2017 VCAA Sample Physics Examination v2 Solutions

SECTION A

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

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

Q3 $F=\dfrac{Gm_1m_2}{r^2}=\dfrac{6.67\times10^{-11}(1.0)(100)}{(0.10)^2}\approx6.7\times10^{-7}$ N **C**

Q4 Point to the left, into the solenoid **A**

Q5 $F=\dfrac{kq_1q_2}{r^2}=\dfrac{9.0\times10^{9}\left(1.0\times10^{-8}\right)\left(1.0\times10^{-9}\right)}{(0.30)^2}\approx1.0\times10^{-6}$ N **B**

Q9 Students' results $=9.81\pm0.03$ m s^{-1} **A**

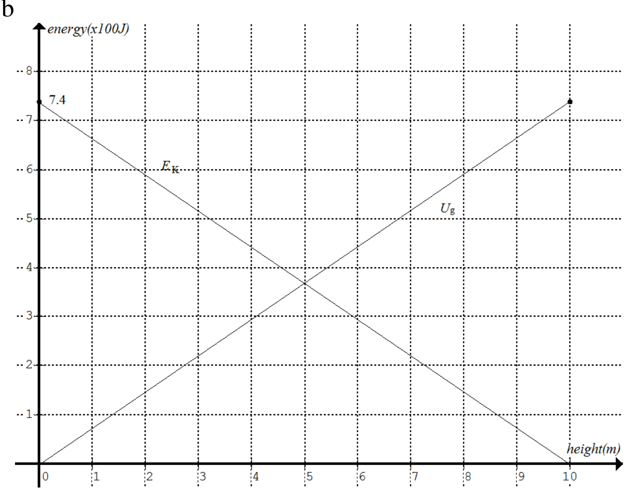
Q11 Area under the graph $=\dfrac{1}{2}(8000)(0.10)=400$ J **B**

Q20 $E=\dfrac{hc}{\lambda}=\dfrac{\left(4.14\times10^{-15}\right)\left(3.0\times10^{8}\right)}{414\times10^{-9}}=3.0$ eV **C**

SECTION B

Q1a $g=\dfrac{GM}{r^2}=\dfrac{\left(6.67\times10^{-11}\right)\left(6.4\times10^{23}\right)}{\left(3.4\times10^{6}\right)^2}\approx3.7$ m s^{-2}

Q1b



Q2a $E=\dfrac{V}{d}=\dfrac{10\,000}{0.10}=1.0\times10^{5}$ N C^{-1}

Q2b

$$v=\sqrt{\frac{2qV}{m}}=\sqrt{\frac{2\left(1.6\times10^{-19}\right)(10\,000)}{9.1\times10^{-31}}}\approx5.9\times10^{7}\text{ m s}^{-1}\ \left(5.93\times10^{7}\right)$$

Q2c $r=\dfrac{mv}{qB}=\dfrac{\left(9.1\times10^{-31}\right)\left(5.93\times10^{7}\right)}{\left(1.6\times10^{-19}\right)(0.020)}\approx1.7\times10^{-2}$ m

Q2d The uniform electric field exerts a constant downward electric force on the electrons. The uniform magnetic field exerts on the electrons a magnetic force of constant magnitude directed perpendicularly to the magnetic field and the path of the electrons.

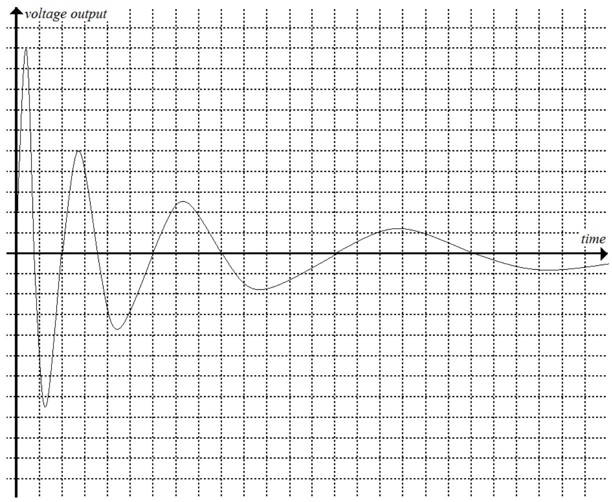
Q3a $F=nBIL\sin\theta$ where θ is the angle between B and I. $\theta=0°$ in Figure 3, .: $F=0$ N on side EH.

Q3b Consider side EF. In the position shown in Figure 3, side EF is on the left, the current flows from F to E, the force on it is upwards, creating a clockwise torque on the loop. After a half-turn of the loop, side EF is on the right, the commutator switches its connections with the + and – brushes and the current flows from E to F, the force on side EF is downwards, creating the same clockwise torque on the loop. Thus the loop keeps turning clockwise.

Q4a $\Delta t=\dfrac{T}{4}=\dfrac{1}{4f}=\dfrac{1}{4\times10}=0.025$ s

$|\varepsilon|=N\dfrac{|\Delta\Phi|}{\Delta t}=20\times\dfrac{0.50\times0.020}{0.025}=8.0$ V

Q4b



Q5a $V_{\text{peak}}=30$ V, $V_{\text{RMS}}=\dfrac{1}{\sqrt{2}}V_{\text{peak}}=\dfrac{30}{\sqrt{2}}\approx21.2$ V

Q5b $f=\dfrac{1}{T}=\dfrac{1}{80\times10^{-3}}=12.5$ Hz

Q6a $v=f\lambda=5\times10=50$ cm s^{-1}

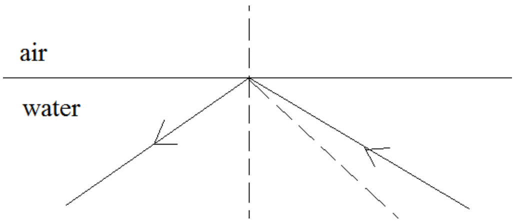
Q6b $\text{YP}-\text{XP}=\left(n-\dfrac{1}{2}\right)\lambda$, $\text{YP}-16.0=\left(2-\dfrac{1}{2}\right)\times10$, $YP=31$ cm

Q6c The width of the diffraction pattern has a direct relationship with the wavelength (i.e. an inverse relationship with the frequency of the source). Increasing the frequency of the source decreases the width of the pattern.

Q7a $n_{\text{glass}} = \dfrac{\sin 45°}{\sin 25°} \approx 1.67$

Q7b $\sin i_c = \dfrac{1}{1.33}$, $i_c \approx 48.8°$

Q7c



Q8

Longest					**Shortest**
radio waves	micro-waves	infra-red rad.	visible light	ultraviolet light	X-rays

Q9 Energies (eV): 12.8, 12.1, 10.2, 2.6, 1.9, 0.7

Q10a $P_{\text{loss}} = I^2 R = 15^2 \times 40 = 9\,000$ W

Q10b $V_{\text{to step-down}} = 50\,000 - 15 \times 40 = 49\,400\ \text{V}_{\text{RMS}}$

Q10c

$P_{\text{loss}} = I^2 R$, reduce power loss by reducing current in the transmission line.
$P = VI$, reduce current by increasing the voltage at the power generation end of the transmission line to keep power delivery constant.
Use a step-up transformer to increase the voltage.
Use a variable input voltage to the transformer in order to produce an output. Transformers do not work with constant input voltage.
Use an alternator to generate a variable voltage (AC) to the step-up transformer.
Use a step-down transformer to lower the voltage at the town end of the line.

Q11a $m_A v_A + m_B v_B = m_A u_A + m_B u_B$
$6.0 \times 1.0 + 2.0 \times v_B = 6.0 \times 2.0 + 2.0 \times 0$, $v_B = 3.0\ \text{m s}^{-1}$

Q11b

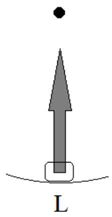
Before: Total kinetic energy $= \frac{1}{2} m_A u_A{}^2 + \frac{1}{2} m_B u_B{}^2 = 12$ J

After: Total kinetic energy $= \frac{1}{2} m_A v_A{}^2 + \frac{1}{2} m_B v_B{}^2 = 12$ J

Same total amount of kinetic energy immediately before and after collision, .: the collision is elastic.

Q11c Pat is correct. Some kinetic energy of the system changes to elastic potential energy in the compressed spring during collision.

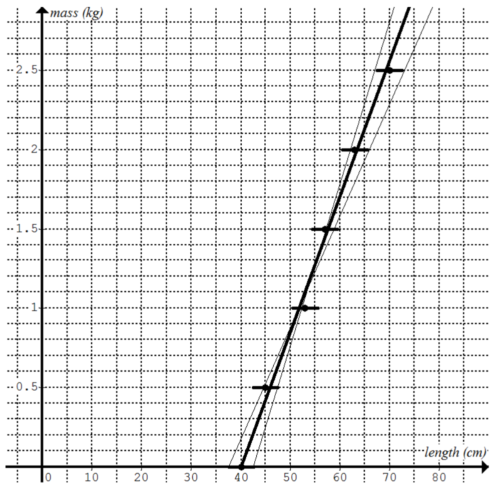
Q12a Assume zero force due to friction.



Q12b $N - 5.00 \times 9.8 = 5.00 \times \dfrac{5.00^2}{4.00}$, $N \approx 80.3$ N

Q13 $E_K = \frac{1}{2} m \times 20^2 + m \times 9.8 \times 15 = 347m$ J
The answer is in terms of m since the value of m is not given.

Q14a



Q14b $k = \dfrac{2.50 \times 9.8}{0.69 - 0.40} \approx 84.5 \pm 14.5\ \text{N m}^{-1}$

Q14c $mgx = \frac{1}{2} kx^2$, $2.50 \times 9.8 = \frac{1}{2} \times 84.5x$, $x = 0.58$ m extension
.: $58 - 30 = 28 \pm 5$ cm below its initial rest position.

Q15a $t = t_0 \gamma = (2.2 \times 10^{-6}) \times 10 = 2.2 \times 10^{-5}$ s

Q15b $L = \dfrac{L_0}{\gamma} = \dfrac{2627}{10} = 262.7$ m

Q15c Scientists' reference frame: The muons move towards the ground at a speed of 0.995*c*. The half-life of muons is dilated by a factor of 10 when observed by stationary scientists on the ground. .: there are many more muons reaching the ground after 2627 m of travel.
The muons' reference frame: The ground moves towards the muons at a speed of 0.995*c*. The distance is contracted to 1/10 of 2627 m when measured by the muons and thus the arrival time of the ground is reduced by a factor of 1/10. .: there are many more muons encountered by the ground.

Q16a $\lambda = \frac{h}{mv} = \frac{6.63\times10^{-34}}{(9.1\times10^{-31})(1.50\times10^{7})} \approx 4.9\times10^{-11}$ m

(4.857×10^{-11})

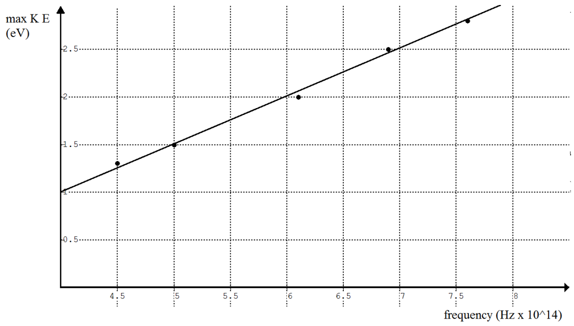
Q16b Accelerating voltage ↑, electron speed v ↑
Since λ is inversely proportional to v, .: λ ↓
Since the spacing of the pattern is proportional to λ, .: the spacing of the pattern ↓.

Q16c The photons and electrons must have similar λ to produce simular diffraction patterns.
X-ray photon energy:

$$E = \frac{hc}{\lambda} = \frac{(4.14\times10^{-15})(3.0\times10^{8})}{4.857\times10^{-11}} \approx 2.56\times10^{4}\ \text{eV}$$

Q17a The voltage is retarding the flow of photoelectrons to the collector electrode. More and more photoelectrons will be stopped from reaching the collector as the voltage increases. At point X all the photoelectrons are stopped and the current drops to zero.

Q17b

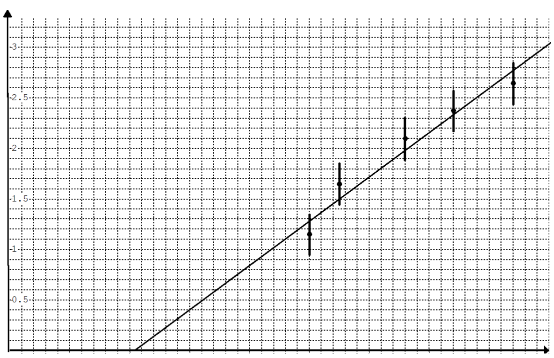


Q17c $h = \frac{2.5 - 1.0}{7.0\times10^{14} - 4.0\times10^{14}} \approx 5.0\times10^{-15}$ eV s

Q17d Dependent variable(s): Stopping voltage; maximum kinetic energy of photoelectrons
Independent variable(s): Frequency of light

Q17e The intensity of lights of different frequencies used in the experiment is the controlled variable. This experiment investigates the relationship between max. kinetic energy of the photoelectrons and the frequency of light causing the emission of the electrons, .: other variables should be kept constant.

Q17f Draw error bars of approximately the same size on the other data points as the one given. Decide whether a straight line can be drawn through all the error bars.



Q18a Direct a white beam (or single colour) of light through a single slit, and then through a pair of very close slits, and observe the result on a screen. The result is a pattern of bright and dark bands appearing on the screen. It is known as an interference pattern. It is caused by the interference of the two light beams, one from each slit. Interference is a wave phenomenon. Young's double-slit experiment demonstrates the wave nature of light.

Q18b When light of extremely low intensity (as low as a single photon at a time) passes through the double-slit, one would expect the single photon passes through either one slit or the other and hence two bright bands would be observed on the screen over time. However a pattern of bright and dark bands appears, same as the interference pattern in Q18a, indicating that a single photon also shows wave nature. Hence this experiment supports the dual nature of light.

Q18c
Experimental observations:
1. The number of photoelectrons increases with the intensity of light used.

2. There is a maximum value of the kinetic energy of the photoelectrons depending on the frequency of light used. It is not affected by the light intensity.

3. There is a minimum light frequency for photoelectrons to be released for a particular metal receiving the light.

From observation 1 Einstein concluded that a beam of light can be considered as a beam of particles called photons. The higher the light intensity the more photons the beam carries causing more interactions with the electrons in the metal to produce more photoelectrons.

From observations 2 and 3 he concluded that each photon in a single frequency f light beam has a fixed amount of photon energy given by $E = hf$. When an electron in the metal interacts with a photon it may gain some of the photon energy (the Compton effect) or the whole amount (the photoelectric effect). If the whole amount is high enough the electron can overcome the binding energy (work function) of the metal to escape as a photoelectron. Otherwise the electron remains in the metal. Surface electrons absorb the full amount and are emitted at maximum kinetic energy. The above can be summarised as $E_{K\,max} = hf - W$ where W is the work function of the metal.

Einstein's conclusions contradicted the simple wave model:
The simple wave model suggested that if more intense light were used the energy of the photoelectrons should be higher.
It also suggested that the frequency of light used should have no effect on the energy or number of electrons emitted.

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

