Part I – A

1. x=(2n+1)π	2. 2A	3. B	4. $\sqrt{\frac{GM}{R_E+h}}-\sqrt{\frac{GM}{R_E+2h}}$	5. $\frac{GMm}{R_E+h}-\frac{GMm}{R_E+2h}$	6. B	7. $\frac{(\rho_{Hg}-\rho)h_2}{\rho}$	8. C
9. f+3	10. 45°	11. $5\omega^3A^2/k$	12. $10\pi\omega^2A^2/k$	13. $2\pi\sqrt{\frac{m(k_1+k_2)}{k_1k_2}}$	14. $2\pi\sqrt{\frac{m}{(k_1+k_2)}}$	15. $20Log\frac{r_2}{r_1}$	16. $-3Gm^2/l$

Part I – B

1. $-3Gm^2/l$	2. $\frac{(\rho_{Hg}-\rho)h_2}{\rho}$	3. $5\omega^3A^2/k$	4. $10\pi\omega^2A^2/k$	5. B	6. C	7. f+3	8. $\sqrt{\frac{GM}{R_E+h}}-\sqrt{\frac{GM}{R_E+2h}}$
9. $\frac{GMm}{R_E+h}-\frac{GMm}{R_E+2h}$	10. B	11. $2\pi\sqrt{\frac{m(k_1+k_2)}{k_1k_2}}$	12. $2\pi\sqrt{\frac{m}{(k_1+k_2)}}$	13. 45°	14. $20Log\frac{r_2}{r_1}$	15. x=(2n+1)π	16. 2A

Part II

1. (a) For the satellite $\sum F = ma \quad \frac{GmM_E}{r^2}=\frac{mv_0^2}{r}$

$$\boxed{v_0=\left(\frac{GM_E}{r}\right)^{1/2}}$$

(b) Conservation of momentum in the forward direction for the exploding satellite:

$$\left(\sum mv\right)_i=\left(\sum mv\right)_f$$

$$5mv_0=4mv_i+m0$$

$$v_i=\frac{5}{4}v_0=\boxed{\frac{5}{4}\left(\frac{GM_E}{r}\right)^{1/2}}$$

(c) With velocity perpendicular to radius, the orbiting fragment is at perigee. Its apogee distance and speed are related to r and v_i by $4mrv_i = 4mr_f v_f$ and $\frac{1}{2}4mv_i^2 - \frac{GM_E 4m}{r} = \frac{1}{2}4mv_f^2 - \frac{GM_E 4m}{r_f}$.

Substituting $v_f = \frac{v_i r}{r_f}$ we have $\frac{1}{2}v_i^2 - \frac{GM_E}{r} = \frac{1}{2}\frac{v_i^2 r^2}{r_f^2} - \frac{GM_E}{r_f}$. Further, substituting $v_i^2 = \frac{25}{16}\frac{GM_E}{r}$ gives

$$\frac{25}{32}\frac{GM_E}{r} - \frac{GM_E}{r} = \frac{25}{32}\frac{GM_E r}{r_f^2} - \frac{GM_E}{r_f}$$
$$\frac{-7}{32r} = \frac{25r}{32r_f^2} - \frac{1}{r_f}$$

Clearing of fractions, $-7r_f^2 = 25r^2 - 32rr_f$ or $7\left(\frac{r_f}{r}\right)^2 - 32\left(\frac{r_f}{r}\right) + 25 = 0$ giving

$\frac{r_f}{r} = \frac{+32 \pm \sqrt{32^2 - 4(7)(25)}}{14} = \frac{50}{14}$ or $\frac{14}{14}$. The latter root describes the starting point. The outer end of the orbit has $\frac{r_f}{r} = \frac{25}{7}$; $\boxed{r_f = \frac{25r}{7}}$.

2. (a) Suppose the flow is very slow: $\left(P + \frac{1}{2}\rho v^2 + \rho g y\right)_{\text{river}} = \left(P + \frac{1}{2}\rho v^2 + \rho g y\right)_{\text{rim}}$

$$P + 0 + \rho g 500 = P_0 + 0 + \rho g 1500$$
$$ans: P = P_0 + 10000\rho$$

(b) The volume flow rate is

$$10\frac{m^3}{s} = \pi\frac{d^2 v}{4}, \rightarrow ans: v = \frac{40}{\pi d^2}$$

(c) Imagine the pressure as applied to stationary water at the bottom of the pipe:

$$P + 0 + \rho g 500 = P_0 + \frac{1}{2}\rho v^2 + \rho g 1500$$
$$P = P_0 + 10000\rho + \frac{1}{2}\rho\left(\frac{40}{\pi d^2}\right)^2 \rightarrow ans = \frac{1}{2}\rho\left(\frac{40}{\pi d^2}\right)^2$$

3. (a) $F = -2T\frac{y}{\sqrt{L^2 + y^2}} \approx -2T\frac{y}{L}$

(b) $F = ma \to -2T\,\dfrac{y}{L} = m\dfrac{d^2y}{dt^2} \to -\dfrac{2T}{mL}y = m\dfrac{d^2y}{dt^2} \to \omega = \sqrt{\dfrac{2T}{mL}}$

4. $I = \dfrac{1}{2}\rho\omega^2 s_{\max}^2 v = 2\pi^2\rho v f^2 s_{\max}^2$

(a) $\dfrac{I_2}{I_1} = \dfrac{2\pi^2\rho v f'^2 s_{\max}^2}{2\pi^2\rho v f^2 s_{\max}^2} \to I_2 = \dfrac{f'^2}{f^2} I_1$

(b) $\dfrac{I_2}{I_1} = \dfrac{2\pi^2\rho v (f/2)^2 (2s_{\max})^2}{2\pi^2\rho v f^2 s_{\max}^2} \to I_2 = I_1$