2019 VCAA Physics Examination Solutions

SECTION A

1	2	3	4	5	6	7	8	9	10
A	B	A	D	B	C	D	A	D	B

11	12	13	14	15	16	17	18	19	20
A	C	C	C	B	D	D	A	C	B

Q1 A

Q2 $V = Ed = \left(2.0\times10^{-4}\right)\left(1.0\times10^{-2}\right) = 2.0\times10^{-6}$ V B

Q3 A

Q4 $2\times\frac{1}{\left(\frac{1}{2}\right)^2}\times g = 8g$ D

Q5 B

Q6 $P_p = P_s$ $V_p I_p = \frac{V_s^{\,2}}{R_s}$, $40 I_p = \frac{240^2}{1200}$, $I_p = 1.20$ A C

Q7 Lower frequency $\rightarrow$ longer period and lower voltage

Q8 $\varepsilon = -N\frac{\Delta\phi}{\Delta t}$ A

Q9 $v_1 > v_2$ and $v_3 > v_1$ D

Q10 Critical angle: $\frac{n}{1.75} = \sin 62.0°$, $n \approx 1.55$ B

Q11 Constant velocity, zero net force A

Q12 Acceleration due to gravity is constant at the Earth's surface. C

Q13 $L_o = \gamma L = 3\times150 = 450$ m C

Q14 Little relativistic effects on momentum $p = mv$

$\lambda = \frac{h}{p} = \frac{6.63\times10^{-34}}{9.1\times10^{-31}\times1.0\times10^{7}} \approx 7.3\times10^{-11}$ m C

Q15 Higher speed, shorter wavelength, less diffraction, decrease in fringe spacing B

Q16 Higher intensity, more photons of the same energy, more photoelectrons of the same max kinetic energy D

Q17 D

Q18 A

Q19 C

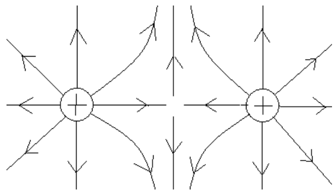
Q20 Some initial kinetic energy of the car is used to crumple the car's front structure. B

SECTION B

Q1a The charge q is negative. Using the right hand slap rule it would curve in the opposite direction if it was positive.

Q1b There is a magnetic force of constant magnitude always acting perpendicular to the particle's motion (velocity) and the magnetic field. This causes the particle to travel in a circular path with the magnetic field perpendicular to the path.

Q2



Q3a X

Q3b Vertically downwards

Q3c The split-ring commutator reverses the direction of the current every half turn in order to provide anticlockwise torque to the coil to keep it rotating in the same direction continuously.

Q3d $F = nBIL = 100\times0.45\times6.0\times0.050 = 13.5$ N

Q4a 9.8 N kg^{-1}

Q4b Assuming Earth is a sphere of constant density, the gravitational field of the matter surrounding the centre has a vector sum of zero at the centre of Earth.

Q4c $\Delta E_{gpe} = m\times$ area under graph

$= 75\times\frac{1}{2}\left(6.37\times10^{6}\right)\times9.8 \approx 2.34\times10^{9}$ J

Q5a Force of gravity exerted by Earth on the satellite perpendicular to the orbit towards the centre of Earth.

Q5b $r = 6.37\times10^{6} + 2.00\times10^{7} = 2.637\times10^{7}$, $\frac{GM}{r^2} = \frac{1}{r}\left(\frac{2\pi r}{T}\right)^2$

$$T = 2\pi\sqrt{\frac{r^3}{GM}} = 2\pi\sqrt{\frac{\left(2.637\times10^{7}\right)^3}{\left(6.67\times10^{-11}\right)\left(5.98\times10^{24}\right)}} \approx 4.26\times10^{4} \text{ s}$$

Q6a $P = \frac{V^2}{R} = \frac{12}{12} = 12$ W

Q6b Total resistance (extension +lighting system) $= 3 + 12 = 15\,\Omega$

$I = \frac{12}{15} = 0.80$ A, power of lighting system $= 0.80^2\times12 \approx 7.7$ W, less power, dimmer

Q6c Place the step-down transformer next to the lighting system. The current in the lighting system will be a tad below 1 A so that the brightness will be slightly dimmer. The current in the extension lead is approximately $\frac{1}{20}$ of 1 A, and will not cause significant drop in voltage input to the transformer.

Q7a Alternator

Q7bi 0 Wb

Q7bii B is parallel to the plane of the loop, i.e. B and A make a $90°$ angle, $\phi = BA\cos 90° = 0$

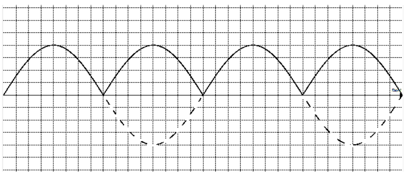
Q7c $T = \frac{1}{f} = \frac{1}{20} = 0.05\,\text{s}$

Q7d $\phi_{\max} = 0.40 \times 0.50 \times 0.25 = 0.05$ Wb

Q7e $V_{av} = \frac{0.05}{\frac{0.05}{4}} = 4$ V

Q7f Increase the frequency of rotation, increase the uniform magnetic field strength

Q7g



Q8a Total energy at A = total energy at B

$0.25 \times 9.8 \times h = 0.25 \times 9.8 \times 0.40 + \frac{1}{2} \times 0.25 \times 3.0^2$, $h = 0.86$ m

Q8b $N + 0.25 \times 9.8 = \frac{0.25 \times 3.0^2}{0.20}$, $N = 8.8\,\text{N}$

Q8c The existence of a non-zero normal reaction force on the car at B shows that the car is in contact with the track and moves along the track. If the normal reaction force is zero, the car will move under constant gravity only in a parabolic path and leave the track.

Q9 Let u be the initial speed of the proton.
Momentum of the isolated system before = momentum of the isolated system after collision

$mu = m(-6.0 \times 10^6) + 4m(4.0 \times 10^6)$, $u = 1.0 \times 10^7$ m s^{-1}

Q10a $u = 25\sin 39° \approx 15.733$, $a = -9.8$, $v = 0$
$0 = 15.733 - 9.8t$, $t \approx 1.6$ s (1.6054)

Q10b Range $R = 2 \times (25\cos 39°) \times 1.6054 \approx 62.4$ m

Q11 The speed of light is constant and independent of the motion of the observer or the motion of the source.
In classical physics speed depends on the motion of the observer or the motion of the source.

Q12 $T = 4 \times 0.12 = 0.48$ s, wave speed $= \frac{\lambda}{T} = \frac{1.40}{0.48} \approx 2.9$ m s^{-1}

Q13a $\lambda = \frac{v}{f} = \frac{40}{7.5} \approx 5.3\,\text{m}$

Q13b No standing wave will be formed. Forming a standing wave requires the length of the string to be an integer multiple of $\frac{\lambda}{2}$.

Q14a P_3 is the third maximum intensity from P_0
Path difference $S_2P_3 - S_1P = 3\lambda$, $80.6 - 72.3 = 3\lambda$, $\lambda \approx 2.77$ cm

Frequency $= \frac{v}{\lambda} = \frac{3.00 \times 10^8}{2.77 \times 10^{-2}} \approx 1.08 \times 10^{10}$ Hz

Q14b At midway between P_0 and P_1 the path difference from the two slits is approximately $\frac{\lambda}{2}$. The two waves from the slits are out of phase by about a half of a period thus causing destructive interference of the two waves.

Q14c Light waves with oscillations of electric field or magnetic field occur in one plane only are called polarised light waves.

Q15a Dispersion of white light. Different colour lights have different refractive indices when travel from a medium to another medium. The differences cause the different colour lights entering the second medium at different angles and spreading out. The same occurs when they leave the second medium back into the first medium.

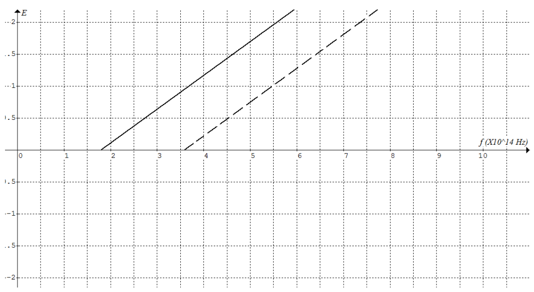
Q15b Point X: Red Point Y: Violet

Q16ai $h \approx \frac{2.0 - 0}{(7.4 - 3.6) \times 10^{14}} \approx 5.3 \times 10^{-15}$ eV s

Q16aii $\lambda_{\max} \approx \frac{3.0 \times 10^8}{3.6 \times 10^{14}} \approx 8.3 \times 10^{-7}\,\text{m} = 8.3 \times 10^2$ nm

Q16aiii Work function $= hf_0 \approx (5.3 \times 10^{-15})(3.6 \times 10^{14}) \approx 1.9\,\text{eV}$

Q16b



Q17a Moving electrons show wave behaviour and have $\lambda = \frac{h}{\sqrt{2mE_k}}$. Since spacing of bands in a diffraction pattern is directly proportional to wavelength for both matter and light waves, the electrons and the X-rays must have the same wavelength to produce the same pattern (same spacing of bands).

Q17b
For the electron

$$\lambda = \frac{6.63 \times 10^{-34}}{\sqrt{2(9.1 \times 10^{-31})(3.0 \times 10^3 \times 1.6 \times 10^{-19})}} \approx 2.24 \times 10^{-11}\,\text{m}$$

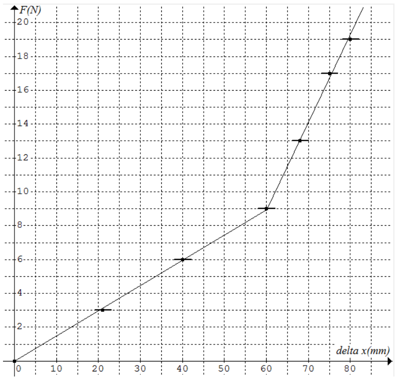
.: the wavelength of X-rays $\approx 2.24 \times 10^{-11}\,\text{m}$

.: frequency of X-rays $\frac{v}{\lambda} = \frac{3.0 \times 10^8}{2.24 \times 10^{-11}} \approx 1.3 \times 10^{19}$ Hz

Q18a The hydrogen atom could be excited to the $n = 4$ state in one step by absorbing a photon of energy 12.8 eV.

Q18b From $n = 4$ to $n = 2$ directly: $E = 12.8 - 10.2 = 2.6$ eV
From $n = 4$ to $n = 3$: $E = 12.8 - 12.1 = 0.7$ eV
From $n = 3$ to $n = 2$: $E = 12.1 - 10.2 = 1.9$ eV

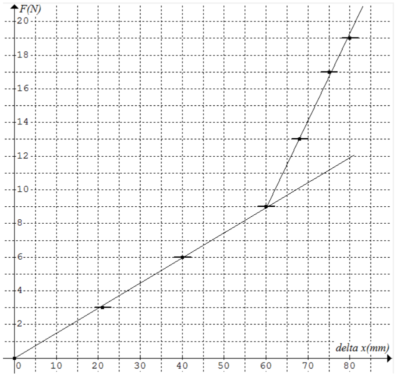
Q19a $g = 10\,\mathrm{N\,kg^{-1}}$ for the following graphs



Q19bi Using $(0, 0)$ and $(0.06, 8.9)$, $k_A \approx \dfrac{8.9}{0.06} \approx 150$ N m^{-1}

Q19bii Using $(0.08, 19.1)$
$19.1 \approx 150(0.08) + k_B(0.08 - 0.06)$
$k_B \approx 360$ N m^{-1}
OR $150 + k_B = \dfrac{19.1 - 8.9}{0.08 - 0.06}$, $k_B \approx 360$ N m^{-1}

Q19ci Spring A:



$PE_A = \dfrac{1}{2} \times 0.08 \times 11.9 \approx 0.48$ J

Q19cii $PE_{A+B} = \dfrac{1}{2}(0.06 \times 8.9 + 0.02 \times (8.9 + 19.1)) \approx 0.55$ J

Q19ciii Work $\approx 0.55 - 0.48 = 0.07$ J

Q19d For small bumps Spring A (lower spring constant) will be stiff enough to absorb the kinetic energy of the upward motion of the car caused by the bump. For more severe bumps, Spring B (higher spring constant) will be activated together with Spring A to absorb higher kinetic energy of the car.

Please inform mathline@itute.com re conceptual and/or mathematical errors.