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2017 Physics Trial Exam Solutions

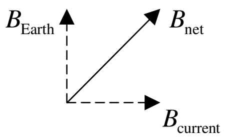
SECTION A

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

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

Q1 Electric field: Pointing from high to low potential and normal to a metal surface.

Q2



Q3 Charged particles spiral in the Earth's magnetic field towards the north or south poles.

Q4 $F \propto \dfrac{m_A m_B}{r^2}$

Q5 $\dfrac{(8.99\times10^9)(0.5q)q}{0.20^2} = 1.0\times10^{-6}$, $q = 3.0\times10^{-9}$

.: $0.5q + q = 4.5\times10^{-9}$

Q6 F_f is the dependent variable.

Q7 F_f is the quantity under investigation.

Q8 Controlled variables: Contact surfaces and angle θ
The mass m of the block is the independent variable which is varied.

Q9 The least precise measurement is 12.5 m which has a precision of 0.1 m. The precision of the sum of the measurements follows that of the least precise measurement.

Q10 % uncertainty of radius measurement $= \dfrac{0.1}{3.28} \approx 0.03 = 3\%$

Area $\approx \pi\times3.3^2 \approx 34$ with uncertainty $34\times3\%\times2 \approx 2$

.: area $= 34 \pm 2$

Q11 $|\Delta p| = m|\Delta v| = m\times$ area under a - t graph

$\approx 8\left(\dfrac{1}{2}\times830\times0.05\right) \approx 170$

Q12 Higher relative speed, greater length contraction

Q13 Both observers measure the same proper time taken for spacecrafts A and B to meet.

Q14 As the periodic wave travels to the right, dot P will be at a trough of the wave. .: dot P is moving downwards.

Q15 The speed of dot P is not the wave speed.

Q16 (I) and (II) can be avoided and should not be included.

Q17 All three interactions are possible.

Q18 Choice C is incorrect because it is true only for total internal reflection.

Q19 $a = \dfrac{GM_{\text{Earth}}}{r^2} = \dfrac{v^2}{r}$ where $v = \dfrac{2\pi r}{T}$
Mass of the satellite does not appear in the equations.

Q20 $\Delta\vec{p}_A + \Delta\vec{p}_B = 0$, .: $\Delta\vec{p}_A \neq \Delta\vec{p}_B$

SECTION B

Q1a $V = \dfrac{4\pi}{3}(1.37\times10^{-6})^3 \approx 1.08\times10^{-17}$ m^3

% uncertainty in the volume $\approx \dfrac{0.02}{1.37}\times3 \approx 4.38\%$

Uncertainty in the volume $(1.08\times10^{-17})\times4.38\% \approx 0.05\times10^{-17}$ m^3

.: $V \approx (1.08\pm0.05)\times10^{-17}$ m^3

Q1b $m = DV = 922.35\times(1.08\pm0.05)\times10^{-17}$

$= (996.138\pm46.1175)\times10^{-17}$

$= (9.96\pm0.5)\times10^{-15} \approx (1.00\pm0.05)\times10^{-14}$ kg

Q1c $E = \dfrac{V}{d} = \dfrac{391.49}{16.0\times10^{-3}} \approx 2.45\times10^4$ N C^{-1}

Q1d $qE = mg$, $q = \dfrac{(1.00\times10^{-14})(9.80)}{2.45\times10^4} \approx 4.00\times10^{-18}$ C

Q1e Number of excess electrons $\approx \dfrac{4.00\times10^{-18}}{1.6\times10^{-19}} = 25$

Q1f The electric force on the oil droplet will be weaker than the force of gravity. The oil droplet will move downwards.

Q2a Estimate the area under the graph from $t = 7$ to $t = 9$, approximately 19 m.

Q2b Acceleration, estimated gradient at $t = 5.5$ is 5.4 m s^{-2}

$F_{\text{net}} \approx ma = 0.1\times5.4 \approx 0.5$ N downwards

Q2c $F_{\text{net}} \approx 0.5$, weight + air resistance ≈ 0.5 ,

$1.0 +$ air resistance ≈ 0.5 , air resistance $\approx {}^{-}0.5$ N,
i.e. 0.5 N upwards

Q3a $\frac{1}{2}\times 0.100v^2 = 20.0$, $v = 20.0$ m s^{-1}

Q3b Horizontal component: $v = 20.0\cos 60° = 10.0$

$E_K = \frac{1}{2}\times 0.100\times 10.0^2 = 5.00$ J

Q3c Total energy $= 0.100\times 9.80\times 2.0 + 20.0 \approx 22$ J

Q3d Just before hitting the ground, $E_K \approx 22 = \frac{1}{2}\times 0.100v^2$

.: $v^2 \approx 440$, .: vertical component of velocity

$\approx {}^{-}\sqrt{440-10.0^2} \approx {}^{-}18.4$, $u={}^{+}20.0\sin 60° \approx {}^{+}17.3$, $a={}^{-}9.80$

$t = \frac{v-u}{a} \approx 3.64$ s

Q4a $\frac{v_A}{v_B} = \frac{r_A}{r_B} = \frac{4.20}{2.10} = 2.00$

Q4b $\frac{F_A}{F_B} = \frac{mv_A{}^2/r_A}{mv_B{}^2/r_B} = \left(\frac{v_A}{v_B}\right)^2 \frac{r_B}{r_A} = 2.00^2\times\frac{1}{2.00} = 2.00$

Q5a $v_A{}^2 r_A = v_B{}^2 r_B$, .: $\frac{v_A{}^2}{v_B{}^2} = \frac{r_B}{r_A} = \frac{1}{2}$, .: $\frac{v_A}{v_B} = \frac{1}{\sqrt{2}} \approx 0.71$

Q5b $\frac{F_A}{F_B} = \frac{mg_A}{mg_B} = \frac{r_B{}^2}{r_A{}^2} = \frac{1}{4} = 0.25$ or quote the inverse square law.

Q5c Read from the graph the values of g at 2.1×10^7 m and 4.2×10^7 m.
Difference $\approx 0.90 - 0.23 = 0.67$ N per kg of the satellite.

Q5d Estimated difference in gravitational potential energy
$=$ estimated area under the graph from 2.1×10^7 m to 4.2×10^7 m
$\approx 9.5\times 10^6$ J per kg of the satellite

Q6a $\frac{x}{50.0} = \frac{25.0}{30.0}$, $x \approx 41.7$ m

Q6b $\frac{L}{L_0} = \sqrt{1-\left(\frac{v}{c}\right)^2}$, $\left(\frac{25.0}{30.0}\right)^2 = 1-\left(\frac{v}{c}\right)^2$

.: $v \approx 0.55277c \approx 1.66\times 10^8$ m s^{-1}

Q6c 0.117 s

Q7a $v = \frac{qBr}{m}$, $a = \frac{v^2}{r} = \left(\frac{qB}{m}\right)^2 r \approx 2.1\times 10^{17}$ m s^{-2}

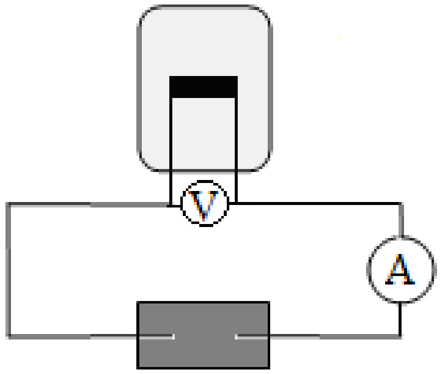
Q7b $\frac{p_\alpha}{p_e} = \frac{q_\alpha B r_\alpha}{q_e B r_e} = \frac{q_\alpha}{q_e}\times\frac{r_\alpha}{r_e} = \frac{2}{1}\times\frac{0.17}{0.017} = 20$

Q8a $V_{drop} = 50000 - 49400 = 600$ V

$P_{loss} = \frac{(V_{drop})^2}{R} = \frac{600^2}{40} = 9000$ W $= 9$ kW

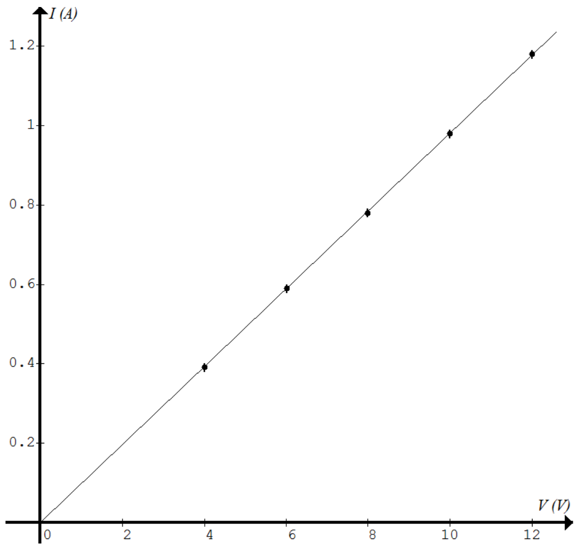
Q8b $\frac{N_{primary}}{N_{secondary}} = \frac{V_{primary}}{V_{secondary}} = \frac{49400}{240} \approx 206$

Q9a



Q9b Voltage across the light globe

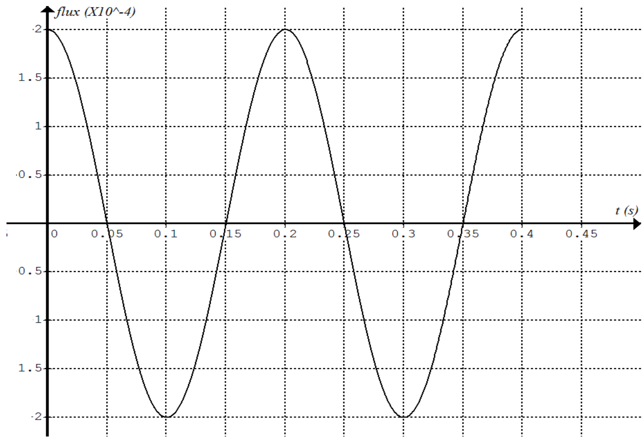
Q9c Enlarge the graph to see the error bars for *I*.



Q9d Yes, a line can be drawn from the origin through the error bars of the data points indicating that the resistance of the light globe remains constant when the voltage across it varies.

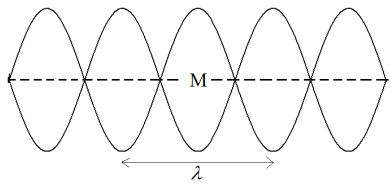
$R \approx \frac{12}{1.2} = 10\ \Omega$

Q10a $\phi_{\max} = 0.020 \times 0.010 = 2.0 \times 10^{-4}$ wb, $T = \frac{1}{f} = 0.20$ s



10b End A is positive after $120°$ turn. At that moment the magnetic flux (into the page) is increasing. To oppose the increase a current is induced flowing from B to A in the coil, providing a magnetic field (out of the page) inside the coil loop.

Q11a



The two particles oscillate in phase at maximum amplitude.

Q11b $v = f\lambda = 5 \times 0.080 = 0.40$ m s^{-1}

Q11c Difference $= 2\lambda - \frac{1}{2}\lambda = \frac{3\lambda}{2} = 0.12$ m

Q11d The fundamental frequency $= \frac{5\text{ Hz}}{5} = 1$ Hz

Q12 The size of the smoke particles is right for diffraction of sunlight at the red end of its spectrum. Diameter of smoke particles $\approx \lambda_{\text{red}}$, .: it passes through the smoke filled air to the observer whilst the other part of the spectrum is scattered to all directions by the smoke particles.

Q13a $\theta_{\text{critical}} = \sin^{-1}\left(\frac{1.30}{1.52}\right) \approx 58.8°$

Q13b Angle of reflection $= 50.5°$

Snell's law: angle of refraction $= \sin^{-1}\left(\frac{1.52 \sin 50.5°}{1.30}\right) \approx 64.4°$

Q14ab Extend the line through the horizontal and vertical axes: Threshold frequency $\approx 5 \times 10^{14}$ Hz is the horizontal axis intercept. The work function $\approx 7.5\rho$, -7.5ρ is the vertical axis intercept.

Q14c Draw a line parallel to the given line and passes through -9ρ on the vertical axis. The threshold frequency $\approx 6 \times 10^{14}$ Hz is given by the axis intercept.

Q14d Planck's constant = gradient of the line $\approx 1.5 \times 10^{-14}$ ρ s

Q15 Two results: (1) The number of electrons emitted varies with the light intensity. (2) The emission and energy of the photoelectrons depends on the frequency of light directed at the metal.
The simple wave model suggests that if more intense light was used the energy of the photoelectrons should be higher.
It also suggests that the frequency of light used should have no effect on the energy or number of electrons emitted.

Q16a $E_K = qV = (1.6 \times 10^{-19})(200) = 3.2 \times 10^{-17}$ J

$$\lambda = \frac{h}{\sqrt{2mE_K}} = \frac{6.63 \times 10^{-34}}{\sqrt{2(9.1 \times 10^{-31})(3.2 \times 10^{-17})}}$$

$= 8.7 \times 10^{-11}$ m $= 8.7 \times 10^{-2}$ nm

Q16b Experiment performed by C. J. Davisson and L. H. Germer: They scattered electrons from the surface of a metal crystal and observed that electrons came off in regular peaks. They interpreted these peaks as a diffraction pattern, and the wavelength of the diffracted electron wave was found to be just that predicted by de Broglie.

Q17a $\lambda = \frac{hc}{E} = \frac{(4.14 \times 10^{-15})(3.0 \times 10^{8})}{({}^{-}1.51 - {}^{-}3.39)} \approx 6.6 \times 10^{-7}$ m $= 660$ nm

Q17b 6 different photons from $n = 4$ (3rd excited state) to $n = 1$ (ground state).

Q17c $p = \frac{h}{\lambda} = \frac{6.63 \times 10^{-34}}{587.5 \times 10^{-9}} \approx 1.13 \times 10^{-27}$ kg m s^{-1}

Q18a Direct light of extremely low intensity (as low as a single photon at a time) through a double-slit over a long period until a pattern of bright and dark bands appears. The pattern is the same as the interference pattern produced by a beam of light through the same double-slit.

Q18b A single photon also shows wave nature. Hence this experiment supports the dual (particle and wave) nature of light.

Q18c Louis de Broglie extended the idea of the dual nature light to matter such as electrons. He assigned a wavelength to an electron of momentum $p = mv$, $\lambda = \frac{h}{p}$. Each electron orbit in an atom, he proposed, is a standing wave. The orbits correspond to circular waves in which the circumference of the orbit equals a whole number of wavelengths, hence the quantised states of the atom.

Please inform itute re mathematical/conceptual errors