2016 Physics Trial Exam Solutions

SECTION A – Core studies

Area of study – Motion in one and two dimensions

Q1a $|F_{net}| = m|a| = m|\text{steepest slope}| \approx 1.0\times 100 = 1.0\times 10^2$ N

Q1b $\Delta p = mv - mu = 1.0\times 0 - 1.0\times 10 = -10$ kg m s^{-1}

Q1c $|\text{Average net force}| = \frac{|\Delta p|}{\Delta t} = \frac{10}{1.6} \approx 6.3$ N

Q1d Impulse on B equals but opposite to impulse on A (change in momentum of A).
.: impulse on B is 10 Ns east

Q2a $k = \frac{64.8\times 10}{0.135} = 4.80\times 10^3$ N m^{-1}

Q2b Depression $x = \frac{72.0\times 10}{4.80\times 10^3} = 0.150\text{ m} = 15.0$ cm

Q2c

Elastic potential energy $= \frac{1}{2}kx^2 = \frac{1}{2}\left(4.80\times 10^3\right)\times 0.150^2 = 54.0$ J

Q2d The performer is in free fall, apparent weight = 0 N

Q2e Let x m be the distance below the flat net.
Maximum speed is reached when acceleration (net force) is zero.
$kx - mg = 0$, $\left(4.80\times 10^3\right)x - 72.0\times 10 = 0$, $x = 0.150$ m
Conservation of energy: (Assign 0 J gravitational potential energy at the flat net)
Total energy at the platform = total energy at max speed
$72.0\times 10\times 9.60 = -72.0\times 10\times 0.150 + 54.0 + \frac{1}{2}\times 72.0v^2$
.: $v_{\max} \approx 13.91$ m s^{-1}

Q2f
Total energy at the platform = total energy at the lowest point
$72.0\times 10\times 9.60 = -72.0\times 10\times x + \frac{1}{2}\left(4.80\times 10^3\right)x^2$
$x \approx 1.85$ m satisfies the equation approximately

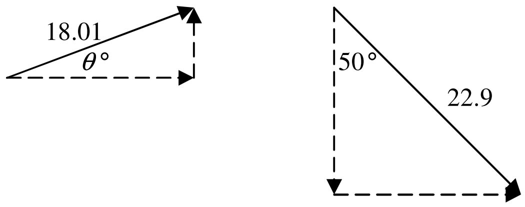
Q3a The design speed is the safe speed, $v = \sqrt{gr\tan\theta}$.
$v = \sqrt{10\times 37.32\tan 15°} \approx 10.00$ m s^{-1}

Q3b $a = \frac{v^2}{r} = \frac{10.00^2}{37.32} \approx 2.680$ m s^{-2}

Q3c Design speed does not depend on the mass of the vehicle
.: $v = \sqrt{10\times 37.32\tan 15°} \approx 10.00$ m s^{-1}

Q3d Conservation of energy:
Total energy at the cliff top = total energy at water level
$\frac{1}{2}mv^2 + m(10)(10) = \frac{1}{2}m\times 22.9^2$, $v \approx 18.0$ m s^{-1} (18.01)

Q3e



The horizontal component of velocity in projectile motion remains the same.
$18.01\cos\theta° = 22.9\sin 50°$, $\theta \approx 13.1$

Q3f Vertical component: $u = {}^{+}18.01\sin 13.1° \approx {}^{+}4.082$
$a = {}^{-}10$, $v = {}^{-}22.9\cos 50° \approx {}^{-}14.72$
$v = u + at$, $t = \frac{v-u}{a} \approx \frac{{}^{-}14.72 - {}^{+}4.082}{{}^{-}10} \approx 1.88$ s

Q4a $d_{Mars,Venus} = (228-108)\times 10^9 = 1.20\times 10^{11}$ m

Q4b $\frac{GM_{Jupiter}}{\left(d_{Jupiter,Mars}\right)^2} - \frac{GM_{Mars}}{\left(d_{Mars,Venus}\right)^2}$
$= \frac{\left(6.67\times 10^{-11}\right)\left(1.90\times 10^{27}\right)}{\left(5.50\times 10^{11}\right)^2} - \frac{\left(6.67\times 10^{-11}\right)\left(0.642\times 10^{24}\right)}{\left(1.20\times 10^{11}\right)^2}$
$\approx 4.16\times 10^{-7}$ N kg^{-1} (i.e. mainly due to the gravity of Jupiter)

Q4c $\frac{R^3}{T^2} = \frac{GM_{Sun}}{4\pi^2}$, $M_{Sun} = \frac{4\pi^2R^3}{GT^2}$
Choose the data for one of the three planets, say Jupiter,
$M_{Sun} = \frac{4\pi^2R^3}{GT^2} = \frac{4\pi^2\left(778\times 10^9\right)^3}{\left(6.67\times 10^{-11}\right)\left(11.9\times 365\times 24\times 60\times 60\right)^2}$
$\approx 1.98\times 10^{30}$ kg

Area of study – Electronics and photonics

Q5a The 100 k ohm resistor is so much higher in resistance than the others that it can be removed without significantly affecting the circuit. Between *X* and *Y*, the branch $20+30$ is parallel to the branch $10+40$, .: the circuit can be replaced with a single resistor of $R=\dfrac{1}{\frac{1}{50}+\frac{1}{50}}=25\ \Omega$

Q5b $V_{XY}=12-7.0=5.0$, current through the 20 ohm resistor $=$current through the $20+30$ branch $=\dfrac{5.0}{50}=0.10$ A

Q5c Current through the 10 ohm resistor is also 0.10 A. Voltages across the 20 ohm and 10 ohm resistors are 2.0 V and 1.0 V respectively.
.: voltage across the 100 k ohm resistor is $2.0-1.0=1.0$ V

Q6a $240-60\times3.2=48$ V

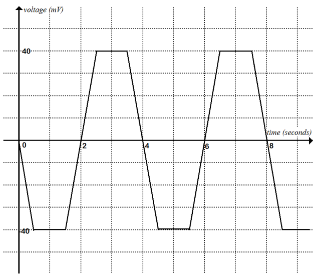
Q6b $\dfrac{48}{4.7\times10^{3}}\approx0.010\text{ A}=10\text{ mA}$

Q6c 240 V across the failed LED

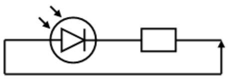
Q6d 0 V across the other components

Q7a $|\text{gain}|=\dfrac{1}{50\times10^{-3}}=20$

Q7b



Q8a

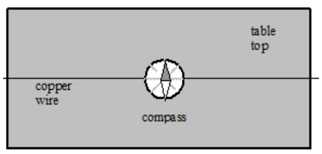


Q8b $15\times10^{-6}\text{ A}=0.015\times10^{-3}\text{ A}=0.015\text{ mA}$

Q8c $0.015\text{ mA}\times10\text{ k}\Omega=0.15\text{ V}$

Area of study – Electric power

Q9a



Q9b $2\times4.0\times10^{-5}=8.0\times10^{-5}$ tesla

Q9c

Q9d $\sqrt{1^2+1^2}\times4.0\times10^{-5}\approx5.7\times10^{-5}$ tesla

Q10a $F=BIL=0.80\times0.025\times0.12=0.0024$ N

Q10b Choice E, into the page

Q10c 50 Hz is too high for the aluminium strip to respond to and .: there is no observable motion of the strip.
However, at the right tension in the strip it can made to vibrate in and out of the page at the same frequency.

Q10d Choice A, up

Q10e $|\xi|=\dfrac{BL\Delta x}{\Delta t}=\dfrac{0.80\times0.12\times0.050}{1}=0.0048$ V

Q11a Input voltage must be increasing or decreasing at a constant rate. Choice E

Q11b Changing input voltage at the primary coil causes changing magnetic field in the ferromagnetic core and thus changing magnetic flux in the secondary coil. The output voltage in the secondary coil, according to Faraday's law, is given by induced emf $\xi=-n\times$ rate of change of ϕ.

Q12a Period $T=\dfrac{0.100}{6}$ s, $f=\dfrac{1}{T}=60$ Hz

Q12b $V_{rms}\approx\dfrac{170}{\sqrt{2}}\approx120$ V

Q12c The average emf is 0 V.

Q12d $E=P_{av}\times\Delta t=\dfrac{V_{rms}^{\ 2}}{R}\times\Delta t=\dfrac{170^2}{2\times25}\times10=5780$ W h
≈5.8 kW h

Q13a $F=nBIL=50\times0.8\times0.1\times0.050=0.2$ N

Q13b Draw arrow pointing vertically upwards

Q13c The split-ring commutator reverses the direction of the flow of current every half turn to keep the torque on the coil in the same direction (clockwise).

Q14a Total resistance on the right side of Light 1
$=1.5\times5+120+1.5\times5=135\ \Omega$
Light 1 is parallel to the section on the right side of Light 1, total resistance $=\dfrac{1}{\frac{1}{120}+\frac{1}{135}}\approx63.53\ \Omega$
Total resistance of the circuit $\approx1.5\times5+63.53+1.5\times5\approx78.5\ \Omega$

Q14b Current in the wires between the power pack and Light 1
$\approx\dfrac{12}{78.5}\approx0.153$ A
Voltage drop $\approx0.153\times1.5\times10\approx2.3$ V (2.293 V)

Q14c Voltage across Light 1 $\approx12-2.293\approx9.707$ V
Current in the wires connected to Light 2 $\approx\dfrac{9.707}{135}\approx0.0719$ A
Total power loss in the resistance wires
$\approx0.153^2\times15+0.0719^2\times15\approx0.43$ W

Area of study – Interactions of light and matter

Q15a The spread of an interference pattern depends on the colour of light. Red light spreads out more than violet light does. All colours of white light hit the centre of the pattern to produce a central white bright band, whilst the dark bands of individual colours will have light of other colours reaching there and .: no dark bands appear in the interference pattern of white light.

Q15b Path difference $= n\lambda$ for bright band

$= 1\times 650\times 10^{-9} \approx 6.5\times 10^{-7}$ m

Q16a Accelerating voltage

Q16b Negative

Q16c $f_{uv} = \dfrac{c}{\lambda_{uv}} = \dfrac{3.0\times 10^{8}}{250\times 10^{-9}} = 1.2\times 10^{15}$ Hz, which is higher than the threshold frequency, .: photoelectric effect will occur.

Q16d Work function $\phi = (4.14\times 10^{-15})(9.0\times 10^{14}) \approx 3.726$ eV

$E_{\max} = hf - \phi = (4.14\times 10^{-15})(1.2\times 10^{15}) - 3.726 \approx 1.24$ eV

Q16e As the photons enter the metal they lose energy before they are absorbed due to the Compton Effect. Thus the electrons absorbing these lower energy photons will have a range of kinetic energy when they are emitted.

Q17 • The maximum kinetic energy of the electrons remains the same when the light intensity changes.
• Different metals have different threshold frequencies.

Q18a

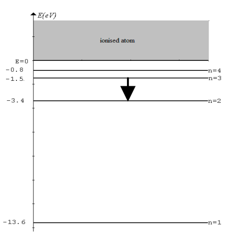
$$\lambda = \frac{h}{\sqrt{2mE_k}} = \frac{h}{\sqrt{2mqV}} = \frac{6.63\times 10^{-34}}{\sqrt{2(9.1\times 10^{-31})(1.602\times 10^{-19})(100)}}$$

$\approx 1.23\times 10^{-10}$ m $= 0.123$ nm

Q18b $\lambda = \dfrac{6.63\times 10^{-34}}{\sqrt{2(9.1\times 10^{-31})(1.602\times 10^{-19})(1)}} \approx 1.23$ nm

The second beam has a longer wavelength. Since the extent of diffraction depends on the ratio, $\dfrac{\text{wavelength}}{\text{size of an atom}}$, .: the second beam diffracts more than the first and would be more suitable to demonstrate the wave nature of matter.

Q19a $\Delta E = \dfrac{hc}{\lambda} = \dfrac{(4.14\times 10^{-15})(3.0\times 10^{8})}{667.8\times 10^{-9}} \approx 1.86$ eV corresponds to the transition from $n = 3$ to $n = 2$.



Q19b $p = \dfrac{h}{\lambda} = \dfrac{6.63\times 10^{-34}}{587.5\times 10^{-9}} \approx 1.13\times 10^{-27}$ kg m s^{-1}

Q19c Photon energy $E = 13.6 - 0.8 = 12.8$ eV

$\lambda = \dfrac{hc}{E} \approx \dfrac{(4.14\times 10^{-15})(3.0\times 10^{8})}{12.8} \approx 9.7\times 10^{-8}$ m $= 97$ nm which is outside the visible range, .: not visible

SECTION B

Detailed study 3 – Sound

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

Q1 $\lambda = 4.0$ m, $f = \dfrac{v}{\lambda} = \dfrac{330}{4.0} = 82.5$ Hz B

Q2 time taken $= \dfrac{\text{distance}}{\text{speed}} = \dfrac{2.0}{330} \approx 0.006$ s A

Q3 D

Q4 When one loudspeaker is turned off, the amplitude of the wave is halved and .: the intensity is quartered. The level drops by 6 dB. C

Q5 When the distance is doubled, the intensity is quartered. The level drops by 6 dB. C

Q6 Same wavelength, .: same frequency A

Q7 Y and Z are on the same equal loudness curve above X. B

Q8 The curve (Y) passes through 1000 Hz, 50 dB. D

Q9 C

Q10 D

Q11 Low frequency (long wavelength) diffracts more. C

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