http://www.learning-with-meaning.com/

2016 VCAA Physics Examination Solutions

Area of study – Motion in one and two dimensions

Q1a $v^2 = u^2 + 2as$,
speed $= v = \sqrt{u^2 + 2as} = \sqrt{2\times 0.10\times 20} = 2$ m s^{-1}

Q1b Consider the wagon: $T - 2000 = 10000\times 0.1$, $T = 3000$ N

Q1c $(20000 + 10000)v = 20000\times 3.0$, $v = 2.0$ m s^{-1}

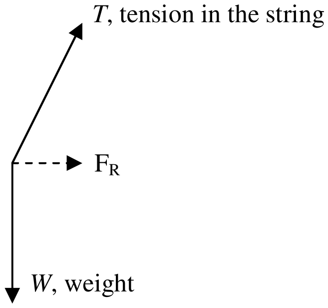
Q1d Total E_k before collision $= \frac{1}{2}\times 20000\times 3.0^2 = 90000$ J

Total E_k after collision $= \frac{1}{2}\times 30000\times 2.0^2 = 60000$ J

Total E_k before and after were different, .: the collision was inelastic.

Q1e $10000\times 2.0 + 20000\vec{v} = 20000\times 2.0$, $\vec{v} = 1.0$ m s^{-1} right

Q2a



Q2b $T\sin 60° = 2.0\times 10$, $T = 23.1$ N

Q3a $k = \frac{F}{x} = \frac{0.050\times 10}{0.25} = 2$ N m^{-1}

Q3b Using conservation of energy, it can be shown that $v = \sqrt{20\Delta x - 10(\Delta x)^2}$, .: graph B

Q4a Stored energy = area under graph $= \frac{1}{2}\times 72\times 0.50 = 18$ J

Q4b $\frac{1}{2}\times 4.0\times v^2 = 18$, $v = 3.0$ m s^{-1}

Q4c Impulse $= \Delta p = 4.0\times 2.0 = 8.0$ kg ms^{-1} (or Ns)

Q4d $2.0\times$ distance $= \frac{1}{2}\times 4.0\times 2.0^2$, distance $= 4.0$ m

Q5a Time taken $= \frac{v-u}{a} = \frac{(-20\sin 30°) - 20\sin 30°}{-10} = 4.0$ s
$d = (20\cos 30°)\times 4.0 \approx 1.4\times 10^2$ m

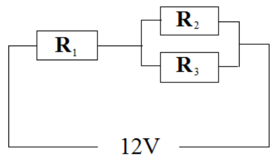
Q5b Using conservation of energy, it can be shown that E_K is a quadratic function of d and non-zero in flight, .: graph A

Q6a (1) Orbital period of 1 Earth day (2) Always directly above the equator of Earth

Q6b Emily is incorrect. The feeling of weightlessness occurs when a person is not pressing against other objects and there is no reaction force on the person. This is possible when the person moves under gravity only. The person is said to be in free fall.

Area of study – Electronics and photonics

Q7a



Total resistance of parallel components $= \frac{1}{\frac{1}{4}+\frac{1}{4}} = 2\ \Omega$

Consider the circuit as a voltage divider:
Voltmeter reading $= \frac{2}{4+2}\times 12 = 4$ V

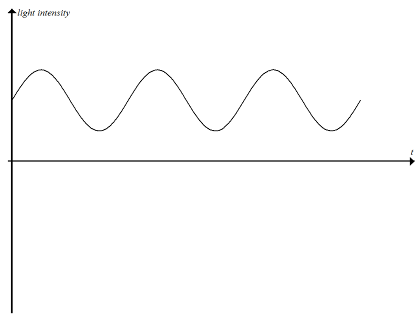
Q7b Ammeter reading $= \frac{4\text{ V}}{4\Omega} = 1$ A

Q7c $V_{\text{LED}} = 5.0$ V, .: $V_{R_2} = 5.0$ V, ammeter reading $\frac{5.0}{4} = 1.25$ A

Q8a Voltage across the parallel LEDs $= 3\times 3 = 9$ V
Voltage across the 1.5 Ω resistor $= 12 - 9 = 3$ V
Current through the 1.5 Ω resistor $= \frac{3}{1.5} = 2.0$ A
Total power dissipated in the LEDs $= 9\times 2.0 = 18$ W

Q8b The current is zero in the branch with the failed LED.
Voltage across the conducting LEDs $= 3\times 3 = 9$ V
Voltage across the 1.5 Ω resistor $= 12 - 9 = 3$ V
.: the same current of 2.0 A through the battery and the resistor
The current through the LEDs is also 2.0 A in comparison with only 1.0 A in part a.

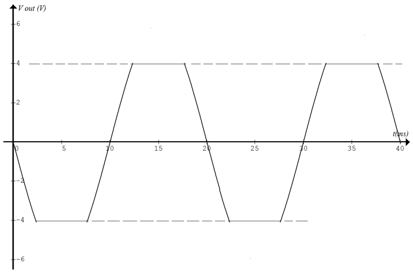
Q9



Q10a 1000 Ω

Q10b $\frac{R\,\Omega}{4000\,\Omega} = \frac{2\text{ V}}{4\text{ V}}$, $R = 2000$

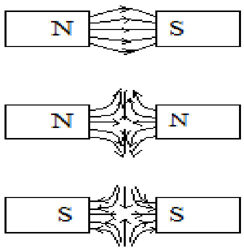
Q11a Gain $= -\dfrac{4}{100\times10^{-3}} = -40$, max. output $= \pm4$ V



Q11b Clipping is a term used to describe the situation when a voltage amplifier is pushed to create a signal with a greater amplitude than it can produce. The amplifier simply cuts or clips the signal at its maximum capacity. As a result a sinusoidal wave becomes a distorted square-wave-type waveform.

Area of study – Electric power

Q12



Q13a $F = BIL$, $0.32 = B\times2000\times3.0$, $B = 5.3\times10^{-5}$ T

Q13b C east

Q14a A

Q14b When the coil is horizontal as shown in Figure 18, or when it is turned 180°. At these orientations the force on each side facing the poles exerts maximum torque on the coil.

Q14c A, B

Q15a $\phi = BA = 0.0050\times0.0060 = 3.0\times10^{-5}$ Wb (weber)

Q15b From right to left
When the external magnetic field decreases, the magnetic flux to the left through the coil decreases. A change in flux induces a current in the coil in the clockwise direction (viewed from the right), generating a magnetic field to the left (hence magnetic flux to the left) to compensate for the decrease according to Lenz's law.

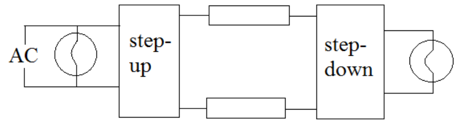
Q16a $P_A = \dfrac{18^2}{9} = 36$ W

Q16b Consider the transmission lines and Globe B as a voltage divider.

$V_{drop} = \dfrac{3.0}{3.0+9}\times18 = 4.5$ V

Q16c $V_B = 18 - 4.5 = 13.5$ V, $P_B = \dfrac{13.5^2}{9} = 20.25$ W

Q16d



Q16e Step-up transformer: $P_{in} = P_{out} = V_{out}I_{out}$, higher voltage and lower current delivering the same power at the output as the input

Transmission lines: $P_{loss} = I^2r$, lower current .: lower power loss

Step-down transformer: $P_{out} = V_{out}I_{out}$, lower voltage and higher current, supplying Globe B with the correct voltage and more power due to less power loss in the transmission lines

Q17a $f = \dfrac{1}{40\times10^{-3}} = 25$ Hz

Q17b RMS of emf $= \dfrac{3.5}{\sqrt{2}} \approx 2.5$ V

Q17c The magnitude of the emf is at a maximum when the plane of the coil is horizontal, i.e. when the magnetic flux is zero. The magnetic flux is sinusoidal, and the magnitude of its rate of change (emf) is at a maximum when the flux is zero.

Q17d

emf
increase
increase
increase
no effect

Area of study – Interactions of light and matter

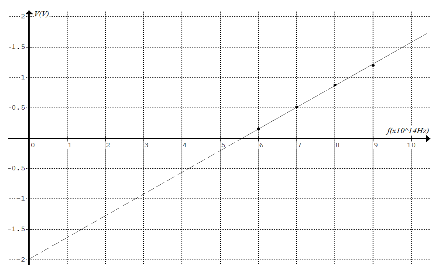
Q18a X is the second dark band from the central bright band.

$\dfrac{3}{2}\lambda = 750$, $\lambda = 500$ nm

Q18b P is a second bright band from the central bright band.
.: path difference $= 2\lambda = 2\times500 = 1000$ nm

Q18c Answer D, extend of spread $\propto \dfrac{1}{\text{width of slit}}$

Q19a



Q19b

Planck's constant	3.6×10^{-15} eV s
Threshold frequency	5.5×10^{14} Hz
Work function of the metal	2.0 eV

Q19c For a particular frequency, the recorded voltage is the voltage required to stop all photoelectrons from reaching the collecting electrode. The fastest moving electrons (those with the highest kinetic energy) will be stopped last.
.: the recorded voltage V gives the maximum kinetic energy of the emitted photoelectrons, $E_{\text{K, max}} = qV$.

Q19d The second graph will be the same as the original graph. The two graphs support the particle model of light.
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.
The graphs have the same equation, $E_{\text{K,max}} = hf - \phi$, where 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 ϕ of the metal, hence the existence of threshold frequency.

Q20a $v = \dfrac{h}{m\lambda} = \dfrac{6.63\times10^{-34}}{\left(9.1\times10^{-31}\right)\times\left(0.36\times10^{-9}\right)} \approx 2.0\times10^{6}$ m s^{-1}

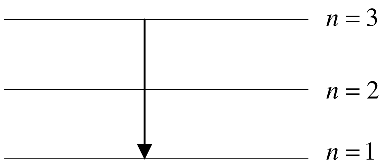
Q20b $\lambda_{\text{X-ray}} \approx 0.36$ nm,

$E = \dfrac{hc}{\lambda} = \dfrac{\left(4.14\times10^{-15}\right)\left(3.0\times10^{8}\right)}{0.36\times10^{-9}} \approx 3.5\times10^{3}$ eV

Q20c
Electrons show wave behaviour, and the de Broglie wavelength of each electron is the same as the wavelength of X-rays. .: the diffraction patterns produced by electrons and X-rays are similar.

Q21a $\lambda = \dfrac{hc}{E} = \dfrac{\left(4.14\times10^{-15}\right)\left(3.0\times10^{8}\right)}{2.6} \approx 4.8\times10^{-7}$ m or 480 nm

Q21b



Q21c 0.7 eV, 2.6 eV, 12.8 eV, 1.9 eV, 12.1 eV, 10.2 eV

Detailed study 1 – Einstein's special relativity

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

Q6 Dilated time $T = \dfrac{26}{\sqrt{1-(0.98)^2}} \approx 130$ ns C

Q7 Contracted length $L = \dfrac{2.0}{2.4} \approx 0.83$ m A

Q9 $\gamma = 1 + \dfrac{E_K}{m_0c^2} = 1 + \dfrac{1.20\times10^{-10}}{\left(1.67\times10^{-27}\right)\left(3.0\times10^{8}\right)^2} \approx 1.8$ B

Q10 Conservation of energy: $E_{\text{before collision}} = E_{\text{after collision}}$
$(\gamma-1)m_0c^2 = m_0c^2 + E_{\text{K,nucleus}}$, $(3-1)m_0c^2 = m_0c^2 + E_{\text{K,nucleus}}$
$E_{\text{K,nucleus}} = 1.0\,m_0c^2$ B

Detailed study 2 – Materials and their use in structures

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

Q4 $E = \dfrac{\sigma}{\varepsilon} = \dfrac{\frac{50000}{3.6\times10^{-3}}}{\frac{0.025}{360}} = 2.0\times10^{11}$ Pa D

Q5 Tension $= \left(1.2\times10^{8}\right)\left(4.0\times10^{-4}\right) = 4.8\times10^{4}$ N
Compression $= \left(1.8\times10^{8}\right)\left(4.0\times10^{-4}\right) = 7.2\times10^{4}$ N A

Q7 $E = \dfrac{1}{2}\times\left(250\times10^{3}\right)\left(10\times10^{-3}\right) = 1250$ J C

Q10 Balance torque about B:
$F_C \times 2 = 70g\times3 + 120g\times1$, $F_C = 1650$ C

Q11 Balance torque about C:
$T\times0.30\sin30° = 0.050g\times0.30 + 0.20g\times0.15$, $T = 3.0$ N B

itute.com

http://www.learning-with-meaning.com/

Detailed study 3 – Further electronics

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

Q2 $N_p = \frac{V_p}{V_s} N_s = \frac{240}{8} \times 120 = 3600$ B

Q5 $C = \frac{\tau}{R} \approx \frac{15\times10^{-3}}{400} \approx 40\times10^{-6}\,\text{F}$ D

Q7 $V_{load} = 5.0\text{ V}$, $V_{R_s} = 9.2 - 5.0 = 4.2\text{ V}$

$I_{load} = I_{R_s} = \frac{4.2}{20} = 0.21\text{ A or 210 mA}$ D

Q8 $I_{load} = \frac{5.0}{1000} = 0.0050$

$I_{R_s} = I_{zener} + I_{load}$, $\frac{4.2}{R_s} \approx 0 + 0.0050$, $R_s \approx 840\,\Omega$ B

Q10 $I_{load} = \frac{5.0}{25} = 0.2\text{ A}$

$P_{supply} = 8.0\times0.2 = 1.6\text{ W}$, $P_{load} = 5.0\times0.2 = 1.0\text{ W}$

$P_{regulator} = 1.6 - 1.0 = 0.6\text{ W}$ D

Q11 $P_{supply} = P_{regulator} + P_{load} = 2.7 + 5.0\times1.0 = 7.7\text{ W}$

Maximum $V_{supply} = \frac{P_{supply}}{I_{supply}} = \frac{7.7}{1.0} = 7.7\text{ V}$

Minimum $V_{supply} = 6.2\text{ V}$ (given) C

Detailed study 4 – Synchrotron and its applications

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

Q2 $V = \frac{mv^2}{2q} = \frac{(9.1\times10^{-31})(8.0\times10^7)^2}{2(1.6\times10^{-19})} \approx 18.2\times10^3\text{ V or 18.2 kV}$ D

Q3 $r = \frac{mv}{qB} = \frac{(9.1\times10^{-31})(8.0\times10^7)}{(1.6\times10^{-19})(4.0\times10^{-4})} \approx 1.1\text{ m}$ A

Q4 $F = qvB = (1.6\times10^{-19})(8.0\times10^7)(4.0\times10^{-4}) \approx 5.1\times10^{-15}\text{ N}$ B

Q8 Conservation of momentum:
$\vec{p} = 6.6\times10^{-23} - 1.1\times10^{-22} = -4.4\times10^{-23}\text{ Ns}$ C

Q10 $d = \frac{n\lambda}{2\sin\theta} = \frac{1\times(0.30\times10^{-9})}{2\sin48°} \approx 2.0\times10^{-10}\text{ m}$ or 0.2 nm

$d = \frac{n\lambda}{2\sin\theta} = \frac{1\times(0.30\times10^{-9})}{2\sin26°} \approx 3.4\times10^{-10}$ or 0.34 nm

$d = \frac{n\lambda}{2\sin\theta} = \frac{1\times(0.30\times10^{-9})}{2\sin22°} \approx 4.0\times10^{-10}$ or 0.40 nm C

Detailed study 5 – Photonics

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

Q3 $E = \frac{hc}{\lambda} = \frac{(6.63\times10^{-34})(3.0\times10^8)}{550\times10^{-9}} \approx 3.62\times10^{-19}\text{ J}$ C

Q4 $\sin\theta_c = \sin83° \approx 0.9925$, $\frac{n_{cladding}}{n_{core}} = \frac{1.31}{1.32} \approx 0.9924$ D

Q5 $1.48\sin\angle r = 1.0\times\sin15°$, $\angle r \approx 10.1°$
$\theta_c = 90° - 10.1° = 79.9°$
$n_{cladding} = 1.48\sin79.9° \approx 1.457$ B

Detailed study 6 – Sound

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

Q2 $\lambda = \frac{v}{f} = \frac{350}{500} = 0.70\text{ m}$ B

Q3 $I = 10^{\frac{80}{10}-12} = 1.0\times10^{-4}\text{ W m}^{-2}$ A

Q4 $L = 80 - 6 = 74\text{ dB}$ B

Q7 Loud region at the centre.
Loud regions are separated by $\frac{\lambda}{2} = 0.50\text{ m}$
Between two adjacent loud regions is a quiet region.
Distance of the second quiet region from the centre
$= 0.50 + 0.25 = 0.75\text{ m}$
Distance of the second quiet region from B
$= 5.00 - 0.75 = 4.25\text{ m}$ D

Q8 Length of closed pipe $= \frac{\lambda}{4} = \frac{0.325}{4} \approx 0.081\text{ m}$ A

Q9 Assuming 256 Hz is the first resonance frequency of the closed pipe the next higher resonance frequency is 3 times the first, i.e. 768 Hz.
C

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