2015 VCAA Physics Examination Solutions

Area of study – Motion in one and two dimensions

Q1a Conservation of momentum: $4.0 \times {}^{+}8.0 = 4.0 \times {}^{-}2.0 + 8.0v$

.: $v = {}^{+}5.0$.: the speed of block B after collision is 5.0 ms^{-1}.

Q1b total kinetic energy after $= \frac{1}{2}(4.0)(2.0^2) + \frac{1}{2}(8.0)(5.0^2) = 108$ J

Total kinetic energy before $= \frac{1}{2}(4.0)(8.0^2) = 128$ J

Kinetic energy is not conserved .: the collision is inelastic.

Q1c impulse on block A = change in momentum of block A

$= 4.0 \times {}^{-}2.0 - 4.0 \times {}^{+}8.0 = {}^{-}40$, i.e. 40 Ns to the left

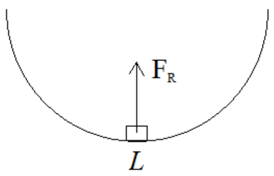
Q2a Consider the motion of the two masses together:

$a_{M1} = a_{M2} = \frac{F}{m} = \frac{1.0 \times 10}{1.0 + 4.0} = 2.0\ \text{ms}^{-2}$

Q2b Consider the motion of M_1 alone:

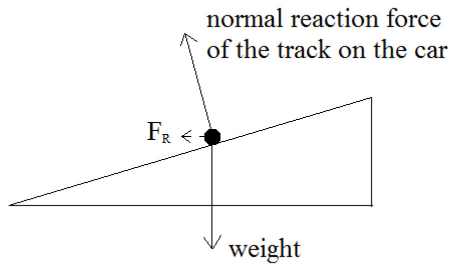
tension $F = ma = 4.0 \times 2.0 = 8.0$ N

Q3a



Q3b $F_R = \frac{mv^2}{r}$, $F - 2.0 \times 10 = \frac{2.0 \times 6.0^2}{4.0}$, $F = 38$ N

Q4a



Q4b Note: In the introduction the speed is 2.0 ms^{-1}, but it is changed to 3.0 ms^{-1} in part b.

$F_R = \frac{mv^2}{r}$, $2.0 \times 10 \times \tan\theta = \frac{2.0 \times 3.0^2}{3.0}$

.: $\theta \approx 17°$ is the angle of bank of the track

Q5a Vertical component: $u = {}^{+}40 \sin 30° = {}^{+}20$, $a = {}^{-}10$, $v = 0$, s?

$v^2 = u^2 + 2as$, $s = {}^{+}20$.: $h = 20$ m

Q5b Horizontal component: $u = {}^{+}40 \cos 30°$, $s = {}^{+}173$, t?

$s = ut$, $t \approx 4.9941$

Vertical component: $u = {}^{+}20$, $a = {}^{-}10$, $t = 4.9941$, s?

$s = ut + \frac{1}{2}at^2$, $s \approx {}^{-}24.8$.: $d = 24.8$ m

Q6a $\Delta U = 0 - 2.0 \times 10 \times 0.80 = -16$ J, i.e. a decrease of 16 J

Q6b Spring potential energy $= \frac{1}{2}kx^2 = \frac{1}{2} \times 50 \times 0.80^2 = 16$ J

Note: Gravitational potential energy changes to spring potential energy.

Q6c Conservation of energy:

Total energy at its midpoint = total energy at its lowest point

$\frac{1}{2} \times 50 \times 0.40^2 + \frac{1}{2} \times 2.0 v^2 + 2.0 \times 10 \times 0.40 = 16$.: $v = 2.0$ ms^{-1}

Q6d Graph C

At the highest point (zero spring extension) gravity is the only cause of acceleration (${}^{-}10$ ms^{-2}). Speed is maximum at the midpoint (0.40 m extension) and .: acceleration is zero. Below the midpoint (greater than 0.40 m extension) force of the spring is greater than the weight force and .: acceleration is positive (upwards).

Q7a period = 10 hours 15 minutes = 36900 s

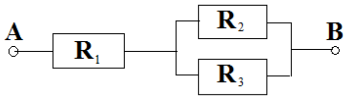
Q7b $a = g$, $\frac{4\pi^2 r}{T^2} = \frac{GM}{r^2}$

$r^3 = \frac{GMT^2}{4\pi^2} = \frac{(6.67 \times 10^{-11})(5.68 \times 10^{26})(36900^2)}{4\pi^2}$, $r \approx 1.09 \times 10^8$ m

Q7c The astronaut and the spacecraft have the same acceleration $g = \frac{GM}{r^2}$, i.e. both are in free fall. The only force on the astronaut is the force of gravity of Saturn. The astronaut would experience negligible reaction force of the spacecraft (due to gravity between the two) and feel weightless.

Area of study – Electronics and photonics

Q8a



Q8b

	Voltage drop (V)
R_1	6
R_2	3
R_3	3
R_4	

Q9a LED – changes electrical signal to light signal

Q9b photodiode – changes light signal to electrical signal

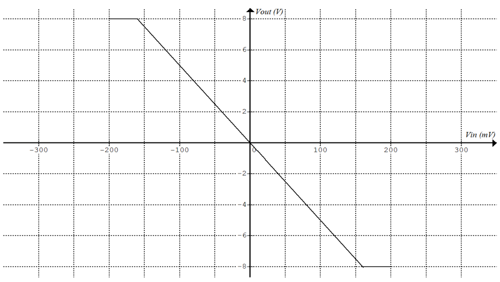
Q10a Read from graph: 15 kV

Q10b $\frac{R}{15}=\frac{60-10}{10}$, $R = 75$ kV

Q11a |voltage gain| $=\frac{5}{100\times10^{-3}}=50$

Q11b The amplifier has an output range of ±8.0 V, corresponding to an input range of $\pm\frac{8.0\times10^{3}\ \text{mV}}{50}=\pm160$ mV. The output signal has the shape shown indicating clipping has occurred, because the input signal has a peak voltage of 200 mV, exceeding 160 mV.

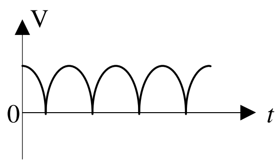
Q11c



Area of study – Electric power

Q12a $F = nI\ell B = 10\times4.0\times0.040\times\left(2.0\times10^{-3}\right)=3.2\times10^{-3}$ N up

Q12b **B**

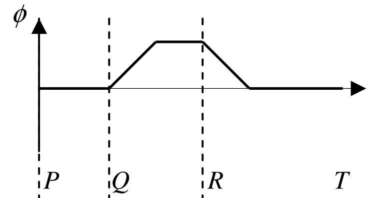


Q12c

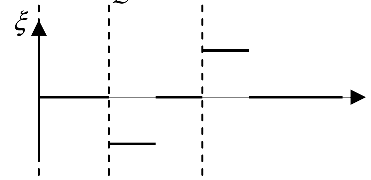
$$|\xi_{av}| = n\left|\frac{\Delta\phi}{\Delta t}\right| = 10\times\frac{\left(2.0\times10^{-3}\right)\times0.040^2}{0.5\times0.25}\approx 2.6\times10^{-4}\ \text{V} = 0.26\ \text{mV}$$

Q12d Replace the split-ring commutator with a pair of slip-rings. The magnetic flux through the square coil changes direction every half-turn and thus the induced current in the coil reverses its direction every half-turn. By removing the split-ring commutator, the two terminals of the coil reverse their polarities every half-turn .: the generator is AC. A pair of slip rings is connected to the two terminals to make contact with an external circuit via the brushes.

Q13a



Q13b

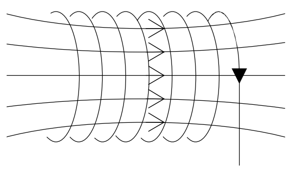


Q13c X to Y: As the loop enters the magnetic field (Fig 14b) magnetic flux (into the page) increases. According to Lenz's law, the induced current flows anticlockwise, generating a magnetic field (out of the page) to oppose the increasing magnetic flux.

Q14a $f=\frac{1}{40\times10^{-3}}=25$ Hz

Q14b Input RMS voltage $=45\times\frac{300}{\sqrt{2}}\approx9.5\times10^{3}$ V

Q15



Q16a $I=\frac{P}{V}=\frac{4.0}{2.0}=2.0$ A

Q16b Voltage drop in the transmission lines
$=IR=2.0\times4.0=8.0$ V
Voltage output of the power supply $=8.0+2.0=10$ V

Q16c Power loss in the transmission lines
$=$ voltage drop $\times$ current $=8.0\times2.0=16$ W

Q16d Consider step-down transformer T_2:

$\frac{I_p}{I_s}=\frac{N_s}{N_p}$, $\frac{I_p}{2.0}=\frac{1}{10}$, $I_p=0.20$ A

.: current in the transmission lines $=0.20$ A

Q16e Power loss in the transmission lines
$=I^2R=0.20^2\times4.0=0.16$ W

Q16f Transmission of electric power from a power station to homes, offices or factories.
At the power station a step-up transformer is connected to the generator to increase its output voltage. This lowers the current in the transmission lines and provides the same power supplied by the generator for transmission, $V_{out}I_{out}=V_{in}I_{in}$.
Lowering the current in the transmission lines reduces loss of power in the lines since $P_{loss}=I^2R$, where I is the current in the transmission lines and R is the total resistance of the lines.
At the user's end of the transmission lines, a step-down transformer decreases the high voltage in the lines to suitable voltages for home or industrial uses.

Area of study – Interactions of light and matter

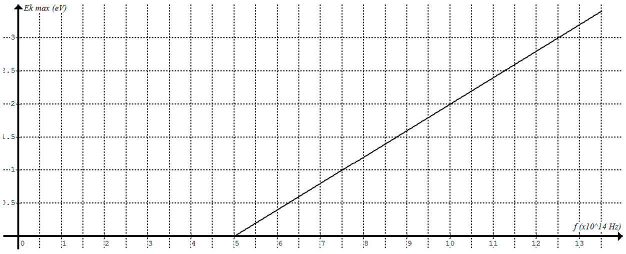
Q17a The point is a bright band. Once the slide (double slits) is in place, the light waves from the two slits are in phase and coherent. There is zero path difference from the two slits to the point and therefore the two waves interfere constructively to produce a bright band.

Q17b C

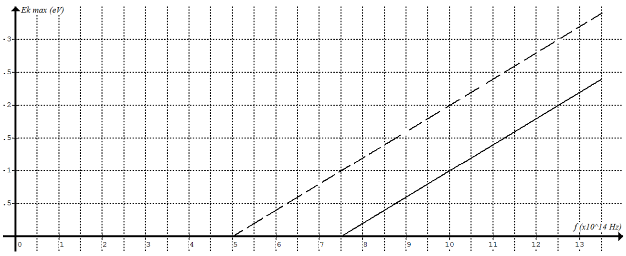
Q18a Read from graph: 5×10^{14} Hz

Q18b Planck's constant $=$ gradient $= \dfrac{2}{5\times10^{14}} = 4\times10^{-15}$ eV s

Q18c

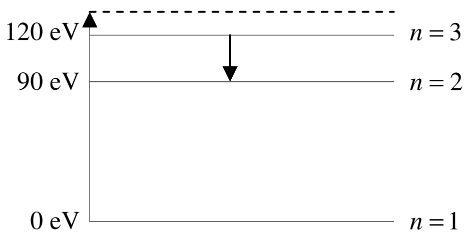


Q18d



Q19a For $n=2$, energy above the $n=1$ ground state
$= \left(4.14\times10^{-15}\right)\times\left(2.22\times10^{16}\right)\approx 91.9$ eV
For $n=3$, energy above the $n=1$ ground state
$= \left(4.14\times10^{-15}\right)\times\left(2.63\times10^{16}\right)\approx 109$ eV

Q19b Photon energy $= \left(4.14\times10^{-15}\right)\times\left(7.25\times10^{15}\right)\approx 30.0$ eV

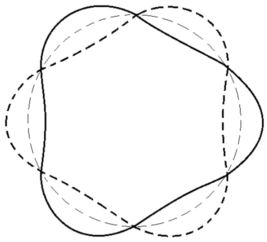


Q20a The photoelectric effect:
By considering light as a beam of particles, one can explain the max E_k of the photoelectrons depends on the frequency of the light and the type of metal used. It does not depend on the intensity of the light.
In the equation, max $E_k = hf - \phi$, hf is the energy of a particle (photon). There will be no emission of electrons if the photon energy is lowered than the work function of the metal, hence the existence of threshold frequency.

Q20b Experiment performed by C. J. Davisson and L. H. Germer: They scattered electrons from the surface of a metal crystal and observed that electrons came off in regular peaks. They interpreted these peaks as a diffraction pattern, and the wavelength of the diffracted electron wave was found to be just that predicted by de Broglie.

Q21a Louis de Broglie proposed that each electron orbit (quantised state) in an atom is actually a circular standing wave that closes on itself. The only waves that are possible are those for which the circumference of the circular orbit contains a whole number of wavelengths.

Q21b For example, $n=3$



Q22 $v = \dfrac{h}{m\lambda} = \dfrac{6.63\times10^{-34}}{\left(9.1\times10^{-31}\right)\times\left(1.0\times10^{-11}\right)} \approx 7.3\times10^{7}$ ms^{-1}

Detailed study 1 – Einstein's special relativity

1	2	3	4	5	6	7	8	9	10	11
C	B	C	A	D	D	D	A	C	B	B

Q3 Red shift **C**

Q5 Time dilation **D**

Q6 $0.115 = \frac{0.100}{\sqrt{1-\left(\frac{v}{c}\right)^2}}$, $v \approx 0.4938c$ **D**

Q7 $L = \frac{L_o}{\gamma} = \frac{500}{1.5} \approx 333\ \text{m}$ **D**

Q9 Conversion of mass to energy:

$E = mc^2$, $m = \frac{E}{c^2} = \frac{1.8\times10^{-13}}{\left(3.0\times10^{8}\right)^2} = 2\times10^{-30}\ \text{kg}$

.: final mass $= M_i - 2\times10^{-30}\ \text{kg}$ **C**

Q11 Ratio $= \frac{E_k}{m_0c^2} = \gamma - 1 = \frac{1}{\sqrt{1-\left(\frac{v}{c}\right)^2}} - 1$

When $v = 0$, ratio $= 0$, when $v \to c$, ratio $\to \infty$ **B**

Detailed study 2 – Materials and their use in structures

1	2	3	4	5	6	7	8	9	10	11
A	A	C	B	B	D	B	C	D	C	D

Q3 $F = \sigma A = \left(450\times10^6\right)\left(1.5\times10^{-3}\right) \approx 6.8\times10^5\ \text{N}$ **C**

Q5 Total energy $=$ area under the graph $\times$ volume of material

$= \frac{1}{2}\times\left(6\times10^{-3}\right)\times\left(300\times10^6\right)\times0.10\times\left(1.5\times10^{-3}\right) = 135\ \text{J}$ **B**

Q6 $E = \frac{\sigma}{\varepsilon} = \frac{400\times10^6}{4\times10^{-3}} = 1.0\times10^{11}\ \text{Pa}$ **D**

Q10 $\tau = Fd_{\perp} = 400\times5.0 = 2000\ \text{N}$ **C**

Q11 $T\times7.0 = 2000 + 200\times2.5$, $T \approx 357\ \text{N}$ **D**

Detailed study 3 – Further electronics

1	2	3	4	5	6	7	8	9	10	11
D	C	A	C	B	D	B	C	A	B	C

Q1 Output: Amplitude $= 240\times\sqrt{2}\times\frac{240}{4800} \approx 17\ \text{V}$ **D**

Q2 $12.0 - 0.7 = 11.3$ **C**

Q5 Time constant $\tau = RC = 1000\times\left(10\times10^{-6}\right) = 0.01\ \text{s} = 10\ \text{ms}$, time taken to charge up the capacitor by 63%. **B**

Q6 Peak voltage across capacitor $\approx 10\times\sqrt{2} - 0.7 \approx 13\ \text{V}$, discharged to 37% (4.8 V) in 10 ms. **D**

Q8 Voltage across the $100\ \Omega$ resistor $= 7.0 - 5.0 = 2.0\ \text{V}$

Current through the $100\ \Omega$ resistor $= \frac{2.0}{100} = 0.020\ \text{A} = 20\ \text{mA}$ **C**

Detailed study 4 – Synchrotron and its applications

1	2	3	4	5	6	7	8	9	10	11
D	A	B	A	D	C	B	B	B	C	C

Q5 $B = \frac{mv}{qr} = \frac{\left(9.1\times10^{-31}\right)\times\left(1.5\times10^6\right)}{\left(1.6\times10^{-19}\right)\times0.50} \approx 1.7\times10^{-5}\ \text{T}$ **D**

Q6 $\frac{1}{2}mv^2 = qV$

$v = \sqrt{\frac{2qV}{m}} = \sqrt{\frac{2\times\left(1.6\times10^{-19}\right)\times\left(50\times10^3\right)}{9.1\times10^{-31}}} \approx 1.3\times10^8\ \text{ms}^{-1}$ **C**

Q8 $d = \frac{n\lambda}{2\sin\theta} = \frac{1\times\left(0.15\times10^{-9}\right)}{2\sin15^\circ} \approx 2.9\times10^{-10}\ \text{m}$ **B**

Q9 For $n = 2$, $\theta = \sin^{-1}\left(\frac{n\lambda}{2d}\right) = \sin^{-1}\left(\frac{2\times\left(0.15\times10^{-9}\right)}{2\times2.9\times10^{-10}}\right) \approx 31^\circ$

For $n = 3$, $\theta = \sin^{-1}\left(\frac{n\lambda}{2d}\right) = \sin^{-1}\left(\frac{3\times\left(0.15\times10^{-9}\right)}{2\times2.9\times10^{-10}}\right) \approx 51^\circ$

Not possible for $n = 4$

.: One additional peak will be seen from 40° to 90°. **B**

Q11 $|\Delta E| = hc\left(\frac{1}{\lambda_i} - \frac{1}{\lambda_f}\right)$

$= \left(6.63\times10^{-34}\right)\times\left(3.0\times10^8\right)\left(\frac{1}{0.0709\times10^{-9}} - \frac{1}{0.0749\times10^{-9}}\right)$

$\approx 1.5\times10^{-16}\ \text{J}$ **C**

Detailed study 5 – Photonics

1	2	3	4	5	6	7	8	9	10	11
D	D	C	A	B	B	B	A	C	A	D

Q7 $n_{\text{cladding}} = 1.44\sin80^\circ \approx 1.42$ **B**

Q8 $\sin\alpha = 1.44\sin(90 - 80.0)^\circ$, $\alpha \approx 14.5^\circ$ **A**

Detailed study 6 – Sound

1	2	3	4	5	6	7	8	9	10	11
B	C	B	B	A	C	B	D	D	B	D

Q1 $\lambda = \frac{v}{f} = \frac{330}{30} = 11\ \text{m}$ **B**

Q3 $I = 10^{\frac{L}{10}-12} = 10^{\frac{80}{10}-12} = 1.0\times10^{-4}\ \text{Wm}^{-2}$ **B**

Q4 When distance is doubled, intensity becomes a quarter of the original .: level drops by 6 dB from 80 dB to 74 dB. **B**

Q5 $\frac{1}{4}\lambda = \frac{1}{4}\times\frac{v}{f} = \frac{1}{4}\times\frac{320}{200} = 0.40\ \text{m}$ **A**

Q6 $\frac{3}{4}\lambda = 1.2\ \text{m}$ **C**

Please inform physicsline@itute.com re conceptual, mathematical and/or typing errors

