itute.com

2014 Physics Trial Exam Solutions

SECTION A – Core studies

Area of study – Motion in one and two dimensions

Q1a Let T N be the tension in the cable.

Vertical component: $T\cos 30° = 15000$, $T \approx 1.73\times 10^4$ N

Q1b Horizontal component:

$F_{net} = T\sin 30° - 2660 \approx 6.00\times 10^3$ N

Q1c $a_{helicopter} = a_{load} = \frac{6.00\times 10^3}{1500} = 4.00$ m s^{-1}

Helicopter $F_{net} = 5000\times 4.00 = 2.00\times 10^4$ N

Q1d Same angle gives the same tension $T \approx 1.73\times 10^4$ N.

$a_{load} = \frac{F_{net}}{m} = \frac{T\sin 30°}{1500} \approx 5.77$ m s^{-2}

Q1e The radius of the path of the load is $5.00\sin 30° = 2.50$ m longer, .: $r = 22.5 + 2.50 = 25.0$ m

$\frac{v^2}{r} = a$, $\frac{v^2}{25.0} = 5.77$, $v \approx 12.0$ m s^{-1}

Q1f The period is constant, .: $v \propto r$

$\frac{v_{helicopter}}{v_{load}} = \frac{r_{helicopter}}{r_{load}}$, $\frac{v_{helicopter}}{12.0} = \frac{22.5}{25.0}$, $v_{helicopter} \approx 10.8$ m s^{-1}

Q2a $\text{Weight} = 75\times 10 = 750$ N

Q2b The reaction force on the rider is zero because the person is in freefall. $a = \frac{v^2}{r} = \frac{15.0^2}{22.5} = 10$ m s^{-2}. .: $a = g$

Q2c The reaction force on the rider points downwards.

$F_{net} = \frac{mv^2}{r}$, $750 + 75 = \frac{75v^2}{22.5}$, $v \approx 15.7$ m s^{-1}

Q3a Horizontal component: $u = \frac{24.0}{1.90} \approx +12.63$

Vertical component: $s = -4.20$, $a = -10$, $t = 1.90$, find u.

$s = ut + \frac{1}{2}at^2$, $u \approx +7.29$

.: speed $\approx \sqrt{12.63^2 + 7.29^2} \approx 14.6$ m s^{-1}

Q3b Vertical component: $u \approx +7.29$, $a = -10$, $v = 0$, find s.

$v^2 = u^2 + 2as$, $s \approx +2.66$

.: maximum height $\approx 4.20 + 2.66 = 6.86$ m

Q3c Conservation of energy:

$\frac{1}{2}m\times 14.6^2 + m\times 10\times 4.20 = \frac{1}{2}mv^2$, .: $v \approx 17.2$ m s^{-1}

Q4a Strain energy changes to heat energy.

.: heat energy $=$ area under the graph

$= \frac{1}{2}\times 0.05\times 50 + \frac{1}{2}(50 + 150)\times 0.05 = 6.25$ J

Q4b $F_{friction}\times 2.50 = 6.25$, $F_{friction} = 2.5$ N

Q4c Maximum speed occurs when net force on the block is 0, i.e. when force of the spring equals force of friction 2.5 N, i.e. when the compression is $x = 2.5\times 10^{-3}$ m and the remaining strain energy is approximately 0.003 J (insignificant).

.: it can be assumed that all strain energy changes to heat and kinetic energy

.: $2.5\times 0.10 + \frac{1}{2}\times 0.5v^2 \approx 6.25$, $v \approx 4.90$ m s^{-1}

Q5a $\Delta p = \text{impulse} = \text{area under graph}$

.: $p_{final} - 0 = F_{av}\times \Delta t = 6.0\,\text{kN}\times 0.50\,\text{ms}$, .: $p_{final} = 3.0$ kg m s^{-1}

Q5b $0.046v = 3.0$, $v \approx 65$ m s^{-1}

Q5c Newton's third law, $6.0\,\text{kN} = 6000\,\text{N}$

Q5d The system consists of the club and the ball. The club is not isolated, it is forced by a person.

Q6a $r_G = 4r_A$, $\frac{r_G^{\,3}}{T_G^{\,2}} = \frac{r_A^{\,3}}{T_A^{\,2}}$, $\frac{T_G}{T_A} = \left(\frac{r_G}{r_A}\right)^{\frac{3}{2}} = 4^{\frac{3}{2}} = 8$

Q6b $g \propto \frac{1}{r^2}$, .: $\frac{g_A}{g_G} = \left(\frac{r_G}{r_A}\right)^2 = 4^2 = 16$

Q6c The two satellites have the same orbit.

Area of study – Electronics and photonics

Q7a $R_{effective} = \frac{1}{\frac{1}{500} + \frac{1}{1500}} + 1000 = 1375\,\Omega = 1.375\,\text{k}\Omega$

Q7b Voltage across R_3 equals $\frac{1.0}{1.375}\times 12 \approx 8.73$ V

.: $V_P \approx -8.73$ V

Q7c $\text{Power} = \frac{V^2}{R_{effective}} = \frac{12^2}{1375} \approx 0.11$ W

Q7d The voltmeter has very high resistance, $R_{voltmeter} >>> R_1$

.: R_1 can be considered as non-existent.

.: the voltmeter measures the voltage across R_2

.: the voltmeter reading $\approx \frac{1.5}{1.0+1.5} \times 12 = 7.2$ V

Q7e The ammeter has very low resistance. It makes a short circuit for the parallel connection of R_1 and R_2.

.: the ammeter reading $\approx \frac{12}{1.0\times10^3} = 12\times10^{-3}$ A $= 12$ mA

Q8a $\mathrm{R} = \frac{2}{0.025} = 80\,\Omega$

Q8b $V_\mathrm{R} = 6.0 - 2.0 - 2.0 = 2.0$ V

$I_{LED} = I_\mathrm{R} = \frac{2.0}{80} = 0.025$ A $= 25$ mA

Q8c Same current (25 mA) in the LED will give the same brightness. $V_\mathrm{R} = 6.0 - 2.0 = 4.0$ V

.: $\mathrm{R} = \frac{4}{0.025} = 160\,\Omega$

Q9a Light intensity $= 2000$ lux, $I = -20\,\mu$A

.: $V_\mathrm{R} = (20\times10^{-6})\times(200\times10^3) = 4.0$ V

Q9b $T = 0.5\times10^{-6}$ s, $f = \frac{1}{0.5\times10^{-6}} = 2.0\times10^6$ Hz

Q9c When $V = 2.0$ V, $I = \frac{2.0}{200\times10^3} = 10\times10^{-6}$ A $= 10\,\mu$A,

light intensity $= 1000$ lux

When $V = 3.0$ V, $I = \frac{3.0}{200\times10^3} = 15\times10^{-6}$ A $= 15\,\mu$A,

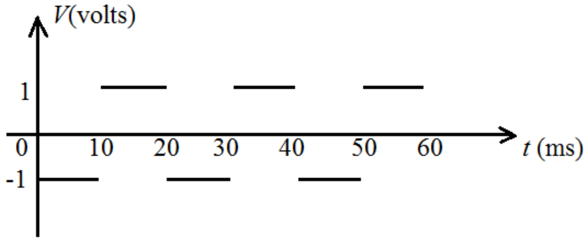
light intensity $= 1500$ lux

.: amplitude $= 500$ lux

Q10a Voltage gain $=$ gradient $= -\frac{1.0}{50\times10^{-3}} = -20$

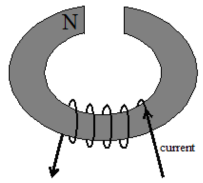
Q10b The output has the same period as the input, i.e. 20 ms, or 0.020 s.

Q10c



Area of study – Electric power

Q11a

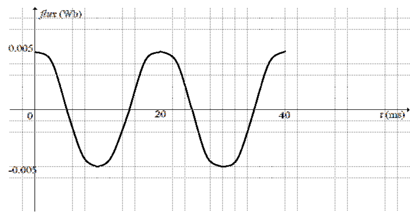


Q11b $B = \sqrt{(4.00\times10^{-5})^2 + (4\times4.00\times10^{-5})^2} \approx 16.5\times10^{-5}$ T

Q11c $\theta = \tan^{-1}\left(\frac{4}{1}\right) \approx 76°$, .: N 76° E

Q12a $\phi_{\max} = BA = 0.50\times0.10^2 = 0.0050$ Wb

Q12b



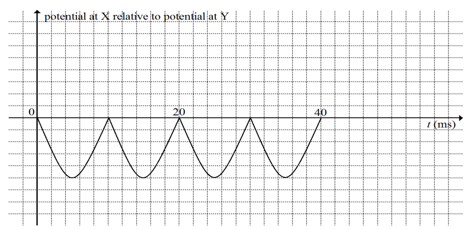
Q12c Maximum $|\xi_{average}| = 5\times\frac{0.0050-0}{5.0\times10^{-3}} = 5.0$ V

Q12d A to B

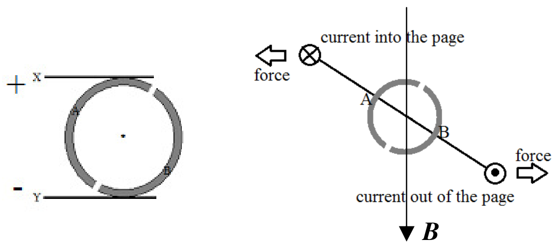
Q12e Lenz's law: As the coil turns magnetic flux through the coil (into the page) decreases. There is an induced current in the coil to generate more magnetic field (hence more flux) through the coil (into the page) to oppose the decrease in flux (Lenz's law). The right hand grip rule gives the direction of the induced current flowing in the coil from A to B.

Q12f A to B

Q12g



Q12h Using the split-ring diagram as direction reference, the two magnetic forces cause the coil to rotate in the anticlockwise direction



Q13a $\frac{N_p}{N_s} = \frac{V_p}{V_s} = \frac{240}{12} = 20$, the ratio is $20:1$

Q13b $V_{peak-peak} = 2\times 12\sqrt{2} = 34\text{ V}$

Q13c $P_{av} = V_{rms} I_{rms}$, $I_{rms} = \frac{P_{av}}{V_{rms}} = \frac{8}{12} \approx 0.67\text{ A}$

Q13d Average output power $=90\% \times$ average input power

.: average input power $= \frac{\text{average output power}}{0.90} = \frac{8}{0.90} \approx 8.9\text{ W}$

Q13e $I_{rms} = \frac{P_{av}}{V_{rms}} \approx \frac{8.9}{240} \approx 0.037\text{ A}$

Q14a The square coil moves 0.10 m into the magnetic field in 0.10 s, $\Delta\phi = 0.10\text{ m}\times 0.50\text{ m}\times 0.50\text{ T} = 0.025\text{ wb}$

.: rate of change in magnetic flux $= \frac{\Delta\phi}{\Delta t} = \frac{0.025}{0.10} = 0.25\text{ wb s}^{-1}$

Q14b $|\xi| = n\left|\frac{\Delta\phi}{\Delta t}\right| = 20\times 0.25 = 5.0\text{ V}$

Q14c $I = \frac{|\xi|}{R} = \frac{5.0}{5.0} = 1.0\text{ A}$

Q14d There is a retarding magnetic force on the coil due to the induced current.
$F = nBIL = 20\times 0.50\times 1.0\times 0.50 = 5.0$ N
To maintain the motion of the coil, a force of 5.0 N is needed to push the coil into the magnetic field at 1.0 m s^{-1}.

Q14e There is no change in flux and .: no induced current once the coil is completely inside the magnetic field. .: there is no retarding magnetic force. Hence no force is required to push the coil.

Q15a Average energy consumption $= P\times\Delta t$

$= \frac{380\times 10^6\text{ w}}{500\times 10^3}\times 1\text{ h} = 760\text{ wh} = 0.76\text{ kwh}$

Q15b In the transmission line, $I = \frac{P}{V} = \frac{400\times 10^6}{500\times 10^3} = 800$ A

$V_{drop} = 800\times 8.00 = 6.4\times 10^3\text{ V} = 6.4\text{ kV}$

.: at the other end of the line, $V = 500 - 6.4 \approx 494\text{ kV}$

Q15c $P_{loss} = 800^2\times 8.00 = 5.12\times 10^6\text{ w} = 5.12\text{ Mw}$

Percentage power loss $= \frac{5.12}{400}\times 100\% = 1.28\%$

Q15d Frequency of rotation remains at 50 Hz.

Area of study – Interactions of light and matter

Q16a The single slit ensures the lights emerging from the double slit are coherent.

Q16b The difference between the distances from the two slits to the location of a dark band is always an integer multiple of $\frac{\lambda}{2}$.

.: the two light waves from the slits are always in opposite phase when they arrive at that location. This results in cancellation (destructive interference) of the waves and hence a dark band.

Q16c Decrease the separation of the slits; increase the light wavelength

Q16d $\frac{n\lambda}{2} = 1.58\times 10^{-6}$ and $\frac{(n-1)\lambda}{2} = 1.13\times 10^{-6}$

.: $\frac{\lambda}{2} = 1.58\times 10^{-6} - 1.13\times 10^{-6} = 0.45\times 10^{-6}$.: $\lambda = 9.0\times 10^{-7}$ m

Q17 The extent of diffraction depends on the ratio $\frac{\lambda}{w}$ where λ is the wavelength of light and w is the size of an obstacle.
The size of air particles has the same order of magnitude as the wavelengths of visible light.
Consider blue light (shorter λ) and red light (longer λ) of the visible spectrum. Red light will diffract more than blue when it passes through air, i.e. they will not be scattered by the air particles as much as the blue light.
If you look at the sky away from the sun, your eyes receive more of the scattered blue light than red. Hence the sky appears blue.

Q18a Maximum kinetic energy

$= \frac{hc}{\lambda} - \phi = \frac{(4.14\times 10^{-15})(3.0\times 10^8)}{250\times 10^{-9}} - 3.70 \approx 1.27\text{ eV}$

Q18b $\frac{hc}{\lambda} - \phi = 0$, $\frac{(4.14\times 10^{-15})(3.0\times 10^8)}{\lambda} - 3.70 = 0$

$\lambda \approx 336$ nm

Q18c Constant light intensity means constant number of photons passing through a unit area in a unit time. .: the metal is exposed to a constant number of photons in a unit time and emits a constant number of electrons independent of the accelerating voltage. Hence the current is constant.

Q18d Higher light intensity (more photons) causes more emission of photoelectrons than lower light intensity. Hence the current is higher.

Q18e The emitted photoelectrons have a range of kinetic energy. Those with low kinetic energy require a low retarding voltage to stop them from reaching the opposite electrode. More electrons will be stopped as the retarding voltage increases. Hence the current decreases with increasing retarding voltage.

Q18f Maximum kinetic energy of the photoelectrons depends on the frequency of light used. Since the same frequency is used in both cases, the same retarding voltage is required to stop those electrons with the highest kinetic energy.

Q18g Shorter wavelength, higher frequency, higher maximum kinetic energy, .: a higher retarding voltage is required to reach zero current.

Q19a When the electron in a hydrogen atom transits from higher energy state to lower energy state, it emits a photon of energy equals to the difference in energy between the two states. $E = \frac{hc}{\lambda} = \frac{(4.14\times10^{-15})(3.0\times10^{8})}{471.3} \approx 2.6\text{ eV}$ corresponds to transition from $n = 4$ to $n = 2$, which has the same energy difference, $(-0.8)-(-3.4) = 2.6$ eV.

Q19b Electrons with the same wavelength (de Broglie wavelength of 471.3 nm) will produce a similar pattern.
$p = \frac{h}{\lambda} = \frac{6.60\times10^{-34}}{471.3\times10^{-9}} \approx 1.40\times10^{-27}$ kg m s^{-1}

SECTION B

Detailed study 2 – Materials and their use in structures

1	2	3	4	5	6	7	8	9	10	11	12
D	D	D	C	C	D	A	B	B	A	C	B

Q1 Equate clockwise and anticlockwise torques about P,
$F_Q \times 20 = 20\times15 + 10\times30$, $F_Q = 30\text{ N}$ D

Q2 $F_P = 30 + 20 + 10 = 60\text{ N}$ D

Q3 D

Q4 C

Q5 C

Q6 $\varepsilon = \frac{70\text{ MPa}}{70\text{ GPa}} = \frac{70\times10^{6}}{70\times10^{9}} = 0.001 = 0.1\%$ D

Q7 Young's modulus
$= \frac{\sigma}{\varepsilon} \approx \frac{230\text{ MPa}}{0.003} \approx 77000\text{ MPa} = 77\text{ GPa}$ A

Q8 Strain energy $=$ area under graph $\times$ volume
$\approx (250\text{ MPa}\times0.08)\times0.5 = 10\text{ MJ}$ B

Q9 $\theta = \tan^{-1}\left(\frac{10}{40}\right) \approx 14°$ B

Q10 A

Q11 C

Q12 Force on the rod $= 200\cos40° + 200\cos50° \approx 282\text{ N}$
$\sigma = \frac{F}{A} \approx \frac{282}{10\times10^{-4}} = 282000\text{ Pa} = 0.282\text{ MPa}$ B

Detailed study 3 – Sound

1	2	3	4	5	6	7	8	9	10	11	12
B	B	C	D	C	A	C	C	D	D	C	B

Q1 $\lambda = \frac{v}{f} = \frac{342}{1100} \approx 0.3\text{ m}$ B

Q2 Same sound speed for all frequencies. B

Q3 $I = \frac{P}{A} = \frac{1.0}{4\pi\times5.0^{2}} \approx 0.003$ w m^{-2} C

Q4 Intensity becomes $\frac{1}{4}$ of the original when the distance is doubled. The sound level drops by about 6 dB. D

Q5 Sound speed in the air is different from the wave speed in the wire. C

Q6 $f_n = \frac{nv}{2L}$, $v = \frac{2Lf_n}{n} = \frac{2\times2.5\times62}{n} = \frac{310}{n}$ where n is a whole number.
Only $v = 155$ m s^{-1} gives a whole number $n = 2$. A

Q7 Same frequency C

Q8 C

Q9 D

Q10 D

Q11 C

Q12 'Flat' response over a wide range B

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

