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2018 Physics Trial Exam Solutions

SECTION A

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

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

Q1 Gravitational field between two masses does not follow the inverse square law.

Q2 Gravitational, electric and magnetic forces also exist in a helium nucleus.

Q3 A charged particle spirals in the Earth's magnetic field towards the north or south poles.

Q4 Electric potential energy decreases and kinetic energy increases when unlike charges attract towards each other.

Q5 Static field: Field remains constant as time progresses. Uniform field: Field remains constant in space.

Q6 $\frac{1}{8}\times 2.00\times 10^{-2} = 2.50\times 10^{-3}$

Q7 Force of gravity depends on the mass of the satellite.

Q8 $v^2 r = v_o{}^2 r_o$, when $r = 4\times r_o$, $v^2 = \frac{1}{4}\times v_o{}^2$, $KE = \frac{1}{4}\times KE_o$

Q9 In addition and subtraction of measured quantities, uncertainties are always added.
$(52.3\pm 0.1)-(49.5\pm 0.5) = 2.8\pm 0.6$

Q10 Average $= \frac{(52.3\pm 0.1)+(49.5\pm 0.5)+(50.0\pm 0.2)}{3}$
$= \frac{151.8\pm 0.8}{3} \approx 50.6\pm 0.3$

Q11 Different colours in sunlight refract differently when sunlight travels from a medium to a different medium of higher refractive index.

Q12 T_S is the proper time.

Q13 D_M and D_E are proper lengths.

Q14 Consider the total energy (kinetic and potential) for both particles:

1-kg particle: $\frac{1}{2}\times 1\times v^2 = 1gh + \frac{1}{2}\times 1\times u^2$, $v = \sqrt{2gh+u^2}$

2-kg particle: $\frac{1}{2}\times 2\times v^2 = 2gh + \frac{1}{2}\times 2\times u^2$, $v = \sqrt{2gh+u^2}$

Q15 It is a displacement node at P.

Q16 $v = \frac{\lambda}{T} = \frac{0.20}{0.50} = 0.40$

Q17 A battery provides a constant current in the primary coil. This constant current generates a constant magnetic field in the transformer core. Thus the magnetic flux through the secondary coil stays constant, resulting in zero induced emf in the secondary coil.

Q18 Magnetic flux decreases when the loop rotates in either direction. Lenz's Law says the induced current flows from Q to P in the loop.

Q19 Speed of light is the dependent variable, medium is the independent variable, and frequency of light is the controlled variable. Although wavelength does change in a different medium, it is not the objective of the experiment to investigate wavelength.

Q20 Medium affects wavelength, and thus it affects the width of the diffraction pattern.

SECTION B

Q1a $\vec{N} + \vec{W} = \vec{F}_{net}$,
$\vec{N} = \vec{F}_{net} - \vec{W} = {}^{+}1.80\times 10^2 - {}^{-}0.80\times 9.80 \approx {}^{+}188$ N

Q1b $v^2 = u^2 + 2as = 0 + 2(9.80)(2.58)$, $v = 7.11$ m s^{-1}

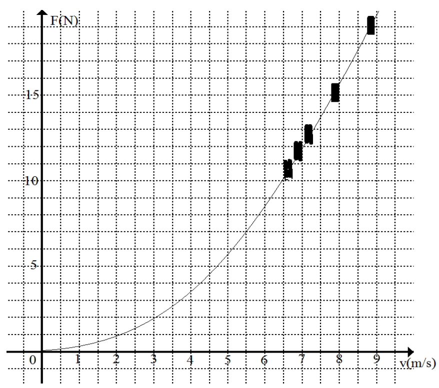
Q1c Speed (leaving the floor) $= \sqrt{2(9.80)(1.80)} \approx 5.94$
$\Delta\vec{p} = m({}^{+}5.94 - {}^{-}7.11) = {}^{+}10.4$ kg m s^{-1}, $|\Delta\vec{p}| = 10.4$ kg m s^{-1}

Q1d $|\vec{F}_{net}|\times\Delta t = |\Delta\vec{p}|$, $\Delta t = \frac{10.4}{180} \approx 0.058$ s

Q2a $v = \frac{2\pi r}{T} = \frac{2\pi\times 1.0}{0.80} \approx 7.854 \approx 7.9$ m s^{-1}

Q2b $a = \frac{v^2}{r} \approx \frac{7.854^2}{1.0} \approx 62$ m s^{-2}

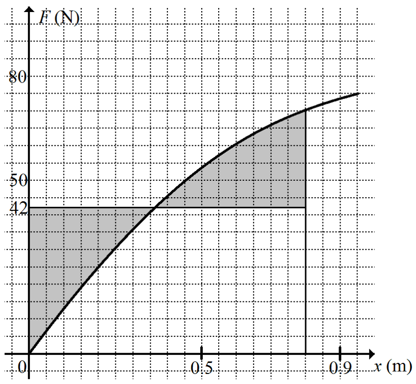
Q2c



Q2d The recorded data do not include a wide spread of speed, especially the lower speeds. The curve should be towards the origin, no force is required if the object is not in motion.

Q2e A graph of F vs v^2 shows a straight line towards the origin fitting the data. $F \propto v^2$.

Q3a Average force ≈ 42 N, work $\approx 42 \times 0.80 \approx 34$ J



Q3b $\frac{1}{2} \times 0.50 \times v^2 \approx 34$, $v \approx 12$ m s^{-1}

Q3c $F_{friction} \times d = E_k$, $F_{friction} \times 5.8 \approx 34$, $F_{friction} \approx 5.9$ N

Q3d $\mu = \dfrac{F_{friction}}{mg} \approx \dfrac{5.9}{0.50 \times 9.80} \approx 1.2$

Q4a For spacecraft A: $L_o = \dfrac{61.5}{\sqrt{1-0.18^2}} \approx 62.5$ m

Q4b For spacecraft B: $L = 60.0 \times \sqrt{1-0.18^2} \approx 59.0$ m

Q5a Mass of particle at $0.25c = \dfrac{m_o}{\sqrt{1-0.25^2}} \approx 1.0328 m_o$

Mass of particle at $0.50c = \dfrac{m_o}{\sqrt{1-0.50^2}} \approx 1.1547 m_o$

$$\frac{\Delta m}{1.0328 m_o} \approx \frac{1.1547 m_o - 1.0328 m_o}{1.0328 m_o} \approx 0.12 \text{ or } 12\%$$

Q5b $\dfrac{E_k \text{ at } 0.50c}{E_k \text{ at } 0.25c} \approx \dfrac{1.1547 m_o c^2 - m_o c^2}{1.0328 m_o c^2 - m_o c^2} = \dfrac{0.1547}{0.0328} \approx 4.7$

Q6a Gravity is the only force on the driver (mass m kg) for the driver to feel weightless. $\dfrac{mv^2}{r} = mg$, $r = \dfrac{v^2}{g} \approx \dfrac{19.6^2}{9.80} = 39.2$ m

Q6b The driver will be in freefall in a parabolic path.

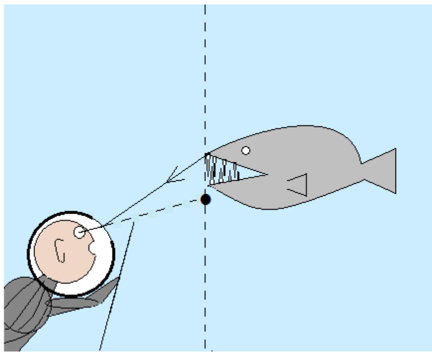
Q7a The total reaction force has a horizontal component a vertical component. The vertical component is the normal reaction force $mg = 450 \times 9.80 = 4410$ N.
The horizontal component is the force due to friction which keeps the cycle in circular motion, $\dfrac{450 \times 20.0^2}{30.0} = 6000$ N

Total reaction force $= \sqrt{4410^2 + 6000^2} \approx 7.45 \times 10^3$ N

Q7b $\tan\theta = \dfrac{6000}{4410}$, $\theta \approx 53.7°$

Q7c $\tan\theta = \dfrac{\frac{mv^2}{r}}{mg} = \dfrac{v^2}{rg}$, the leaning angle does not depend on the mass.

Q8a

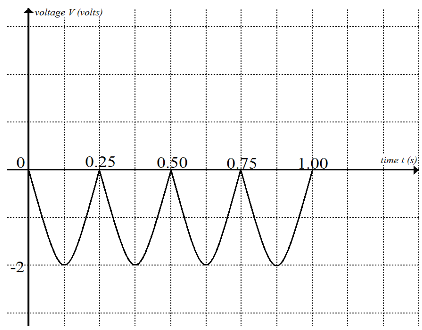


Q8b $1\sin\theta = 1.33\sin 10°$, $\theta \approx 13.4°$

Q8c $\theta_{\text{critical}} = \sin^{-1}\left(\dfrac{1}{1.33}\right) \approx 48.8°$

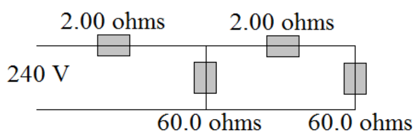
Q9a $V_{peak} = \sqrt{2} \times V_{rms} = \sqrt{2} \times \sqrt{2} = 2$ V

Q9b



Q9c Heat $= P_{av} \times \Delta t = \dfrac{V_{rms}^2}{R} \times \Delta t = \dfrac{\left(\sqrt{2}\right)^2}{5.0} \times 1 = 0.40$ J

Q10a



Total resistance $= 2.00 + \dfrac{1}{\frac{1}{60.0} + \frac{1}{62.0}} \approx 32.5\ \Omega$

10b $I = \dfrac{240}{32.5} \approx 7.39$ A

10c Voltage drop in the 1st extension cord $\approx 7.39 \times 2.00 \approx 14.8$ V
Power board voltage $\approx 240 - 14.8 \approx 225$ V

10d Current in the 2nd extension cord $\approx \dfrac{225}{62} \approx 3.63$ A
Voltage drop in the 2nd extension cord $\approx 3.63 \times 2.00 \approx 7.26$ V

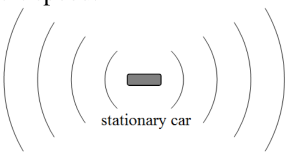
Q11a $v^2 \times r = GM_E$

$= (6.67\times10^{-11})(6.0\times10^{24}) \approx 4.0\times10^{14}$ N m^2 kg^{-1} or m^3 s^{-2}

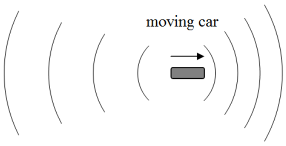
Q11b $v = \frac{2\pi r}{T}$, $r = \frac{vT}{2\pi}$

.: $v^3T = 2\pi \times GM_E \approx 2.5\times10^{15}$ N m^2 kg^{-1} or m^3 s^{-2}

Q12 When the engine of a stationary racing car sends out sound waves (constant frequency assumed), the wavelengths (distance between 2 adjacent compressions) in front and behind the car are the same. The compressions travel away from the car in both directions at constant speed.



When the car moves forwards, the compressions in front of the car are closer together (shorter wavelength) whilst those behind are further apart (longer wavelength), but the speed of travel remains the same as in the stationary situation.



A person listens to the approaching car will receive more compressions per second because they are closer together and travel at the same speed, and the person will hear a higher frequency sound. The compressions from the departing car are further apart and travel at the same speed. The person will receive fewer compressions per second and hence it sounds like to be at a lower frequency to the person.

Q13a For significant diffraction to occur at each slit, $\frac{\lambda}{w} \geq 1$,

$w \leq \lambda = \frac{c}{f} = \frac{3.0\times10^8}{3.0\times10^{10}} = 0.010$ m

.: the upper limit of w is about 1 cm.

Q13b B is the second position of strong microwave on one side of the central maximum.

$S_2B - S_1B = 2\lambda = 2\times0.010 = 0.020$ m

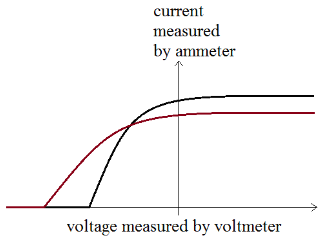
Q13c K is the third position of weak microwave on the other side of the central maximum.

$S_1K - S_2K = \left(3 - \frac{1}{2}\right)\lambda = \frac{5}{2}\times0.010 = 0.025$ m

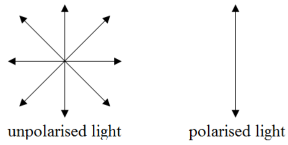
Q13d Increase the wavelength, decrease the separation of the two parallel slits.

Q14a Region III: For certain light intensity a fixed number of photoelectrons will be emitted per second. Hence the current remains constant (maximum value) when the accelerating voltage increases.
Region II: As retarding voltage increases it stops more photoelectrons from reaching the collecting electrode and hence the current decreases.
Region I: Retarding voltage is sufficiently high to stop all photoelectrons from reaching the collecting electrode and no current is registered.

Q14b



Q15a Unpolarised light is an electromagnetic wave with equal vibrations of the electric field vectors (or magnetic field vectors) in all directions perpendicular to the direction of propagation of the light wave. Polarised light is an electromagnetic wave with vibrations of the electric field vector (or magnetic field vector) in only one direction perpendicular to the direction of propagation of the light wave.



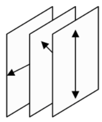
Q15b The vibrations of the electric field vectors in unpolarised light can be resolved into two perpendicular components. A polarising sheet allows one component to pass through and completely absorbs the other component.

Q15c 0.5

Q15d 0.5

Q15e 0

Q15f



Estimation:
Let the amplitude of the original unpolarised wave be 1 unit.
Light becomes vertically polarised after passing through the front polariser.
The amplitude of this polarised wave becomes $1\cos45° \approx 0.71$.
It becomes polarised at $45°$ with amplitude $0.71\cos45° \approx 0.5$ after passing through the middle polariser.
It becomes horizontally polarised with amplitude $0.5\times\cos45° \approx 0.35$ after passing through the third polariser.
Light intensity is proportional to amplitude^2, .: it is 0.13 of its original value. The ratio has a max value of 0.13 approximately.
Note: Light intensity is halved after passing through each polariser, $0.5^3 = 0.125$.

Q16a $p = \frac{h}{\lambda} = \frac{6.63\times10^{-34}}{410\times10^{-9}} \approx 1.62\times10^{-27}$ kg m s^{-1}

Q16b max $E_K = (1.6\times10^{-19})(0.75) = 1.2\times10^{-19}$ J

$p = \sqrt{2mE_K} = \sqrt{2(9.1\times10^{-31})(1.2\times10^{-19})} \approx 4.7\times10^{-25}$ kg m s^{-1}

Q16c $w = \frac{hc}{\lambda} - \max E_K$

$= \frac{(6.63\times10^{-34})(3.0\times10^8)}{410\times10^{-9}} - 1.2\times10^{-19} \approx 3.7\times10^{-19}$ J

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