Web link

https://www.physicsclassroom.com/class/momentum/Lesson-2/The-Law-of-Action-Reaction-(Revisited)

Question 10 B

Answers A and C are wrong because the spread is not random.
Answer B is correct because it establishes the basis of a systematic error.
Answer D is wrong. It does identify a systematic error, but it would lengthen the race times, not shorten them.

Study Design

- systematically generate, collect, record and summarise both qualitative and quantitative data

Web links

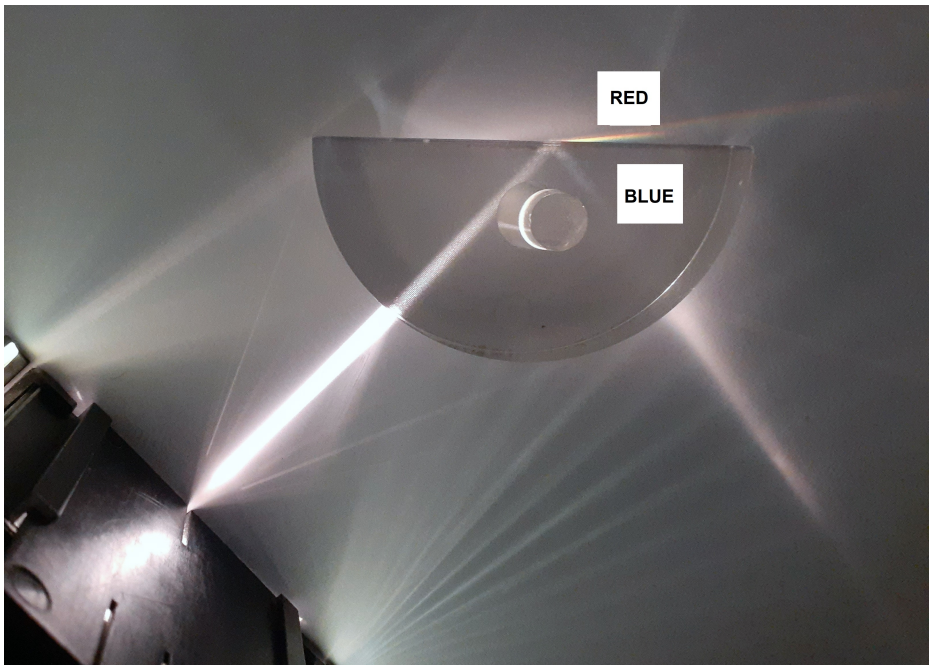
www.physicsworld.com/a/a-decathalon-of-questions-on-the-physics-of-sport/

https://www.matrix.edu.au/the-beginners-guide-to-physics-practical-skills/physics-practical-skills-part-3-systematic-vs-random-errors/

https://www.thoughtco.com/random-vs-systematic-error-4175358

Question 11 C

For a critical angle at 37° the index of refraction n = 1 / sin(37°) = 1/0.602 = 1.66
Given the slight differences in the indices of refraction and the blue index is larger, then blue will have a smaller critical angle than red.
Blue does TIR at a smaller angle than red, so at this situation Beam N is red. The index of refraction is 1.66 approximately.



Study Design

- investigate and analyse theoretically and practically the behaviour of waves including:

—refraction using Snell's Law: $n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$ and $n_1 v_1 = n_2 v_2$

—total internal reflection and critical angle including applications: $n_1 \sin(\theta_1) = n_2 \sin(90)$

- investigate and explain theoretically and practically colour dispersion in prisms and lenses with reference to refraction of the components of white light as they pass from one medium to another

Web links

https://www.youtube.com/watch?v=yfawFJCRDSE
(ray reverse direction, only white seen)

https://www.youtube.com/watch?v=d7U3k2XtzVU
(at 52 s, the exit beam shows that the lower part of the exit beam is blue, the upper is red)

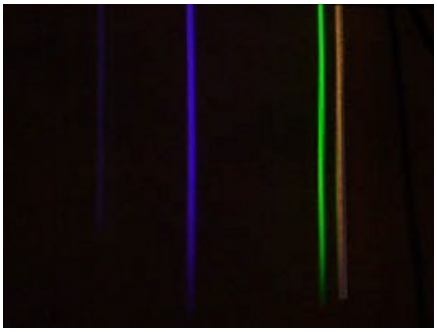
https://www.vcaa.vic.edu.au/Documents/exams/physics/2019/2019physics-w.pdf

https://www.vcaa.vic.edu.au/Documents/exams/physics/2019/physics_examrep19.pdf
VCAA paper 2019 section B 15

http://labman.phys.utk.edu/phys222core/modules/m7/dispersion.html

Question 12 B

The light produced by mercury vapour lamps is generated from a range of electron transitions in the energisation of mercury. While there are a range of frequencies generated, their light is dominated by green and violet emissions. There are some reddish spectral lines too.
A pure white light is always produced by acceleration of charged particles.
The "whiteness" of mercury lights or LEDs is produced by combining a range of colours which can approximate white. (White LED torches use just a combination of blue and yellow.)
Neither of these light producing processes generates coherent or polarised light.



The mercury emission spectrum

By Timichio at English Wikipedia - This file was derived from: HG-Spektrum.jpg, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=23246535

Study Design

- describe light as an electromagnetic wave which is produced by the acceleration of charges, which in turn produces changing electric fields and associated changing magnetic fields
- compare the wavelength and frequencies of different regions of the electromagnetic spectrum, including radio, microwave, infrared, visible, ultraviolet, x-ray and gamma, and identify the distinct uses each has in society
- explain polarisation of visible light and its relation to a transverse wave model
- explain the production of atomic absorption and emission line spectra, including those from metal vapour lamps

Web links

https://www.real-world-physics-problems.com/how-light-bulbs-work.html

https://www.dummies.com/article/academics-the-arts/science/physics/transferring-heat-through-radiation-174255/

https://edisontechcenter.org/MercuryVaporLamps.html

https://en.wikipedia.org/wiki/Mercury-vapor_lamp

Question 13 D

$EMF = -N\ \Delta\phi/\Delta t$ and the flux change $\Delta\phi$ is always the same.
However the time taken initially is longer so the initial cycles must be longer than the later ones.
This allows Answers C and D.
However, if Δt is longer then $\Delta\phi/\Delta t$ must be smaller. Initial voltages must be lower. Initial cycles must be longer. Only Answer D is allowed by this requirement.
Answer B is wrong because the cycle lengths are all equal.

Study Design

- investigate and analyse theoretically and practically the generation of electromotive force (emf) including AC voltage and calculations using induced emf: $\varepsilon = -\mathrm{N}\Delta\,\varphi_{\mathrm{B}}/\Delta\mathrm{t}$, with reference to:

—rate of change of magnetic flux
—number of loops through which the flux passes
—direction of induced emf in a coil

Web links
https://www.walter-fendt.de/html5/phen/generator_en.htm
You can see what happens at slow speed by changing the speed of rotation

https://www.vcaa.vic.edu.au/Documents/exams/physics/2019/NHT/2019physics-nht-w.pdf

https://www.vcaa.vic.edu.au/Documents/exams/physics/2019/NHT/physicsnht_examrep19.pdf
Northern hemisphere paper, Section A Question 7

Question 14 D

The input winding is the primary, the output is the secondary.
This is seen in answers A and D

Windings
$N_1/N_2 = V_1/V_2$
$N_2 = N_1\ V_2/V_1$ = 400 × 240 / 30 = 3200 turns Answer D

Study Design

- analyse action with reference to electromagnetic induction for an ideal transformer: $\mathrm{N_1/N_2 = V_1/V_2 = I_2/I_1}$

Web links
https://www.electrical4u.net/transformer/transformer-turns-ratio-calculator-with-formula/

https://goodcalculators.com/transformer-calculator/

https://www.electronics-tutorials.ws/transformer/transformer-basics.html

Question 15 A

R_{tot} = 15.4 + 1.2 = 16.6
I = 240 / 16.2 = 14.46 A
$P_{1.2\Omega} = I^2 R =$ 14.46^2 × 1.2 = 250.8. best answer is 250 W Answer A

Study Design

- analyse the supply of power by considering transmission losses across transmission lines

Web links

https://www.schoolphysics.co.uk/age14-16/Electricity%20and%20magnetism/Electromagnetic%20induction/text/Transmission_of_electricity/index.html

https://www.youtube.com/watch?v=yst89Vy7dUo

http://vcephysics.com/content/wp-content/uploads/2012/01/Power-Transmission.pdf

Question 16 D

Using the right hand rule, (three perpendicular vectors): the magnetic field is down and current (positive) is into the page (right).
This means force will be to the left, the Electrode X which become positively charged.
Current will flow out of this terminal to Electrode Y
Note: The flow of positive current is left, into the page.

Study Design

- investigate and analyse theoretically and practically the generation of electromotive force (emf) including AC voltage and calculations using induced emf: $\varepsilon = -N\Delta\varphi_B/\Delta t$, with reference to:

—rate of change of magnetic flux
—number of loops through which the flux passes
—direction of induced emf in a coil

Web links

https://testbook.com/question-answer/what-is-the-principle-of-operation-of-magneto-hydr--6035406b8c02bf3e52914a1c#:~:text=The%20principal%20of%20MHD%20power,of%20current%20across%20the%20terminals.

https://www.yourelectricalguide.com/2022/04/mhd-generator-working-principle.html

https://www.livescience.com/53509-faradays-law-induction.html

Question 17 C

All waves, transverse or longitudinal transfer energy and do not transfer matter.
Matter can be damaged or locally moved in wave actions, but there is no overall transfer from the source outwards.
It makes no difference whether the wave is in air, liquid or solid.

Study Design

- explain a wave as the transmission of energy through a medium without the net transfer of matter
- distinguish between transverse and longitudinal waves

Web links

https://www.sciencelearn.org.nz/resources/120-waves-as-energy-transfer#:~:text=Waves%20transfer%20energy%20but%20not%20mass&text=The%20particles%20involved%20in%20waves,one%20another%20and%20transferring%20energy.

https://www.physicsclassroom.com/class/waves/Lesson-1/What-is-a-Wave

https://www.physicsclassroom.com/class/waves/Lesson-1/Categories-of-Waves#:~:text=Transverse%20waves%20are%20always%20characterized,direction%20that%20the%20wave%20moves.

https://www.sciencelearn.org.nz/resources/342-canterbury-earthquakes

Question 18 C

Answers A and B wrong. The work function is always expressed positively, even if it is a negative intercept on the graph. The equation is $E_{Kmax} = hf - W$ (it is not in the form y = mx + c)
Answer D wrong. The maximum kinetic energy cannot be negative. The energy will be zero.
Answer C correct. All three measurements are consistent with the graph and numerically correct.

Study Design

- analyse the photoelectric effect with reference to:

—evidence for the particle-like nature of light
—experimental data in the form of graphs of photocurrent versus electrode potential, and of kinetic energy of electrons versus frequency
—kinetic energy of emitted photoelectrons: $E_{k\,max} = hf - \phi$, using energy units of joule and electron-volt
—effects of intensity of incident irradiation on the emission of photoelectrons

Web links
http://hyperphysics.phy-astr.gsu.edu/hbase/mod2.html

http://hyperphysics.phy-astr.gsu.edu/hbase/mod1.html

https://researchtweet.com/threshold-frequency-definition-equation/

https://phys.libretexts.org/Bookshelves/University_Physics/Book%3A_University_Physics_(OpenStax)/University_Physics_III_-_Optics_and_Modern_Physics_(OpenStax)/06%3A_Photons_and_Matter_Waves/6.03%3A_Photoelectric_Effect

Question 19 A

The upper projectile will gather speed as it falls as in Answers A and D.
The lower projectile will lose speed as it rises and its graph will flatten; only Answer A has both features.

Study Design

- investigate and analyse theoretically and practically the motion of projectiles near Earth's surface, including a qualitative description of the effects of air resistance

Web links
https://www.webassign.net/question_assets/buelemphys1/chapter04/section04dash7.pdf

https://www.youtube.com/watch?v=2kLvoDOYcBI

Question 20 C

$k = mg/x$ = 20 × 9.8 / 0.04 = 4900
at the maximum, if the drop is d, then
$mgd = kd^2/2$ gravitational potential energy loss = stored potential spring energy. Kinetic energy = 0
$d = 2mg/k =$ 2 × 20 × 9.8 / 4900 = 0.080 m

Study Design

- investigate and apply theoretically and practically the concept of work done by a constant force using:

—work done = constant force × distance moved in direction of net force
—work done = area under force-distance graph

- analyse transformations of energy between kinetic energy, strain potential energy, gravitational potential energy and energy dissipated to the environment (considered as a combination of heat, sound and deformation of material):

—kinetic energy at low speeds: $E_k = \frac{1}{2} mv^2$; elastic and inelastic collisions with reference to conservation of kinetic energy
—strain potential energy: area under force-distance graph including ideal springs obeying Hooke's Law: $E_s = \frac{1}{2} k\Delta x^2$
—gravitational potential energy: $E_g = mg\Delta h$ or from area under a force-distance graph and area under a field-distance graph multiplied by mass

Web links
https://www.physicsclassroom.com/class/waves/Lesson-0/Motion-of-a-Mass-on-a-Spring

https://www.youtube.com/watch?v=-3OUOpl_xbo

https://www.youtube.com/watch?v=nQSpgYMksoM

http://astro1.panet.utoledo.edu/~mheben/PHYS_2130/Chapter08_mh.pdf

END OF SECTION A ANSWERS

SECTION B

Question 1 (5 marks)

a

Δy = 0.30 – 0.10 = 0.20 m

$\Delta y = gt^2/2$ so $t_{to\ the\ top\ of\ the\ reeds} = \sqrt{(2\Delta y/g)} =$ √ (2 × 0.2 / 9.8) = 0.202 s *(1)*

Δx = 0.35 m

v_x = 0.35 / 0.202 = 1.732 = 1.7 ms^{-1} *(1)*

b

$t_{to\ reeds}$ = 0.202

height at reeds = 0.30 m

$t_{down} = \sqrt{(2h/g)} =$ √(2 × 0.3 / 9.8) = 0.247 *(1)*

t_{total} = 0.202 + 0.247 = 0.449 = 0.45 s *(1)*

c

t_{total} = 0.449 s

v_x = 1.732

x_{total} = 0.449 × 1.732 = 0.777 = 0.78 m *(1)*

so she does reach the pad, having passed over the reeds.

Study Design

- investigate and analyse theoretically and practically the motion of projectiles near Earth's surface, including a qualitative description of the effects of air resistance

Web links

https://www.omnicalculator.com/physics/projectile-motion

https://openstax.org/books/physics/pages/5-3-projectile-motion#:~:text=The%20following%20steps%20are%20used,axes%20are%20called%20x%20and

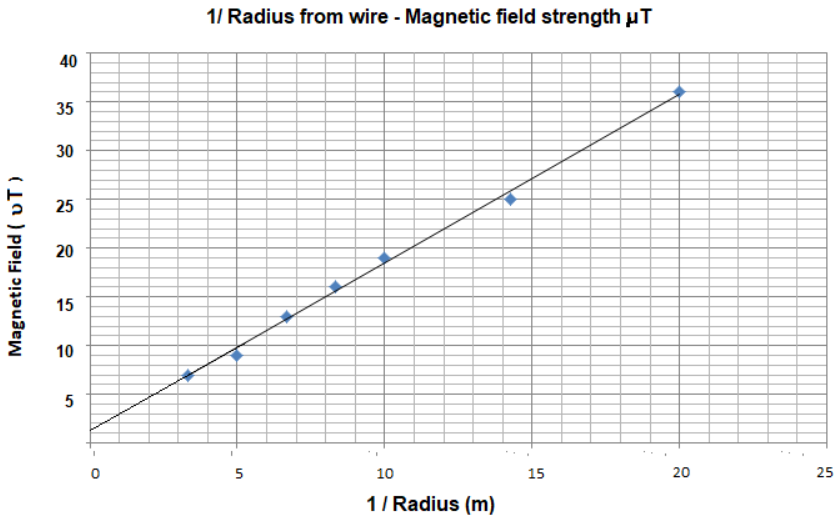
https://www.physicsclassroom.com/class/vectors/Lesson-2/Characteristics-of-a-Projectile-s-Trajectory

Question 2 (8 marks)

a

points well plotted *(1)*

reasonable line of best fit *(1)*



b

the radius (or 1/Radius) is the independent variable, that is the variable the students chose *(1)*

the magnetic field strength is the dependent variable, this is what they measured at the chosen radius positions. *(1)*

c

The errors are likely to be systematic; the 1/Radius values could be less than is expected. This would mean that the actual radius was larger than the recorded value. *(1)*
Students need only identify a consistent pattern of error in 1/Radius or in the B field.

The students should look for an error in the process measuring the radius. *(1)*
It is worth noting that the end of the ruler rests against the wire to measure the radius. This could minimally reduce the measurements of radius which were made.

Many rulers have several millimetres of blank end on the ruler and this could also be the error. There is insufficient information to confirm this here.
An explanation can be presented for a systematic error in the B field measurement, perhaps some fault in the detector.

d

accuracy is quite good about the trend-line, but is reduced by the presence of a systematic error *(1)*

precision is high, because the data points are closely gathered around a line of best fit. *(1)*

Question 2 continued

Study Design

- organise, present and interpret data using tables, line graphs, correlation, line of best fit, calculations of mean and fitting an appropriate curve to graphical data, including the use of error bars on graphs
- independent, dependent and controlled variables
- the characteristics of scientific research methodologies and techniques of primary qualitative and quantitative data collection relevant to the selected investigation, including experiments (gravity, magnetism, electricity, Newton's laws of motion, waves) and/or the construction and evaluation of a device; precision, accuracy, reliability and validity of data; and the identification of, and distinction between, uncertainty and error
- methods of organising, analysing and evaluating primary data to identify patterns and relationships including sources of uncertainty and error, and limitations of data and methodologies

Web links

https://www.youtube.com/watch?v=Po4yRQ5pLuk

https://www2.nau.edu/lrm22/lessons/graph_tips/graph_tips.html#:~:text=The%20independent%20variable%20belongs%20on,are%20(0%2C0).

https://www.precisa.co.uk/difference-between-accuracy-and-precision-measurements/

Question 3 (5 marks)

a

$a/g = tan\theta$

a = 9.8 × tan 19° = 3.374 *(1)*

$a = 4\pi^2 R/T^2$ so $T = \sqrt{(4\ \pi^2\ 0.22\ /\ 3.374)}$ *(1)* = 1.604 = 1.6 s *(1)*

b

vertical support = mg = 2.5 × 9.8 = 24.5

centripetal force = ma = 2.5 × 3.374 = 8.436 *(1)*

Load $= \sqrt{(24.5^2 + 8.436^2)}$ = 25.91 = 26 N *(1)*

Study Design

- investigate and analyse theoretically and practically the uniform circular motion of an object moving in a horizontal plane: $F_{net} = m\,v^2/r$, including:

—a vehicle moving around a circular road

—a vehicle moving around a banked track

—an object on the end of a string

Web links

http://hyperphysics.phy-astr.gsu.edu/hbase/cf.html

https://www.wired.com/story/the-physics-of-swinging-a-mass-on-a-string-for-fun/

https://www.physicsclassroom.com/class/circles/Lesson-1/Mathematics-of-Circular-Motion

https://phys.libretexts.org/Bookshelves/University_Physics/Book%3A_University_Physics_(OpenStax)/Book%3A_University_Physics_I_-_Mechanics_Sound_Oscillations_and_Waves_(OpenStax)/06%3A_Applications_of_Newton's_Laws/6.06%3A_Centripetal_Force

Question 4 (6 marks)

a

$R_{orbit} = R_{planet} + h_{above\ the\ planet} = 1.2\times10^7 + 8.0\times10^6 = 9.0\times10^7$ m

$m = R^3 4\pi^2/(T^2G) =$ $(9.0\times10^7)^3\ 4\ \pi^2$ / $(1.58\times10^5)^2$ / 6.67×10^{-11} *(1)* $= 1.728\times10^{25} = 1.73\times10^{25}$ kg *(1)*

b

$g = GM/R^2 =$ $6.67\times10^{-11} \times 1.73\times10^{25}$ / $(9.0\times10^7)^2$ *(1)* $= 0.142$ m s^{-2} *(1)* accuracy 3 sig figs

c

$\Delta E_{pg} = m(g_1 + g_2)\Delta h/2 =$ $0.5 \times 2300 \times (0.142 + 0.180) \times 1.0\times10^7 = 3.71\times10^9$ J

Study Design

- analyse the use of gravitational fields to accelerate mass, including:

—gravitational field and gravitational force concepts: $g = GM/r^2$ and $F = Gm_1 m_2/r^2$

—potential energy changes in a uniform gravitational field: $E_g = mg\Delta h$

—the change in gravitational potential energy from area under a force-distance graph and area under a field-distance graph multiplied by mass.

- apply the concepts of force due to gravity, F_g, and normal reaction force, F_N, including satellites in orbit where the orbits are assumed to be uniform and circular
- model natural and artificial satellite motion as uniform circular motion
- model satellite motion (artificial, Moon, planet) as uniform circular orbital motion: $a = v^2/r = 4\pi^2 r/T^2$

Web links

https://www.physicsclassroom.com/class/circles/Lesson-4/Mathematics-of-Satellite-Motion

https://lms.craigieburnsc.vic.edu.au/pluginfile.php/33090/mod_folder/content/0/PHYSICS/Hein_Physics-Ch1.pdf?forcedownload=1
page 23 onwards

https://www.physicsclassroom.com/class/circles/Lesson-4/Energy-Relationships-for-Satellites
kinetic energy changes are not on the course

https://artofsmart.com.au/hsctogether/change-in-energy-between-orbits/

Question 5 (5 marks)

a

Particle model:

Threshold frequency and instantaneous emission of photo-electrons support particle theory, so energy is quantised. Threshold frequency suggests that energy for emission is delivered by quanta of energy. *(1)*

or

Instantaneous emission of photo-electrons suggests that energy build-up is not required to release electrons. *(1)*

or

Brightness of light changes the current but not the maximum kinetic energy. *(1)*

Wave model:

All waves, of any frequency would eventually release photo electrons even if not quickly because the energy will build up. *(1)*

or

Brighter light should increase the electron maximum kinetic energy. *(1)*

b

E_{Kmax} at 6.6×10^{14} Hz = 0.55 x 1.6×10^{-19} = 8.80×10^{-20} *(1)*

$h = E_{Kmax}/(f_1 - f_o)$ = 8.8×10^{-20} / ($6.6\times10^{14} - 5.2\times10^{14}$) J *(1)* = 6.29×10^{-34} = 6.3×10^{-34} J s . *(1)*

if answer = 3.9×10^{-15} eV *(0)*

Instructions include not changing the unit.

Study Design

- analyse the photoelectric effect with reference to:

—evidence for the particle-like nature of light

—experimental data in the form of graphs of photocurrent versus electrode potential, and of kinetic energy of electrons versus frequency

—kinetic energy of emitted photoelectrons: $E_{k\,max} = hf - \phi$, using energy units of joule and electron-volt

—effects of intensity of incident irradiation on the emission of photoelectrons

- describe the limitation of the wave model of light in explaining experimental results related to the photoelectric effect.

Web links

https://www.khanacademy.org/science/physics/quantum-physics/photons/a/photoelectric-effect

https://photonterrace.net/en/photon/duality/

https://www.sarthaks.com/180157/using-figure-stopping-potential-incident-frequency-photons-calculate-plancks-constant

http://hyperphysics.phy-astr.gsu.edu/hbase/mod2.html#c2

Question 6 (5 marks)

a

$E_{K\ electron} = 2 \times 1.6\times10^{-19} = 3.2\times10^{-19}$ J

$v = \sqrt{2E_K/m} = \sqrt{(2 \times 3.2\times10^{-19} / 9.1\times10^{-31})} = 8.39\times10^{5}$ ms^{-1} *(1)*

$\lambda = h/mv = 6.63\times10^{-34} / 9.1\times10^{-31} / 8.39\times10^{5} = 8.68\times10^{-10} = 8.7\times10^{-10}$ m *(1)*

(Alternatively use $\lambda = h / (\sqrt{(E_K / 2 / m)}$

b

$\lambda/w_{electron} = 8.7\times10^{-10} / 1.4\times10^{-7} = 6.202\times10^{-3}$ *(1)*

ratio must be the same for the photon

$w_{photon} = \lambda$ / ratio $= 430\times10^{-9} / 6.2\times10^{-3} = 6.934\times10^{-5} = 6.9\times10^{-5}$ m *(1)*

c

ratio of λ / w (or the inverse) *(1)*

Study Design

- investigate and explain theoretically and practically diffraction as the directional spread of various frequencies with reference to different gap width or obstacle size, including the qualitative effect of changing the w/λ ratio.
- calculate the de Broglie wavelength of matter: $\lambda = h/mv$
- compare the momentum of photons and of matter of the same wavelength including calculations using: $p = h/\lambda$

Web links

https://www.vcaa.vic.edu.au/Documents/exams/physics/2020/2020physics-w.pdf

https://www.vcaa.vic.edu.au/Documents/exams/physics/2020/2020physics-exam-report.pdf
Section B Question 16

https://personal.math.ubc.ca/~cass/courses/m309-03a/m309-projects/krzak/

https://www.coursehero.com/study-guides/physics/27-5-single-slit-diffraction/

Question 7 (5 marks)

a

Length of the ship will be observed as less, because the rest length was not measured under these relativistic speed conditions. Length is contracted for the observer. *(1)*

This is changed at relativistic speeds because the speed of light is invariant for all observers, the key observation behind Einstein's Special Relativity *(1)*

b

$\gamma = L_o/L$ = 800 / 600 = 1.3333
$\beta^2 = 1 - 1/\gamma^2$ = 1 – 1 / 1.3333^2 = 0.4375 *(1)*
$v = \sqrt{}$ 0.4375 × 3×10^8 = 0.6614 × 3×10^8 = 1.984×10^8 = 1.98×10^8 m s^{-1} (1)

c

γ = 1.3333
$E_k = (\gamma - 1)mc^2$ = (1.3333 – 1) 1.5×10^7 × (3×10^8)^2 = 4.5×10^{23} J *(1)*

Study Design

- describe Einstein's two postulates for his theory of special relativity that:

—the laws of physics are the same in all inertial (non-accelerated) frames of reference
—the speed of light has a constant value for all observers regardless of their motion or the motion of the source

- describe proper time (to) as the time interval between two events in a reference frame where the two events occur at the same point in space
- describe proper length (L_o) as the length that is measured in the frame of reference in which objects are at rest
- model mathematically time dilation and length contraction at speeds approaching c using the equations: $t = t_o\gamma$ and $L = L_o/\gamma$ where $\gamma = (1 - v^2/c^2)^{-1/2}$
- interpret Einstein's prediction by showing that the total 'mass-energy' of an object is given by:

$E_{tot} = E_k + E_o = \gamma mc^2$ where $E_o = mc^2$, and where kinetic energy can be calculated by: $E_k = (\gamma - 1)mc^2$

Web links

https://www.calctool.org/CALC/phys/relativity/gamma

http://hyperphysics.phy-astr.gsu.edu/hbase/Relativ/tdil.html

Question 8 (4 marks)

a

The observers see the life time of the muon dilated by the Lorentz factor, which allows for the observation that it has travelled longer during that lifetime from an Earth surface observer's reference frame. *(1)*

b

$t = t_o\gamma = 2.2 \times 7.1 = 15.6 = 16$ μs

c

The muon based observer records the distance it travels through the atmosphere as length contracted by the Lorentz factor, so it travels further than expected from its frame of reference. *(1)*

d

$x = 650 \times 7.1 = 4.61 \times 10^3 = 4.6 \times 10^3$ .m *(1)*

Study Design

- explain why muons can reach Earth even though their half-lives would suggest that they should decay in the outer atmosphere.

Web links

http://hyperphysics.phy-astr.gsu.edu/hbase/Relativ/muon.html

https://en.wikipedia.org/wiki/Experimental_testing_of_time_dilation

https://www.schoolphysics.co.uk/age16-19/Relativity/text/Muons_time_dilation/index.html
(Note average life of the population = 2.2 μs, half life of a single muon = 1.5 μs)

Question 9 (7 marks)

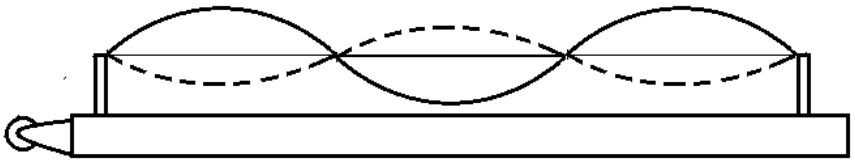
a

$\lambda = 2 \times 0.85 = 1.7$ (only a half wave in the string)

$f = v / \lambda = 255 / 1.7 = 150$ Hz *(1)*

b

waves must be 1.5 cycles long



(1) for each.

One wave can be a straight line.

c

Waves travel both ways along the string as transverse waves, and then reflect, inverted. *(1)*

The superimposed waveforms have static nodes. Antinodes between them *(1)*

d

This reflecting form is a standing wave, with transverse structure in the wire. *(1)*

The transverse movements create the compressions and rarefactions which carry sound through the air longitudinally. *(1)*

Question 9 continued

Study Design

- distinguish between transverse and longitudinal waves
- identify the amplitude, wavelength, period and frequency of waves
- calculate the wavelength, frequency, period and speed of travel of waves using: $v = f\lambda = \lambda/T$
- investigate and analyse theoretically and practically constructive and destructive interference from two sources with reference to coherent waves and path difference: $n\lambda$ and $(n - 1/2)\lambda$ respectively
- explain resonance as the superposition of a travelling wave and its reflection, and with reference to a forced oscillation matching the natural frequency of vibration
- analyse the formation of standing waves in strings fixed at one or both ends

Web links

https://sciencetrends.com/transverse-waves-examples/#:~:text=A%20guitar%20string's%20motion%20can,the%20string%20itself%20for%20now).

https://byjus.com/jee/standing-wave-on-a-string/#:~:text=The%20standing%20waves%20are%20formed,also%20known%20as%20stationary%20waves.

https://www.walter-fendt.de/html5/phen/standingwavereflection_en.htm
shows the original travelling wave, meeting the reflected wave and superimposing to the standing wave

https://www.physicsclassroom.com/class/waves/Lesson-4/Mathematics-of-Standing-Waves

http://hyperphysics.phy-astr.gsu.edu/hbase/Waves/string.html

Question 10 (8 marks)

a

ϕ_{max} = BA = 0.25 × 0.05 × 0.06 = 7.5×10^{-4} Wb *(1)*

(Do not multiply by the 300 turns.)

b

T = 1/ f = 1/40 = 0.025

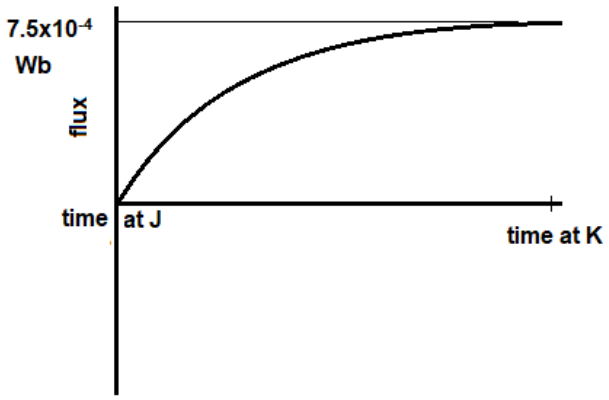
emf = nBA/Δt = 300 × 0.25 × 0.05 × 0.06 / 0.025 × 4 *(1)* = 36 V *(1)*

c

Graph rises in a *curve (1)*

Flux is zero at J, 7.5×10^{-4} Wb at *K* *(1)*

The negative graph is correct too.



d

0 V *(1)*

The emf produced in the first quarter turn is opposite in polarity to that in the second quarter. The average is zero.

e

The voltage in the generator inverts in the second quarter turn, but this is countered by the commutators so the polarity is unchanged and the average voltage in the second quarter is the same as the first.

36 V. *(1)*

Study Design

- calculate magnetic flux when the magnetic field is perpendicular to the area, and describe the qualitative effect of differing angles between the area and the field: $\varphi_B = B_\perp/A$
- explain the production of DC voltage in DC generators and AC voltage in alternators, including the use of split ring commutators and slip rings respectively.

Web links

https://www.coursehero.com/study-guides/physics/23-5-electric-generators/ Example 1

https://www.youtube.com/watch?v=CPRozhVX65o

Question 11 (2 marks)

a

initial mass = $1.673\times10^{-27} + 1.8281\times10^{-26} = 1.9954\times10^{-26}$

final mass = $3 \times 6.645\times10^{-27} = 1.9935\times10^{-26}$

mass defect = $1.9954\times10^{-26} - 1.9935\times10^{-26} = 1.9\times10^{-29}$ *(1)*

energy release $E = mc^2 = 1.9\times10^{-29} \times (3\times10^{8})^2 = 1.71\times10^{-12} = 1.7\times10^{-12}$ J *(1)*

Study Design

- describe how matter is converted to energy by nuclear fusion in the Sun, which leads to its mass decreasing and the emission of electromagnetic radiation.

Web links

https://chem.libretexts.org/Courses/University_of_Missouri/MU%3A__1330H_(Keller)/21%3A_Nuclear_Chemistry/21.8%3A_Nuclear_Fusion

https://www.amnh.org/exhibitions/einstein/educator-resources/how-the-sun-works

https://hb11.energy/how-it-works/

https://physics.stackexchange.com/questions/32699/how-to-explain-e-mc2-mass-defect-in-fission-fusion#:~:text=mass%20defect%20is%20the%20surplus,system%20before%20and%20after%20reaction

Question 12 (5 marks)

a

$V_{peak\ to\ peak}$ = 12.4 × 4 × 2 × √2 *(1)* = 140.3 = 140 V *(1)*

b

$P = V_{out\ RMS}{}^2/R =$ (4 × 12.4)² / 130 *(1)* = 18.9 = 19 W *(1)*

c

ability to change voltage in a transformer, with low losses
high voltage transmission reduces currents and transmission losses
switching is much simpler (DC switches can spark and burn at high current)
residual current safety switches work on AC only *(1)* for any correct answer

Study Design

- compare sinusoidal AC voltages produced as a result of the uniform rotation of a loop in a constant magnetic field with reference to frequency, period, amplitude, peak-to-peak voltage (V_{p-p}) and peak-to-peak current (I_{p-p})
- compare alternating voltage expressed as the root-mean-square (rms) to a constant DC voltage developing the same power in a resistive component
- convert between rms, peak and peak-to-peak values of voltage and current
- analyse action with reference to electromagnetic induction for an ideal transformer: $N_1/N_2 = V_1/V_2 = I_2/I_1$
- identify the advantage of the use of AC power as a domestic power supply.

Web links

http://sparks-activities.concord.org/sparks-content/tutorials/tutorial-22.html#:~:text=There%20are%20three%20different%20measures,P%2C%20measured%20with%20an%20oscilloscope.

https://www.electronics-tutorials.ws/resistor/res_8.html

https://www.electricalclassroom.com/transformer-ratio-calculator-online/

https://www.electronics-tutorials.ws/transformer/transformer-basics.html

Question 13 (4 marks)

a

Positron is positively charged and is forced into a circular path.
By the right hand three vector rule, current is clockwise and the force is towards the centre.
The magnetic field must have been up through the film (page) *(1)*
(This could be answered with a diagram.)

b

Using curled fingers this field is down, into the film (page). *(1)*
Note: The movement of the positrons is that of a positive current.

c

$v = RqB/m =$ 0.011 × 1.6×10^{-19} × 0.012 / 9.1×10^{-31} *(1)* = 2.32×10^{-7} = 2.3×10^{7} m s^{-1} *(1)*

Study Design

- analyse the use of a magnetic field to change the path of a charged particle, including:

—the magnitude and direction of the force applied to an electron beam by a magnetic field: $F = qvB$ in cases where the directions of v and B are perpendicular or parallel

—the radius of the path followed by a low-velocity electron in a magnetic field: $qvB = mv^2/r$

- investigate and analyse theoretically and practically the force on a current carrying conductor due to an external magnetic field, $F = nIlB$, where the directions of I and B are either perpendicular or parallel to each other

Web links

https://www.khanacademy.org/test-prep/mcat/physical-processes/magnetism-mcat/a/using-the-right-hand-rule#:~:text=Moving%20charges,-When%20charges%20are&text=We%20can%20remember%20this%20diagram,pushing%20on%20the%20moving%20charge.

https://openstax.org/books/university-physics-volume-2/pages/11-3-motion-of-a-charged-particle-in-a-magnetic-field

Question 14 (7 marks)

a

$\Delta x = \lambda L/D$ = $5.5\times10^{-7} \times 1.25 / 4.3\times10^{-4}$ *(1)*= 0.001599 = 0.0016 m

ten slits = 10 × 0.0016 = 0.016 m *(1)*

b

The screen would show an alternating spectrum of colours with a white centre. *(1)*

At each point where constructive interference occurs for a particular wavelength, that colour will be seen. *(1)*

c

Difference = 2.5 λ = 2.5 × 550 = 1.376×10^{-6} = 1.38×10^{-6} m *(1)*

d

Path difference to the dark band from the two slits differ by (n – ½)λ *(1)*

When the waves differ by a ½ wavelength, there is destructive interference. *(1)*

Study Design

- identify that all electromagnetic waves travel at the same speed, c, in a vacuum
- explain the results of Young's double slit experiment with reference to:

—evidence for the wave-like nature of light

—constructive and destructive interference of coherent waves in terms of path differences: $n\lambda$ and $(n - 1/2)\lambda$ respectively

—effect of wavelength, distance of screen and slit separation on interference patterns: $\Delta x = \lambda L/d$

Web links

https://www.schoolphysics.co.uk/age16-19/Wave%20properties/Interference/text/Young's_double_slits/index.html

https://thefactfactor.com/facts/pure_science/physics/youngs-experiment/6798/#:~:text=If%20the%20fringe%20width%20is,7.5%20x%2010%2D4%20m.

https://www.youtube.com/watch?v=njgU1r82e98 see view at 2 min 00 sec

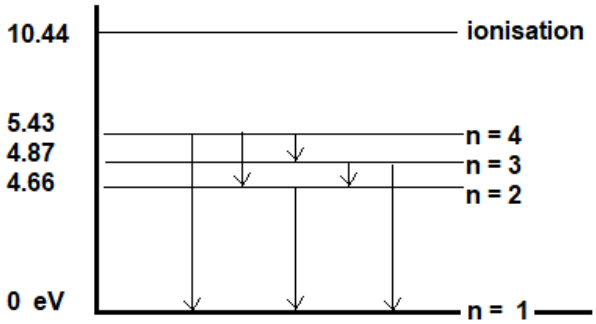
https://opentextbc.ca/universityphysicsv3openstax/chapter/youngs-double-slit-interference/

Question 15 (6 marks)

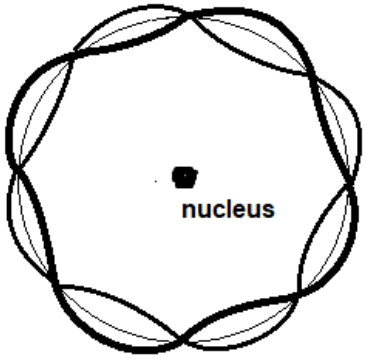
a

(1) 3 to 5 of the transitions shown correctly, none wrong. Arrows must indicate down.

(2) all 6 transitions shown correctly (n=4 to n=1, n=4 to n=2, n=4 to n=3, n=3 to n=1, n=3 to n=2, n=2 to n=1)



b



The waveforms shown must be any two possible waves, including the circle form. It must be clear than the circle answer has been drawn over the original guide to provide an answer.

c

The standing wave consists of a whole number of complete waves. *(1)*

The lengths of these whole waves are related to their electron's momentum and energy. The electron energy in an atom must be quantised to match the whole waves. *(1)*

Study Design

- describe light as an electromagnetic wave which is produced by the acceleration of charges, which in turn produces changing electric fields and associated changing magnetic fields
- calculate the de Broglie wavelength of matter: $\lambda = h/mv$
- interpret spectra and calculate the energy of absorbed or emitted photons: $\Delta E = hf$
- analyse the absorption of photons by atoms, with reference to:

—the change in energy levels of the atom due to electrons changing state

—the frequency and wavelength of emitted photons: $E = hf = h\,c/\lambda$

- describe the quantised states of the atom with reference to electrons forming standing waves, and explain this as evidence for the dual nature of matter
- compare the production of light in lasers, synchrotrons, LEDs and incandescent lights.

Question 15 continued

Web Links
https://www.researchgate.net/figure/Energy-level-diagram-of-mercury-atom_fig1_226415521

https://imagine.gsfc.nasa.gov/educators/lessons/xray_spectra/background-atoms.html

https://www.toppr.com/ask/question/an-accelerated-electron-would-produce/

https://thecuriousastronomer.wordpress.com/2014/05/13/why-do-accelerated-electrons-radiate-electromagnetic-radiation/#:~:text=In%20order%20for%20an%20electron,and%20hence%20produce%20EM%20radiation.

https://www.coursehero.com/study-guides/physics/30-6-the-wave-nature-of-matter-causes-quantization/

Question 16 (9 marks)

a

Eps $_{delivered}$ = 3.4 × 0.75 = 2.55 J which is the initial kinetic energy *(1)*

E_{Ktop} = 2.55 – *mgh* = 2.55 – 0.61 × 9.8 × 2 × 0.15 = 2.55 – 1.793 = 0.757 J *(1)*

$v_{top} = \sqrt{2\,E_K/m}$ = √(2 × 0.757 / 0.61) = 1.575 = 1.6m s^{-1} *(1)*

b

$W = mg =$ 0.61 × 9.8 = 5.978 N down

$F_{centrip} = m\,v^2/R =$ 0.61 × 1.575^2 / 0.15 = 10.088 N down

$F_{track} + W = F_{centrip}$

$F_{track} =$ 10.088 – 5.978 = *(1)* = 4.11 = 4.1 N *(1)* down *(1)*

c

Occurs when $g = v_{top}{}^2/R$

$v = \sqrt{Rg}$ = 0.3 × 9.8 = 1.212 = 1.2 m s^{-1} *(1)*

d

At the top total energy = $E_{Ktop} + E_{pg} = 0.5\,mv^2 + mgh$ = 0.61 × 0.5 × 1.212^2 + 0.61 × 9.8 × 0.3

= 0.448 + 1.793 *(1)* = 2.242

fraction = 2.242 / 3.4 = 65.93% = 66% *(1)*

Study Design

- investigate and apply theoretically and practically Newton's three laws of motion in situations where two or more coplanar forces act along a straight line and in two dimensions
- investigate and apply theoretically Newton's second law to circular motion in a vertical plane (forces at the highest and lowest positions only)

Web links

https://www.pbslearningmedia.org/resource/hew06.sci.phys.maf.rollercoaster/energy-in-a-roller-coaster-ride/

https://www.physicsclassroom.com/mmedia/energy/ce.cfm

https://www.schoolphysics.co.uk/age16-19/Mechanics/Circular%20mtion/text/Motion_in_a_vertical_circle/index.html

Question 17 (5 marks)

a

$p = mv = \sqrt{2E_K m}$ = $\sqrt{}$(2 × 160 × 1.6×10^{-19} × 9.1×10^{-31}) *(1)* = 6.8258×10^{-24} *(1)*

λ = 6.63×10^{-34} / 6.8258×10^{-24} = 9.71×10^{-11} *(1)* = 9.7×10^{-11} m

imaging resolution limit is at 9.7×10^{-11} m *(1)*

b

If the object viewed with the microscope is smaller than the wavelength, then diffraction obscures the image. *(1)*

c

$E = hc/\lambda =$ 4.14×10^{-15} × 3×10^{8} / 9.71×10^{-11} = 1.279×10^{4} = 1.3×10^{4} eV *(1)*

Study Design

- investigate and explain theoretically and practically diffraction as the directional spread of various frequencies with reference to different gap width or obstacle size, including the qualitative effect of changing the w/λ ratio.
- investigate and describe theoretically and practically the effects of varying the width of a gap or diameter of an obstacle on the diffraction pattern produced by light and apply this to limitations of imaging using light
- interpret electron diffraction patterns as evidence for the wave-like nature of matter
- calculate the de Broglie wavelength of matter: $\lambda = h/mv$

Web links

https://www.omnicalculator.com/physics/electron-speed

https://www.omnicalculator.com/physics/de-broglie-wavelength
(many interesting calculators on this site)

https://www.coursehero.com/study-guides/cheminter/de-broglie-wave-equation/

https://spark.iop.org/speed-electrons#:~:text=The%20electron%20starts%20from%20rest,and%20v%20is%20its%20speed.&text=For%20an%20electron%20gun%20with,%C3%97%2010%206%20m%2Fs.

https://www.youtube.com/watch?v=jmpnLDLVdfo

Question 18 (6 marks)

a

$p = p'$ so $m_{alpha}\,u_{alpha} + m_{proton}\,u_{proton} = m_{alpha}\,v_{alpha} + m_{proton}\,v_{proton}$

v_{proton} = (3.97 × 9.6×10^6 + 0 - 3.97 × 5.74) / 1 *(1)* = 1.532×10^7 = 1.53×10^7 m s^{-1} *(1)*

b

Check if $E_K = E_K{}'$

½ (3.97 × (9.6×10^6)^2 + 1 × 0^2) = ½ (3.97 × (5.74×10^6)^2 + 1 × (1.53×10^6)^2) *(1)*

1.83×10^{14} = 1.83×10^{14} equal so elastic *(1)*

(1) for one energy only correctly calculated

c

There are no external forces like friction acting.

or

The only forces acting are the Coulomb force, which is the same when approaching and departing.

d

The velocity was low enough that the errors in Newton's motion are insignificant.

or

The accuracy of the data will not show the differences between Newton's motion and Einstein's more accurate description.

Study Design

- investigate and apply theoretically and practically the laws of energy and momentum conservation in isolated systems in one dimension.
- compare Einstein's theory of special relativity with the principles of classical physics

Web Links

https://www.physicsclassroom.com/Class/momentum/u4l2d.cfm

https://www.varsitytutors.com/high_school_physics-help/understanding-elastic-and-inelastic-collisions

http://hyperphysics.phy-astr.gsu.edu/hbase/elacol.html

https://phys.libretexts.org/Bookshelves/University_Physics/Book%3A_Physics_(Boundless)/27%3A__Special_Relativity/27.2%3A_Consequences_of_Special_Relativity#:~:text=Thus%2C%20time%20dilation%20effects%20and,10%20the%20speed%20of%20light).
(see Time Dilation)

Question 19 (5 marks)

a

It will produce a diffraction pattern, with a similar form to that produced by a beam of electrons. *(1)*

b

The photons and electrons are behaving as particles when passing through the slits, one at a time. *(1)*

Particles and photons are both exhibiting wave properties in their diffraction pattern. *(1)*

c

electrons have wavelength but no frequency, unlike photons which have both
frequency determines the energy of photons, for electrons it is speed
electrons have variable speeds, which determine wavelength, unlike photons which have a fixed vacuum speed
electrons have mass, photons have none
any two, *(1)* each, including any other correct answer

Study Design

- distinguish between the diffraction patterns produced by photons and electrons
- interpret the single photon/electron double slit experiment as evidence for the dual nature of light/matter
- models and theories, and their use in organising and understanding observed phenomena and physics concepts including their limitations

Web Links

https://www.youtube.com/watch?v=ZUI3lhRje_0 electron

https://www.youtube.com/watch?v=I9Ab8BLW3kA photon, most after 5 min

https://photonterrace.net/en/photon/duality/

https://theconversation.com/explainer-what-is-wave-particle-duality-7414

Question 20 (3 marks)

a

TV, mobile phones, communication systems, Bluetooth, Wi-Fi, some radio use *(1) for any answer*

b

UV light (will kill Covid-19 viruses in aircraft cabins. The upper end of this light spectrum band is lethal.) *(1)*

c

These mostly visible colours plus some IR and UV are those available given the available natural light sources, like the sun.
They match up. *(1)*
or
The light which is not damaging and available covers the IR, visible and lower UV bands. It has enough energy to activate chemicals in the eye which produce vision. *(1)* Lower IR lacks the necessary energy and the upper UV is damaging.
or
The photon energy available in this range is enough to twist a molecule which activates vision, without damaging it with too much energy. *(1)*

Study Design

- compare the wavelength and frequencies of different regions of the electromagnetic spectrum, including radio, microwave, infrared, visible, ultraviolet, x-ray and gamma, and identify the distinct uses each has in society

Web Links

https://www.highlandwireless.com/the-differences-between-uhf-and-vhf-radio-frequencies/

https://spectrum.ieee.org/germfalcon-coronavirus-airplane-ultraviolet-sterilizer-news

https://www.kmlabs.com/en/wavelength-to-photon-energy-calculator

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End of answers for the 2022 Kilbaha VCE Physics Trial Examination

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