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2021 VCAA Physics Examination Solutions

SECTION A

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

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

Q4 $a=\frac{Gm}{r^2}$, $G=\frac{ar^2}{m}$.: $\frac{a_P r_P{}^2}{m_P}=\frac{a_E r_E{}^2}{m_E}$, $\frac{18r_P{}^2}{4m_E}=\frac{9.8R^2}{m_E}$

$r_P\approx 1.5R$ B

Q6 $|\xi_{av}|=n\left|\frac{\Delta\phi}{\Delta t}\right|$, $1.2=6\times\frac{0.05}{\Delta t}$, $\Delta t=0.25$ s C

Q7 $P_{in}=P_{out}$, $240I_{in}=5.0\times 3.0$, $I_{in}=0.0625$ A D

Q10 $\frac{1}{2}\times 9.8t^2=8.0$, $t\approx 1.3$ s C

Q11 Spring constant $=$ gradient $=\frac{4.0\times10^3}{0.04}=1.0\times10^5$ D

Q12 At 0.02 m compression, force $=2.0\times10^3$ N

Elastic potential energy $=\frac{1}{2}\times2.0\times10^3\times0.02=20$ J C

Q13 $f=\frac{v}{\lambda}=3.0$ Hz A

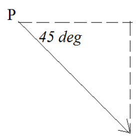
Q17 de Broglie $\lambda=\frac{h}{p}=\frac{6.63\times10^{-34}}{663\times10}=1.0\times10^{-37}$ m A

Q18 $E=\frac{hc}{\lambda}=\frac{(6.63\times10^{-34})(3.0\times10^8)}{550\times10^{-9}}\approx3.62\times10^{-19}$ J

$P=(3.62\times10^{-19})(2.8\times10^{16})\approx1.0\times10^{-2}$ W A

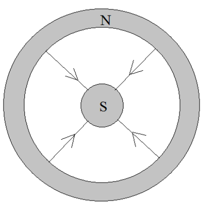
SECTION B

Q1a



Q1b $10.0\sqrt{2}\approx14.1$ mT

Q2a



Q2b E

Q2c $F=nI\ell B=20(2.0)(2\pi0.050)(200\times10^{-3})\approx2.5$ N

Q3a $\frac{GM}{r^2}=\frac{\left(\frac{2\pi r}{T}\right)^2}{r}$,

$M=\frac{4\pi^2r^3}{GT^2}=\frac{4\pi^2(6.9\times10^{10})^3}{(6.67\times10^{-11})(8.47\times10^6)}=2.7\times10^{30}$ kg

Q4 Newton's third law: The Earth attracts Liesel (action force), Liesel attracts the Earth (reaction force).

Q5a The charge is stationary, $v=0$

.: Magnetic force $F=qvB=0$.

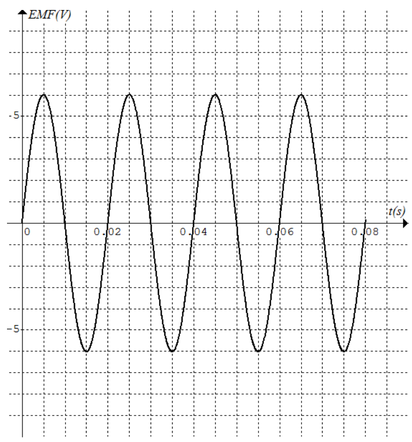
Q5b Electric force $=qE=(1.6\times10^{-19})\times\frac{200}{6.0\times10^{-3}}\approx5.3\times10^{-15}$ N downwards.

Q5c The electric field increases the speed of the charge whilst the magnetic field changes the direction of the charge motion. The direction of the magnetic force is always perpendicular to the charge motion. The magnetic force increases in magnitude because of the increase in the speed of the charge.

So Ravi is incorrect to say the magnitude of the magnetic force is constant but correct to say the direction is continually changing. Mia is correct to say the magnitude of the magnetic force is constantly increasing but incorrect to say it will always be acting in the same direction.

Q6a $V_{peak}=\sqrt{2}\times4.25\approx6.01$ V, $T=\frac{1}{50}=0.02$ s

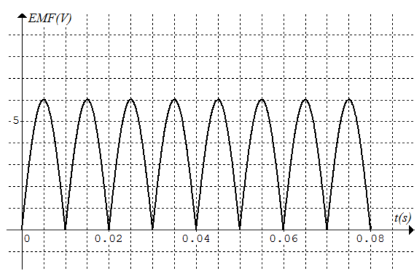
Max flux initially, EMF $=0$



Q6b Slip rings and brushes allow an external circuit **receiving the AC** to remain stationary while connected to P and Q.

Q6ci Replace the slip rings with a split-ring commutator and connect the loop terminals to each half-ring.

Q6cii



Q7a Power loss $= I^2R$ is directly proportional to current. Step up voltage $\rightarrow$ reducing current (for the same power transmission) $\rightarrow$ less power loss.

Q7b $500\times10^3 I = 500\times10^6$, $I = 1.0\times10^3\text{ A} = 1.0\text{ kA}$

Q7c Maximum power at 240V $= P_{in} - P_{loss}$

$= 500\times10^6 - (1.0\times10^3)^2 30.0 = 470\times10^6\text{ W} = 470\text{ MW}$

Q8a $F_{thrust} - (531\times10^3)\times 9.80 = (531\times10^3)\times 7.20$

$F_{thrust} \approx 9.03\times10^6\text{ N} = 9.03\text{ MN}$ vertically upwards

Q8b $E_K = \frac{1}{2}\times1000\times\left(\frac{20000}{3.6}\right)^2 \approx 1.54\times10^{10}\text{ J}$

Q8c

$E_{gpe} = \text{area under graph} = \frac{1}{2}(3.7+3.2)(300\times10^3) \approx 1.04\times10^6\text{ J}$

Q8d If there is no atmosphere on Mars's surface, the capsule's kinetic energy increases and its potential energy decreases by equal amounts as it descends. With atmosphere, aerodynamic braking changes the kinetic energy to heat and dissipates to the atmosphere.

Q9a $\frac{1}{2}mv^2 = mgh$, $v = \sqrt{2\times9.8\times15} \approx 17.1\text{ m s}^{-1}$

Q9b Centripetal force = force of gravity, $\frac{mv^2}{r} = mg$.: $\frac{v^2}{r} = g$

Q9c Condition $v^2 = gr$

Conservation of energy:

$mg(15) = mg(2r) + \frac{1}{2}mv^2 = mg(2r) + \frac{1}{2}mgr$.: $15 = 2r + 0.5r$,

$r = 6$.: maximum height $= 2r = 12\text{ m}$

Q9d Decrease

Some energy is changed to heat due to friction

.: $mg(15) = mg(2r) + \frac{1}{2}mgr + heat$.: $r < 6$

Q10a The length is in the same direction of motion and subject to length contraction when observed by the Earth bound technician. The width is perpendicular to the direction of motion and no contraction is observable.

Q10b $L_0 = \gamma L = \frac{135}{\sqrt{1-0.7^2}} \approx 189\text{ m}$

Q11 No light will be observed at point P. Unpolarised light has its electric field vectors $\vec{E}$ pointing in all directions on the *x*-*y* plane. F_1 removes all *x*-components of vectors $\vec{E}$ and allows the *y*-components to pass through. F_2 removes all remaining *y*-components of vectors $\vec{E}$ and .: no light will pass through.

Q12a $1.00\sin\theta = 1.46\sin 32°$, $\theta \approx 50.7°$

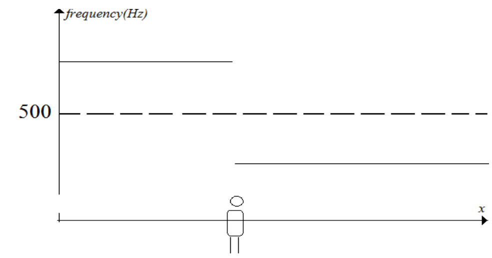
Q12b $\sin\theta_{critical} = \frac{1.42}{1.46}$, $\theta_{critical} \approx 76.6°$

Since $\angle i = 90° - 32° = 58° < \theta_{critical}$.: total internal reflection will not occur and some light will be transmitted into the cladding.

Q13a $\Delta x = \frac{\lambda L}{d} = \frac{(620\times10^{-9})\times1.0}{2.0\times10^{-3}} \approx 3.1\times10^{-4}\text{ m} = 0.31\text{ mm}$

Q13b Waves interfere when they cross path. This experiment produces an interference pattern demonstrating that light behaves like waves and interferes. Hence the experiment supports the wave model of light.

Q14a



Q14b Doppler's effect

Q15 Gradient of line joining $(0, -3.2\times10^{-19})$ and $(6.5\times10^{14}, 0)$

$= \frac{3.2\times10^{-19}}{6.5\times10^{14}} \approx 4.9\times10^{-34}\text{ Js}$

Q16 The photon model

According to the photon model:

Very low light intensity $\rightarrow$ very small number of photons, once an electron absorbs a photon, it will be emitted rapidly.

According to the wave model:

Very low light intensity $\rightarrow$ very small wave amplitude $\rightarrow$ very low energy. It will take a long time for an electron to absorb enough energy to become a photoelectron .: slow emission of electron

Q17a $p = \frac{h}{\lambda} = \frac{hf}{c} = \frac{(6.63\times10^{-34})(7.0\times10^{15})}{3.0\times10^8} \approx 1.55\times10^{-26}\text{ kg ms}^{-1}$

Q17b

$F = n\frac{\Delta p}{\Delta t} = \frac{n}{\Delta t}\Delta p = (2.0\times10^{18})(2\times1.55\times10^{-26}) \approx 6.2\times10^{-8}\text{ N}$

Q18a de Broglie wavelength

$\lambda = \frac{h}{p} = \frac{6.63\times10^{-34}}{(9.1\times10^{-31})(5.0\times10^5)} \approx 1.46\times10^{-9}\text{ m}$

Q18b X-ray $\lambda = \frac{hc}{E_{photon}} = \frac{(4.14\times10^{-15})(3.0\times10^8)}{100} \approx 1.24\times10^{-8}\text{ m}$

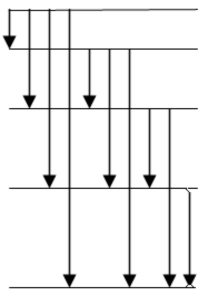
$\frac{\lambda_X}{w_X} = \frac{\lambda_e}{w_e}$, $\frac{1.24\times10^{-8}}{1.24\times10^{-6}} = \frac{1.46\times10^{-9}}{w_e}$

.: diameter of the aperture $= w_e \approx 1.46\times10^{-7}\text{ m}$

Q19a $E_{photon} = \frac{hc}{\lambda} = \frac{(4.14\times10^{-15})(3.0\times10^{8})}{565\times10^{-9}} \approx 2.2\text{ eV}$

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

Q19b 10 (see diagram below)



Q20a To estimate the uncertainty $(\pm)$ in the time measurements

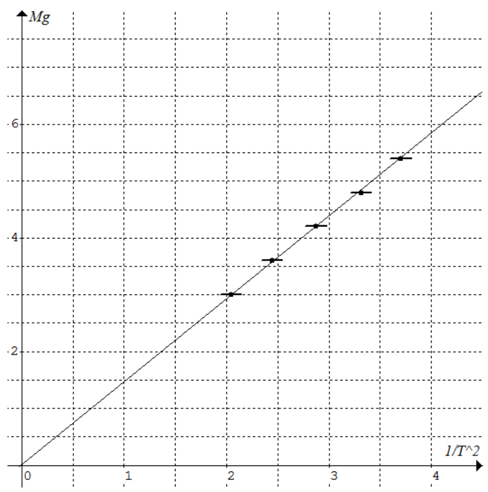
Q20b The cord pulls the rubber stopper to change its direction continuously to keep it in circular motion .: the rubber stopper pulls the cord according to Newton's third law. The cord supports the metal washers .: the metal washers pull the cord.
.: the cord is in tension

Q20c $v = \frac{2\pi R}{T}$, $F = \frac{mv^2}{R} = \frac{4\pi^2 mR}{T^2}$.: $Mg = \frac{4\pi^2 mR}{T^2}$

Q20d

Mg (N)	*T* (s)	$1/T^2$ (s^{-2})
3.0	0.700	2.04
3.6	0.640	2.44
4.2	0.590	2.87
4.8	0.550	3.31
5.4	0.520	3.70

Q20e



Q20f Gradient $\approx \frac{4.2}{2.87} \approx 1.4634 \approx 1.5$

Q20g $Mg = 4\pi^2 mR \times \frac{1}{T^2}$

.: $4\pi^2 m \times 0.75 \approx 1.5$, $m \approx 0.05\text{ kg} \approx 50\text{ grams}$