MCQ's

1(d), 2(e), 3(c), 4(d), 5(e), 6(b), 7(b), 8(a), 9(c), 10(c), 11(a), 12(a), 13(d), 14(e), 15(a), 16(b), 17(a), 18(b), 19(d), 20(a)

Open Q's

Q1 **(5 points)**

The work done by the electric field is proportional to the vertical displacement of the particle in the E-field. In case-B the magnetic field force has an upwards component so the vertical displacement of the particle is less than in case-A. Then, follow the energy conservation, we have $v_a > v_b$.

Q2. **(15 points)**

Solution:

$PV = NRT$, (2 points)

$NRT_1 = P_0 LS$ (2 points)

$(P_0 + d\rho)(\frac{3}{4}L - d)S = P_0 LS$ (3 points)

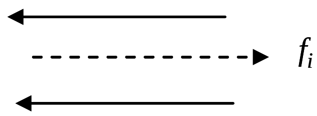
$(P_0 - d\rho)(L - d)S = P_0 LS / 2$ (3 points)

Solving the two equations, $\rho = 4\sqrt{3}P_0 / L$, and $d = \frac{1}{4}(2-\sqrt{3})L$ (5 points)

Q3. **(15 points)**

Solution:

As shown in figure below, the i[th] page of book *B* subjects two frictional forces, $f_i^{'}$ (the page above i[th] page) and $f_i^{''}$ (the page below i[th] page)



The force required to pull out the i[th] page from book *A* is given by $f_i = f_i^{'} + f_i^{''}$ (3 points)

Since $f_i^{'} = 2(i-1)\mu mg$ and $f_i^{''} = (2i-1)\mu mg$, (3 points for each equation) thus we have

$f_i = (4i - 3)\mu mg$. .... (3 points)

From equation 1, when $i = 1, f_1 = 1\mu mg$; when $i = 200, f_{200} = 797\ \mu mg$

Summing up all the forces, $F = f_1 + f_2 + .. f_{200} = \frac{f_1 + f_{200}}{2} \times 200 = 79800\mu mg$

$\therefore F = 79800 \times 0.3 \times 0.005 \times 9.8 = 1173N$ (3 points)

Q4. **(15 points)**

Solution:

The spaceship moves under the influence of the Earth's gravity, given by

$F = G\frac{MM_E}{R_1^2}$ (2 points)

The net force acting on the spaceship is $G\frac{MM_E}{R_1^2} - T = MR_1\omega^2$ ....(1) (2 points)

where T is the tension of the communication cable. Similarly, for the astronaut,

$G\frac{mM_E}{R_2^2} + T = mR_2\omega^2$ ....(2) (2 points)

Equation ω from (1) and (2), we obtain

$\frac{1}{MR_1}(G\frac{MM_E}{R_1^2} - T) = \frac{1}{mR_2}(G\frac{mM_E}{R_2^2} + T)$ ...(3) (3 points)

From equation (3), we can easily find the tension T:

$T = G(\frac{mM}{MR_1 + mR_2})(\frac{R_2^3 - R_1^3}{R_1^2 R_2^2})M_E$ (2 points)

Using $R_1 \approx R_2 \approx R$; $R_2^3 - R_1^3 = (R_2 - R_1)(R_2^2 + R_1R_2 + R_1^2) \approx 3R^2L$

We can now rewrite T in the following form:

$$T = 3\left(\frac{mM}{m+M}\right)\cdot L\cdot\frac{GM_E}{R^3} = 3\left(\frac{L}{R}\right)\left(\frac{mM}{m+M}\right)g \text{ ; where } g = \frac{GM_E}{R^2}$$ (2 points)

Since $M >> m$, we can write an even simpler formula as an estimate:

$$T = 3\frac{mLg}{R} = 3\frac{(110)(9.8)(100)}{6400\times 10^3} \approx 0.05N$$ (2 points)

5. **(10 points)**

Solution:

a) $\omega_\alpha = \frac{\sqrt{1 - v^2/c^2}}{1 + \frac{v\cos\theta}{c}}\omega \simeq \left(1 - \frac{v\cos\theta}{c}\right)\omega$

For $\theta = 0$, $\omega_\alpha = (1 - v/c)\omega$,

For $\theta = \pi$, $\omega_\alpha = (1 + v/c)\omega$. (2 points)

b) $F = \Delta Np/t$, (2 points)

$\frac{\Delta N}{t} = nA\left(\frac{1}{(\omega_\alpha^{(1)} - \omega_0)^2 + \gamma^2} - \frac{1}{(\omega_\alpha^{(2)} - \omega_0)^2 + \gamma^2}\right)$,(2 points)

$F = nA\left(\frac{1}{(\omega_\alpha^{(1)} - \omega_0)^2 + \gamma^2} - \frac{1}{(\omega_\alpha^{(2)} - \omega_0)^2 + \gamma^2}\right)\frac{h\omega}{2\pi c}$.(2 points)

c) $F = nA\frac{h\omega}{\pi c^2}\frac{2\omega(\omega - \omega_0)}{\left(\gamma^2 + (\omega - \omega_0)^2\right)^2}v$, hence, $\beta = nA\frac{h\omega}{\pi c^2}\frac{2\omega(\omega - \omega_0)}{\left(\gamma^2 + (\omega - \omega_0)^2\right)^2}$.(2 points)