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2019 Physics Trial Exam Solutions

SECTION A

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

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

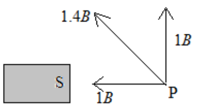
Q1 Electric field between two oppositely charged plates is constant.

Q2 Double the charge on one will double the force, double the distance the force will become a quarter of the original value. Overall the force will be halved.

Q3 Unless the particle moves towards the Earth centre, a force is required to overcome the gravity of Earth. .: the particle is not in freefall.

Q4 Electric potential energy is highest when like charges are closest because of the repulsive force between them.

Q5



Q6 All riders have acceleration pointing towards the centre of the circle.

Q7 Geostationary satellites all have the same speed but they can be different in mass, .: different kinetic energy.

Q8 $E=\frac{F}{q}=\frac{ma}{q}=\frac{V}{d}$, .: $a=\frac{qV}{md}$, a is inversely proportional to md, not proportional.

Q9 Before adding/subtracting all measurements need to be corrected to the same number of decimal places as the least precise measurement.

$2.3\text{ cm}+5.5\text{ mm}+2.3\text{ cm}+5.5\text{ mm}$

$=2.3\text{ cm}+0.6\text{ cm}+2.3\text{ cm}+0.6\text{ cm}=5.8\text{ cm}=58\text{ mm}$

Q10

Q11 No change in magnetic flux

Q12

Q13 Let n be the number of periods between the first compression and another compression, .: n must be a whole number. $T=\frac{1\text{ second}}{n}=\frac{1}{f}$, .: $f=n$, 50.0 is closest to a whole number.

Q14 Energy consideration: $\frac{1}{2}mu^2+mgh=\frac{1}{2}mv^2$

.: $v^2=u^2+2gh$

Q15 $n_s v_s=n_a v_a$, $v_s=\frac{1.000v_a}{n_s}=\frac{1.000f\lambda_a}{n_s}=1.000f\lambda_s$

.: $v_s\propto\lambda_a$ or λ_s

Q16 A travelling sound wave and its reflection have the **same frequency**. The superposition of the two waves produces a standing wave.

Q17 A uniformly decreasing input voltage produces a constant rate of change in magnetic flux through the secondary coil. Hence a constant voltage is induced at the transformer output.

Q18 Uncertainties have single digit.

Q19 $\frac{0.80\times10^{-6}}{1.6\times10^{-19}}=5.0\times10^{12}$

Q20 $E_\text{k}=(\gamma-1)mc^2\approx1.294mc^2$

SECTION B

Q1a $E=\frac{V}{d}=\frac{250}{0.050}=5000\ \text{NC}^{-1}$

Electric force $F=qE=1.6\times10^{-19}\times5000=8.0\times10^{-16}\,\text{N}$

Force of gravity $F=mg=9.1\times10^{-31}\times9.8\approx8.9\times10^{-30}\,\text{N}$

Force of gravity is very much less than the electric force, .: it has no significant effect on the straight line path of the electron.

Q1b $E_\text{k}=$ work done on the electron by the electric force

$=8.0\times10^{-16}\times0.050=4.0\times10^{-17}\,\text{J}$

Q1c $F=qvB=q\sqrt{\frac{2E_\text{k}}{m}}B$

$=1.6\times10^{-19}\times\sqrt{\frac{2\times4.0\times10^{-17}}{9.1\times10^{-31}}}\times0.010$

$\approx1.5\times10^{-14}\,\text{N}$ perpendicular to the motion of the electron

Q1d The constant force perpendicular to the motion causes the electron to move in a semi-circular path at the constant speed of $\sqrt{\frac{2\times4.0\times10^{-17}}{9.1\times10^{-31}}}\approx9.4\times10^{6}\ \text{m s}^{-1}$.

Acceleration $=\frac{F}{m}=\frac{1.5\times10^{-14}}{9.1\times10^{-31}}\approx1.6\times10^{16}\ \text{m s}^{-2}$.

Radius $=\frac{v^2}{a}\approx\frac{8.8\times10^{13}}{1.6\times10^{16}}\approx0.005\,\text{m}$

The path curves upward and the electron hits Plate Q at the end of the semi-circular path.

Q2a $2T\sin 5° = 75\times 9.80$, $T \approx 4.2\times 10^3$ N

Q2b Elastic potential energy = gravitational potential energy
$= 75\times 9.80\times(6.00+0.75) \approx 5.0\times 10^3$ J

Q2c $\frac{1}{2}k\times 0.75^2 = 75\times 9.80\times(6.00+0.75)$,
$k \approx 1.8\times 10^4$ N m^{-1} (17640)
Force required to depress the net by 1 m $\approx 1.8\times 10^4$ N

Q2d Maximum force $= kx \approx 17640\times 0.75 \approx 1.3\times 10^4$ N

Q2e If air resistance is insignificant, the clown will rebound to a height 6.00 m above the hozizontal net and the motion repeats.

Q3a $5.0 = 4.0\times\frac{1}{\sqrt{1-\left(\frac{v}{c}\right)^2}}$, $\sqrt{1-\left(\frac{v}{c}\right)^2} = 0.80$, $\frac{v}{c} = 0.6$

Q3b Contracted distance $= 3.80\times 10^8\times 0.80 \approx 3.04\times 10^8$ m

Q3c Time measured by astronaut $= \frac{3.04\times 10^8}{0.6c} \approx 1.7$ s

Q4a Minimum speed
$=$ constant horizontal component of velocity
$= 25.0\sin 60° \approx 21.7$ m s^{-1}

Q4b Vertical component: $u = 0$, $v = -25.0\cos 60° = -12.5$
$a = -9.8$, .: $s \approx -7.97$, maximum height ≈ 7.97 m

Q5a Mass of electron at $0.99c$ $= \frac{9.1\times 10^{-31}}{\sqrt{1-0.99^2}} \approx 6.5\times 10^{-30}$ kg

Q5b Rest energy + kinetic energy $= E_{\text{total}} = \gamma mc^2 \approx 2.0\times 10^{-13}$ J

Q6a $r = \sqrt{\frac{GM}{g}} = \sqrt{\frac{(6.67\times 10^{-11})(5.98\times 10^{24})}{0.22}} \approx 4.26\times 10^7$ m
Altitude $\approx 4.26\times 10^7 - 6.37\times 10^6 \approx 3.6\times 10^7$ m

Q6b $T = 2\pi\sqrt{\frac{r}{g}} = 2\pi\sqrt{\frac{4.26\times 10^7}{0.22}} \approx 8.74\times 10^4$ s

Q6c Increase in gravitational potential energy
$\approx mgh = 1\times 0.22\times 1000 = 2.2\times 10^2$ J

Q7a $\frac{mv^2}{5.00} = 9.80m\tan 30°$, $v \approx 5.32$ m s^{-1}

Q7b $\frac{m6.00^2}{r} = 9.80m\tan 30°$, $r \approx 6.36$
$\frac{\Delta h}{6.36-5.00} \approx \tan 30°$, $\Delta h \approx 0.79$ m

Q8a 150 Hz is the third harmonic, $\frac{3\lambda}{2} = 0.48$, $\lambda = 0.32$ m

Q8b Same speed for wave of any frequency travelling in the same wire, $v = f\lambda = 150\times 0.32 = 48$ m s^{-1}

Q8c 345 m s^{-1}

Q9 The speed of sound increases relative to you inside a car approaching at high speed the sounding siren of the stationary police car. Since $f = \frac{v}{\lambda}$ and the sound wavelength remains constant, .: $f \propto v$, higher sound speed, higher frequency, higher pitch.

Q10a $240\times I = 2\times 2200$, $I \approx 18.3$ A, this amount of current is over the current allowed for the fuse rated 15 A. The fuse will be blown to prevent overheating of the wiring in the house.

Q10b Total resistance of extension cord $= 0.025\times 50 = 1.25$ Ω
Resistance of the power tool $= \frac{240^2}{3000} = 19.2$ Ω
Current through the power tool $= \frac{240}{19.2+1.25} \approx 11.74$ A
Voltage across power tool $\approx 11.74\times 19.2 \approx 225$ V which is within 220 - 240 V. The power tool is operational.

Q11a $\phi = 0.10\times 0.06\times 4.0\times 10^{-5} = 2.4\times 10^{-7}$ wb

Q11b $\tau = 0$

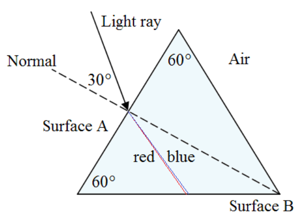
Q11c $T = \frac{1}{5.0} = 0.20$ s, 0.050 s is the time for a quarter turn.
Magnetic flux changes from maximum to zero.
The induced current flows from Q to P through the coil.
.: terminal P is at a higher potential relative to Q.
$|\xi| = 50\times\frac{2.4\times 10^{-7}}{0.050} = 2.4\times 10^{-4}$ V
Average potential at P is $+2.4\times 10^{-4}$ V.

Q12a As the right side of the coil enters the magnetic field, a clockwise current is induced in it and the magnetic field exerts a force opposite to its motion. This force retards the motion of the coil. As the left side of the coil leaves the magnetic field, an anticlockwise current is induced in it and the magnetic field again exerts a force opposite to its motion. Every time the coil swings past the magnetic field it is retarded by the magnetic force and its height drops at the end of a swing. This gradually reduces the amplitude of the swinging coil.

Q12b Gravitational potential energy changes to electrical energy $= mgh = 0.50\times 9.80\times 0.20 = 0.98$ J

Q13a Red: $\sin\theta = \frac{0.5}{1.514}$, $\theta \approx 19.3°$
Blue: $\sin\theta = \frac{0.5}{1.528}$, $\theta \approx 19.1°$

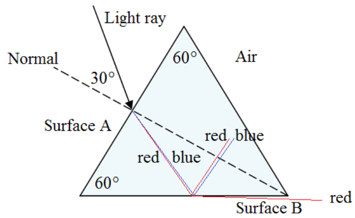
Q13b



Q13c Red: $\theta_c = \sin^{-1}\left(\frac{1}{1.514}\right) \approx 41.34°$

Blue: $\theta_c = \sin^{-1}\left(\frac{1}{1.528}\right) \approx 40.88°$

Q13d For the blue component the angle of incidence at surface B is $180-120-19.1 = 40.9°$. It is greater than the critical angle. Total internal reflection will occur for the blue component.
For the red component the angle of incidence at surface B is $180-120-19.3 = 40.7°$. It is less than the critical angle.
Some internal reflection as well as refraction into air will occur for the red component.



Q14a Approximately $5\times\frac{\lambda}{2} \approx 5.0\,\text{cm}$ or $0.050\,\text{m}$

Q14b When the waves from the two sources meet, destructive interference occurs when the waves are out of phase by half of a period. At places (nodal lines) where this occurs the water surface is fairly calm.

Q14c $QS_1 - QS_2 = 2\lambda = 4.0\,\text{cm}$ or $0.040\,\text{m}$

Q14d Location P is on an anti-nodal line (region of constructive interference). Water surface at P oscillates at maximum amplitude, the sum of the amplitudes of the waves from the two sources. The cork moves up and down (no horizontal motion) at P as time progresses and at the same frequency as the waves.

Q15 Light passing the coin edge diffracts. Some light will diffract behind the coin. At the central axis diffracted light interfere constructively and if the screen is at the right distance from the coin, a bright spot appears. Some light will diffract away from the coin. Constructive and destructive interferences occur forming the bright and dark fringes around the shadow.

Q16 Wavelength λ of visible light is about the size w of smoke particles, .: diffraction occurs for visible light. Since the extent of diffraction $\propto \frac{\lambda}{w}$, .: light of longer wavelength (red end of the visible spectrum) diffracts more than light of shorter wavelength (blue end). Observer A will see more light from the red end of the spectrum. Light from the blue end will be scattered in all directions by the smoke particles and some to Observer B.

Q17a Wave model: Varying frequency of light has no effects on the number and kinetic energy of emitted electrons.
Light energy is related to the amplitude of the light wave.
Brighter light (larger amplitude) will pass on more energy to the electrons and they will be emitted with higher kinetic energy.
The number of emitted electrons remains constant.

Q17b $E = \frac{hc}{\lambda} = \frac{(4.14\times10^{-15})(3.0\times10^{8})}{410\times10^{-9}} \approx 3.0\,\text{eV}$

Max $E_k = 3.03 - 1.755 \approx 1.27$ eV,

$\frac{1}{2}\times9.1\times10^{-31}v^2 \approx 1.27\times1.6\times10^{-19}$, $v \approx 6.7\times10^5\,\text{m s}^{-1}$

Q17c The results are consistent. Use any two pairs of data, $hc \approx 1.24\times10^{-6}$ eVm

Q17d Max $E_k = \frac{hc}{\lambda} - \phi$,

$\phi = \frac{hc}{\lambda} - \max E_k \approx \frac{1.24\times10^{-6}}{700\times10^{-9}} - 0.500 \approx 1.27$ eV

$\frac{hc}{\lambda} = \phi$, $\frac{1.24\times10^{-6}}{\lambda} \approx 1.27$, $\lambda \approx 9.8\times10^{-7}$ m

Q18 When a photon passes through a single slit, there is uncertainty Δx (width of the slit) in its position at the slit.
According to Heisenberg's uncertainty principle $\Delta p_x \Delta x \geq \frac{h}{4\pi}$, the uncertainty in its momentum Δp_x (direction spread) increases as uncertainty in its position Δx decreases. This explains the widening of the diffraction pattern when the width of the slit decreases.

Q19 An interference pattern appears over time when very dim light (as dim as one photon at a time) is used in a double slit experiment. To explain this, one can consider a single photon as a wave itself. The single photon, being a particle itself, behaves like a wave as well to produce the pattern. This experiment demonstrates the wave-particle duality of light.

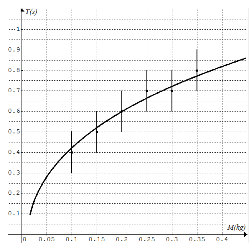
Q20a Dependent: period T Independent: mass of load M
Controlled: air resistance r, mass of spring m, elastic constant k, and gravity g

Q20b Reduce air resistance by using a smooth dense (large in mass but small in volume) load. Choose a spring with insignificant mass in comparison with the mass of the load.

Q20c

Period (s)
0.4 ±0.1
0.5 ±0.1
0.6 ±0.1
0.7 ±0.1
0.7 ±0.1
0.8 ±0.1

Q20d



The shape of the curve suggests that $T \propto M^n$ where $0 < n < 1$.

Try $n = \frac{1}{2}$, $T = k\sqrt{M}$, $k = \frac{T}{\sqrt{M}} \approx 1.3, 1.3, 1.3, 1.4, 1.3, 1.4$

Within the margin of error, the relationship is $T \approx 1.3\sqrt{M}$ where T is in seconds and M is in kg.

Q20e A straight line can also be fitted to the data across all the error bars. By adding more data and extending the mass range the curve can be made more pronounced and thus a linear relationship can be eliminated.

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