2013 Physics Trial Exam Solutions

SECTION A – Core studies

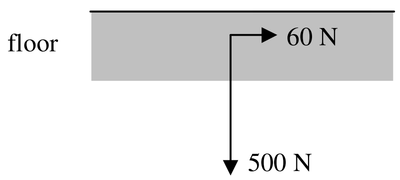
Area of study – Motion in one and two dimensions

Q1a $F_{net} = ma = 50 \times 0.20 = 10\,\text{N}$

Direction: $\tan\theta = \frac{45}{60} \approx 37°$, $N37°W$

Q1b $\textit{Sum of the two pulling forces} = \sqrt{45^2 + 60^2} = 75\,\text{N}$
$\textit{Friction} = 75 - 10 = 60\,\text{N}$

Q1c The box exerts on the floor 500 N due to its weight and 60 N due to friction.
$\textit{Sum of the two forces} = \sqrt{500^2 + 60^2} \approx 5.0 \times 10^2\,\text{N}$



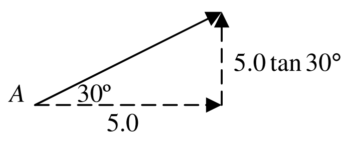
Q2a $\textit{Force of friction} = \textit{weight} = 75 \times 10 = 750\,\text{N}$

Q2b The normal reaction force of the wall on Ranjiv provides the centripetal force: $F = \frac{mv^2}{r} = \frac{4\pi^2 mr}{T^2}$, $N = \frac{4\pi^2(75)(5.0)}{T^2}$
and $\frac{3}{5} \times N = 750$, .: $\frac{750 \times 5}{3} = \frac{4\pi^2(75)(5.0)}{T^2}$,
$T \approx 3.4$ s

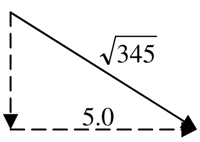
Q2c Same, independent of the person's mass. $T \approx 3.4$ s

Q3a Assume zero gravitational potential energy at *B*.
Total energy at *B* = total energy at *P*
$\frac{1}{2}mv^2 = \frac{1}{2}m(5.0^2) + m(10)(16.0)$, $v^2 = 345$, $v \approx 19$ m s^{-1}

Q3b Velocity vector diagram at *A*:



Velocity vector diagram at *B*:



Vertical component from *A* to *B*:
$u = {}^{+}5.0\tan 30° = {}^{+}2.89$, $a = {}^{-}10$, $v = {}^{-}\sqrt{345 - 5.0^2} = {}^{-}17.89$, use $v = u + at$ to find $t \approx 2.1\,\text{s}$ (2.08 s)

Q3c $\textit{Horizontal diatance} = 5.0 \times 2.08 \approx 10\,\text{m}$

Q4a Maximum speed is reached when the net force is zero, i.e. at $t = 20\,\text{s}$

Q4b Maximum acceleration first occurs when net force first reaches its maximum value, i.e. at $t = 5$ s

Q4c For 5 s (from $t = 20\,\text{s}$ to $t = 25\,\text{s}$)

Q4d *Area between the graph and the time axis = change in momentum* $= \frac{1}{2}(5 + 20)(25) - \frac{1}{2}(5)(12.5) = 281.25$ kg m s^{-1}
$\textit{Change in velocity} = \frac{\Delta p}{m} = \frac{281.25}{37.5} = 7.5$ m s^{-1}
Since the cart starts from rest, at $t = 25$ s, *speed* = 7.5 m s^{-1}

Q5a $\Delta E_{gp} = mgh = 65(10)(3.0\sin 60°) \approx 1.7 \times 10^3\,\text{J}$ (1688.75 J)

Q5b $\textit{Heat energy} = 25 \times 3.0 = 75\,\text{J}$

Q5c ΔE_{gp} = *heat energy + elastic potential energy*
$1688.75 = 75 + \frac{1}{2}k(1.0^2)$, $k \approx 3.2 \times 10^3\,\text{N m}^{-1}$

Q6a 0 N

Q6b The normal reaction force of the space station on Ali provides the centripetal force: $F = \frac{mv^2}{r} = 4\pi^2 mrf^2$,
$F = 4\pi^2(65)(100)(0.050^2) \approx 640\,\text{N}$ (641.5 N)
$\textit{Apparent weight} \approx 640\,\text{N}$

Q7a $\frac{g_{asteroid}}{g_{moon}} = \left(\frac{r_{moon}}{r_{asteroid}}\right)^2 = \left(\frac{13 \times r_{asteroid}}{r_{asteroid}}\right)^2 = 169$

Q7b Geostationary satellite:
$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$, $T = 24(60)(60) = 86400$ s,
.: $r \approx 42000000$ m or 42000 km
.: $v_{satellite} \approx \frac{42000}{24} \approx 1750\,\text{km h}^{-1}$
$\frac{v_{asteroid}}{v_{satellite}} \approx \frac{28000}{1750} \approx 16$

Area of study – Electronics and photonics

Q8a R_1 and R_2 are parallel, total $= \frac{1}{\frac{1}{1}+\frac{1}{0.5}} = \frac{1}{3}$ kΩ

(R_1 and R_2) and R_3 form a voltage divider:

$V_1 = V_2 = \frac{\frac{1}{3}}{\frac{1}{3}+1.5} \times 9.0 \approx 1.6$ V (1.64 V)

Q8b $I_A = I_2 = \frac{V_1}{R_1} \approx \frac{1.64}{1000} = 1.64\times10^{-3}$ A ≈ 1.6 mA

Q8c 1.6 V approximately

Q8d *Total resistance* $= \frac{1}{3} + 1.5 = \frac{11}{6}$ kΩ

Total power $= \frac{V^2}{R} = \frac{9.0^2}{\frac{11}{6}\times1000} \approx 4.4\times10^{-2}$ W

Q9a When $I = 5$ mA, $V_R + V_{LED} = 0.4 + 2.0 = 2.4$ V

Q9b Same brightness as in part a, .: same current (5 mA) in each LED as in part a, .: $I_R = 2\times5 = 10$ mA

Voltage $V = V_R + V_{LED} = 0.8 + 2.0 = 2.8$ V

Q10a D

Q10b D

Q11a 14 kΩ

Q11b Circuit B: The total resistance of the parallel connection of the 500 Ω resistor and the thermistor does not vary much in the 35° to 5° temperature range as shown in the following calculations.

At 35°, $R_{thermistor} \approx 6$ kΩ, $R_{total} = \frac{1}{\frac{1}{6}+\frac{1}{0.5}} \approx 0.46$ kΩ

At 5°, $R_{thermistor} \approx 23$ kΩ, $R_{total} = \frac{1}{\frac{1}{23}+\frac{1}{0.5}} \approx 0.49$ kΩ

.: $V_{thermistor}$ does not vary much in the 35° to 5° range.

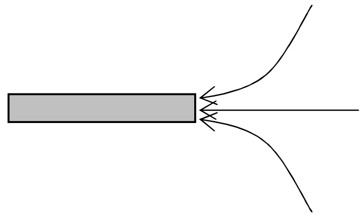
Q12a $f = \frac{1}{T} = \frac{1}{20\times10^{-3}} = 50$ Hz

Q12b *Voltage gain* $= \frac{1.5}{-0.075} = -20$ B

Q13 Output power is greater than the input power in a voltage amplifier; output and input powers are the same in a transformer.

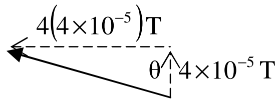
Area of study – Electric power

Q14a



Q14bi

$B = \sqrt{4^2+1^2}\left(4\times10^{-5}\right) \approx 1.6\times10^{-4}$ T



Q14b $\theta = \tan^{-1} 4 \approx 76°$

Direction of ***B*** is N 76° W

Q15a The magnetic force on the back horizontal wire is up and on the front horizontal wire is down. This force couple causes the motor to turn clockwise as viewed from the left. When the back wire moves to the front and the front wire to the back, the same force couple acts on the wires, and the clockwise motion continues.

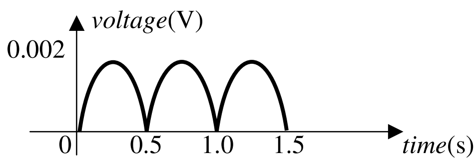
Q15b $F = BIL = 0.10\left(\frac{1.5}{5.0}\right)(0.050) = 0.0015$ N

Q15c At the moment shown the front horizontal wire moves upwards carrying electrons with it. The electrons in upward motion in the magnetic field experience a magnetic force to the left, forcing them to move to the left of the wire. This constitutes an electric current flowing in the horizontal wire to the right. Hence the current flows from right to left through the front resistor R_{front} .

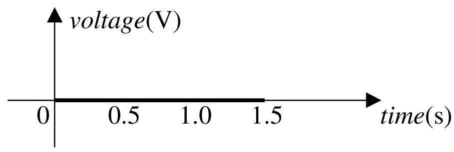
Q15d The front horizontal wire moves with a speed of $2\pi(0.050)(1) \approx 0.314$ m s^{-1} vertically at the moment shown in the diagram. In a short time interval $\Delta t = 0.01$ s, it moves a vertical distance of 0.314×0.01 m approximately.

$|\xi_{av}| = \left|\frac{\Delta\phi}{\Delta t}\right| = \left|\frac{B\Delta A}{\Delta t}\right| \approx \frac{0.10(0.050\times0.314\times0.01)}{0.01} \approx 0.002$ V

Q15e



Q15f



Q16a $\frac{N_{primary}}{N_{secondary}} = \frac{V_{primary}}{V_{secondary}} = \frac{240}{6.0} = 40$

Q16b $P_{in} = P_{out} = 10\,\text{W}$

Q16c $P_{in} = P_{out} = 10 \times 3 = 30\,\text{W}$

Q16d $V_{peak} = \sqrt{2} \times 6.0 \approx 8.5\,\text{V}$

Q16e $P_{av} = V_{rms} I_{rms}$, $30 = 240 \times I_{rms}$, $I_{rms} \approx 0.13\,\text{A}$ (0.125 A)

Q16f For one device, $10 = 240 \times I_{rms}$, $I_{rms} = \frac{1}{24}\,\text{A}$

$\textit{Maximum number of devices} = \frac{8}{\frac{1}{24}} = 192$

Q17a $\textit{Resistance in the active wire} = 0.020 \times 200 = 4.0\,\Omega$

Q17b $\textit{Heater resistance } R_{heater} = \frac{V^2}{P} = \frac{240^2}{1800} = 32\,\Omega$

Q17c $\textit{Total resistance of the circuit } R_{total} = 4.0 + 32 + 4.0 = 40\,\Omega$

$\textit{Heater current } I_{heater} = I_{circuit} = \frac{V}{R_{total}} = \frac{240}{40} = 6.0\,\text{A}$

Q17d $\textit{Heater voltage} = I_{heater} R_{heater} = 6.0 \times 32 \approx 190\,\text{V}$

Q17e $P_{loss} = (I_{circuit})^2 R_{cord} = 6.0^2 \times 8.0 \approx 290\,\text{W}$

Q17f $P_{heater.output} = (I_{heater})^2 R_{heater} = 6.0^2 \times 32 \approx 1.2 \times 10^3\,\text{W}$

Q18a 11 kW

Q18b $E = P_{av} \Delta t \approx 11 \times 24 = 264\,\text{kWh}$

$\textit{Cost} = \$0.25 \times 264 = \$66$ approx.

Area of study – Interactions of light and matter

Q19 Behaviour 1: Light travels in a straight line. ***B***

Behaviour 2: Light changes direction when it enters a different medium. ***B***

Behaviour 3: Light can cause the emission of electrons when it is directed at certain materials. ***P***

Q20 Visible light spectrum: Red (~800nm) to violet (~400nm)

Size of smoke particles ~900nm

Since the extent of diffraction $\propto \frac{\lambda}{w}$, sunlight in the red end (longer wavelengths) of the spectrum diffracts more than sunlight in the violet end. Hence orange/red light easily passes through the smoke to reach the viewer whilst blue/violet light is reflected (scattered) by the smoke particles. Thus the sun appears orange/red when it is viewed through the smoke in a bushfire.

Q21a $\lambda_{threshold} = \frac{c}{f_{threshold}} = \frac{3.0 \times 10^8}{9.7 \times 10^{14}} \approx 3.1 \times 10^{-7}\,\text{m} = 310\,\text{nm}$

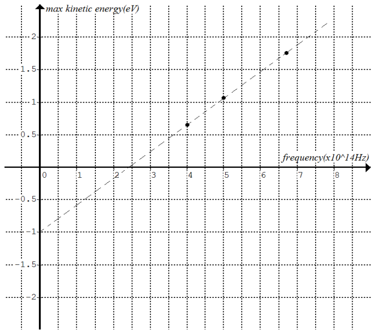
Q21b *A*, *B* and *C*

Light beam	λ (nm)	f ($\times 10^{14}$ Hz)
A	450	6.7
B	600	5.0
C	750	4.0

All three light beams have frequencies lower than the threshold frequency of the metal.

Q21c $\textit{Maximum } E_k = qV = (1.6 \times 10^{-19})(1.76) \approx 2.8 \times 10^{-19}\,\text{J}$

Q21d



Q21e $\textit{Work function} \approx 1\,\text{eV}$

Q22a $E_k = qV = (1.6 \times 10^{-19})(1.5 \times 10^5) = 2.4 \times 10^{-14}\,\text{J}$

$\lambda = \frac{h}{\sqrt{2mE_k}} = \frac{6.63 \times 10^{-34}}{\sqrt{2(9.1 \times 10^{-31})(2.4 \times 10^{-14})}} \approx 3.2 \times 10^{-12}\,\text{m}$

$= 3.2 \times 10^{-3}\,\text{nm}$

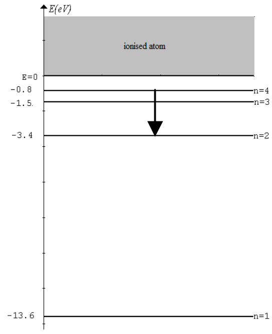
Q22b Electron microscope: λ is in the order of 10^{-3} nm

Light microscope: λ is in the order of 10^2 nm

Size of atoms/molecules: λ is in the order of 10^{-1} nm

Light has a wavelength much longer than the size of atoms and molecules. This results in great light diffraction and hence blurred images. Electrons in an electron microscope have much shorter wavelength than the size of atoms and molecules.
.: diffraction is insignificant and sharper images are produced.

Q23a $E = \frac{hc}{\lambda} = \frac{(4.14 \times 10^{-15})(3.0 \times 10^8)}{478 \times 10^{-9}} \approx 2.6\,\text{eV}$



Q23b According to de Broglie, each electron orbit in an atom is actually a circular standing wave and .: must consist of a whole number of wavelengths. This explains the discrete energy levels in Bohr's model of a hydrogen atom.

SECTION B

Detailed study 2 – Materials and their use in structures

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

Q1 Compressive force at the bottom of the column is proportional to the weight of the column. A

Q2 Compressive stress at the bottom of the column is proportional to the height of the column, and it is independent of the cross-section of the column. C

Q3 *Strain* $\propto$ *stress* C

Q4 B

Q5 $k = \frac{EA}{\ell}$ where E is Young's modulus, A cross-sectional area and ℓ length of the cable. D

Q6 The stress required to break the material equals the strength of the material 272 MPa. C

Q7 Toughness of a material is measured by the area under its stress-strain graph up to the breaking point 20 MPa (20 MJ m^{-3}). D

Q8 The total anticlockwise torque of the composite block equals $250 \times 0.10 = 25$ Nm. The lock is in equilibrium, .: the total clockwise torque equals 25 Nm. B

Q9 D

Q10 *Tensile strength* $\frac{15 \times 10}{\pi\left(0.40 \times 10^{-3}\right)^2} \approx 2.98 \times 10^8$ Pa (298 MPa) A

Q11 $P \times 0.40 = 150 \times 2.0$, $P = 750$ N B

Q12 $F = P + 150 = 900$ N B

Detailed study 3 – Sound

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

Q1 $\frac{\lambda}{2} = 1.30$, $\lambda = 2.60$ m, $f = \frac{v}{\lambda} = \frac{340}{2.60} \approx 131$ Hz C

Q2 The paper tape could be positioned at a pressure anti-node (particle displacement node), .; the tape is motionless. A

Q3 Point P could be a pressure node where there is no variation in air pressure. C

Q4 $L = 10 \times \log_{10}\left(\frac{5 \times 10^{-9}}{10^{-12}}\right) \approx 37$ dB D

Q5 $L = 10 \times \log_{10}\left(\frac{3 \times 5 \times 10^{-9}}{10^{-12}}\right) \approx 42$ dB D

Q6 $\frac{I_f}{I_i} = \frac{r_i^2}{r_f^2}$, $I_f = \frac{5.0^2}{3.0^2} \times \left(3 \times 5 \times 10^{-9}\right) \approx 4.2 \times 10^{-8}$ W m^{-2} D

Q7 $\frac{3}{4}\lambda = 0.75$, $\lambda = 1.0$ m C

Q8 $f = 3 \times \frac{v}{2L} = 3 \times \frac{340}{2 \times 0.75} = 680$ Hz B

Q9 The wave speed in the stretched wire is unknown. D

Q10 A flat response B

Q11 To compensate for diffraction to different extents due to different wavelength ranges. D

Q12 To prevent interference of back and front waves generated by the loudspeakers. C

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