Answers to Special Round 2010

1. (a) $t = 0.694s$
   (b) $v_f = 0.780ms^{-1}$
   (c) The stone will touch the ground again after 0.226s.

2. (a) $F = \dfrac{2(M+m)}{M+2m} f_s$
   (b) $F = \dfrac{2(M+m)}{M} f_s$

3. (a) Coordinates of centre of mass $= (16.9cm, 17.3cm)$

   (b) Coordinates of centre of mass $= (16.9cm, 16.9cm)$

4. $\theta = 72.5°$

5. (a) 16.6 *cm* from the end

   (b) Range of frequencies: $424Hz - 457Hz$

6. $\therefore$ The new equilibrium position for the piston is 0.4*H*, the piston dropped by 0.6*H*.

7. (a) $1.7 \times 10^{-2} Vm^{-1}$
   (b) $1.50 \times 10^{-19} C$

8. $R = \dfrac{5+\sqrt{41}}{4}\Omega$

9. (a) $\dfrac{kr^2}{R}\left(\dfrac{2\pi}{3} - \dfrac{\sqrt{3}}{2}\right)$, anti-clockwise

   (b) $B_1 \dfrac{kr^3}{R}\left(\dfrac{2\pi\sqrt{3}}{3} - \dfrac{3}{2}\right)(\text{to the right})$

10. (a) 7 increments

(b) (i) $0.99946c$

(ii) 0.597T

11. (a) $2\times10^{-8}cm$

(b) ~500 collisions (answers between 400 to 1000 acceptable; working should be sensible)

12. (a)

Ground state energy, $E_1 = -\frac{hc}{\lambda} = -8.18eV$

$E_2 = -2.04eV$
$E_3 = -0.904eV$
$E_4 = -0.510eV$
$E_5 = -0.325eV$

(b) For transition from E_3 to E_2, $\Delta E_{3\to2} = 2.04 - 0.904 = 1.14eV$

$\lambda_{3\to2} = 1092nm$

For transition from E_4 to E_2, $\Delta E_{4\to2} = 2.04 - 0.510 = 1.53eV$

$\lambda_{4\to2} = 811nm$

For transition from E_5 to E_2, $\Delta E_{5\to2} = 2.04 - 0.325 = 1.72eV$

$\lambda_{5\to2} = 723nm$

For the short wavelength limit, $\lambda = 609nm$

(c) Using $\frac{1}{\lambda} = R_{\infty}\left[\frac{1}{n_i^2} - \frac{1}{n_f^2}\right]$, for Lyman series, $n_i = 1$

For transition from E_2 to E_1, $\frac{1}{\lambda_{2\to1}} = \left(1.097\times10^7\right)\left[1-\frac{1}{2^2}\right] \Rightarrow \lambda_{2\to1} = 122nm$

$\text{Ratio} = \frac{122}{202.6} = 60\%$

For transition from E_3 to E_1, $\frac{1}{\lambda_{3\to1}} = \left(1.097\times10^7\right)\left[1-\frac{1}{3^2}\right] \Rightarrow \lambda_{3\to1} = 103nm$

$\text{Ratio} = \frac{103}{170.9} = 60\%$

For transition from E_4 to E_1, $\frac{1}{\lambda_{4\to1}} = \left(1.097\times10^7\right)\left[1-\frac{1}{4^2}\right] \Rightarrow \lambda_{4\to1} = 97.2nm$

$\text{Ratio} = \frac{97.2}{162.1} = 60\%$

For transition from E_5 to E_1, $\frac{1}{\lambda_{5\to1}} = \left(1.097\times10^7\right)\left[1-\frac{1}{5^2}\right] \Rightarrow \lambda_{5\to1} = 95.0nm$

$\text{Ratio} = \frac{95.0}{158.3} = 60\%$

For shortest wavelength limit, $\frac{1}{\lambda} = \left(1.097\times10^7\right) \Rightarrow \lambda = 91.2nm$

$\text{Ratio} = \frac{91.2}{152.0} = 60\%$

(d) 0.471c