1. A) F Depends on the indices of refraction.
   B) F sound waves are longitudinal
   C) T $v = c/n$
   D) T if traveling in opp. direction, standing waves are formed. No destructive interference.
   E) T
   F) T $v = \sqrt{\tau/\mu}$ depends on tension & mass per unit length.

2. $v = \sqrt{\tau/\mu}$ & $v = \omega/k$

   A) $v = 10/4 = 2.5\ m/s$ ← must have different tension
   B) $v = 20/10 = 2\ m/s$
   C) $v = 4/2 = 2\ m/s$
   D) $v = 16/8 = 2\ m/s$
   E) $v = 12/6 = 2\ m/s$

   (A)

3. I - net phase shift of π (inverted relative to incoming)
   U - Unchanged
   N - no pulse

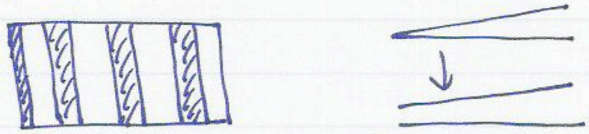
   IIUNI

4. NUUUU

5. layer 1 $N = 4.7$
   layer 2 $N = 3.2$
   layer 3 $N = 5.3$ ← most compressed ⇒ highest n

   2, 1, 3

   (E)

6. 

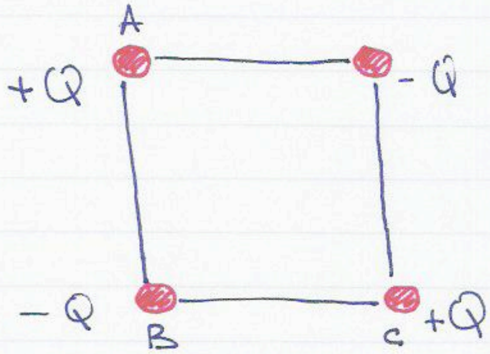
   left edge slowly lifted.

As the left edge is lifted the plates become more parallel. Dark bands will spread out, disappearing off the left edge. (Right edge thickness remains unchanged.)

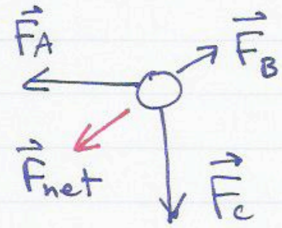
(D)

7. electrons do not flow very easily (C)

8.



FBD for charge at upper right corner



(C)

9. repulsive force ⇒ equal charges - A, C not possible.

B, D or E

B : $\frac{k|q_1||q_2|}{r^2} = \frac{7kq^2}{L^2}$

D : $\frac{k|q_1||q_2|}{r^2} = \frac{4kq^2}{L^2}$

E : $\frac{k|q_1||q_2|}{r^2} = \frac{8kq^2}{L^2}$ ← (E)

10. $\frac{\Delta L}{\lambda} = \frac{\phi}{2\pi} \Rightarrow \Delta L = \frac{\phi}{2\pi} \cdot \lambda$

$v = f\lambda \Rightarrow \lambda = \frac{v}{f}$

$\boxed{\Delta L = \frac{\phi}{2\pi}\frac{v}{f}}$

$\Delta L = \frac{\phi}{2\pi} \cdot \frac{v}{f} = \frac{\pi/5}{2\pi} \cdot \frac{265}{595} = \underline{0.0445\ m}$ (G)

11. $I = \frac{P}{4\pi r^2}$ same power, so $I_1 4\pi r_1^2 = I_2 4\pi r_2^2$

$\therefore \boxed{\frac{I_2}{I_1} = \frac{r_1^2}{r_2^2}}$

$\frac{I_2}{I_1} = \frac{(3.2)^2}{(16.64)^2} = 0.03698$ (B)

12. $\beta_1 = (10dB)\log\left(\frac{I_1}{I_0}\right)$ $\beta_2 = (10dB)\log\left(\frac{I_2}{I_0}\right)$

$\therefore \quad \beta_2 - \beta_1 = (10dB)\log\left(\frac{I_2}{I_1}\right)$

$\Rightarrow \log\left(\frac{I_2}{I_1}\right) = \frac{\beta_2-\beta_1}{(10dB)} \Rightarrow \boxed{\frac{I_2}{I_1} = 10^{\left(\frac{\beta_2-\beta_1}{10}\right)}}$

$\frac{I_2}{I_1} = 10^{\left(\frac{8.19}{10}\right)} = 10^{0.819} = \underline{6.59}$ (C)

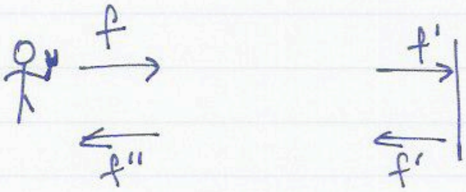
13.

$f' = \left(\frac{V - V_D}{V - V_s}\right) f$

f' was given in the problem. We want f

$\therefore \quad \boxed{f = \left(\frac{V - V_s}{V - V_D}\right) f'} = \left(\frac{340-34}{340-18}\right) 392 = \underline{372.5 \text{ Hz}}$

14.



student is the "source" for onward trip and the "detector" for return trip.

$f' = \left(\frac{V}{V-V_s}\right) f$ (onward trip)

$f'' = \left(\frac{V+V_D}{V}\right) f'$ (return trip)

$\Rightarrow f'' = \left(\frac{V+V_D}{V}\right)\left(\frac{V}{V-V_s}\right) f = \left(\frac{V+V_p}{V-V_p}\right) f$ $V_D = V_s = V_p$ (speed of physics student)

$f''(V - V_p) = f(V + V_p)$

$\Rightarrow f''V - fV = fV_p + f''V_p \Rightarrow (f'' - f)V = V_p(f'' + f)$

$\Rightarrow \boxed{V_p = \frac{(f''-f)}{(f''+f)} V} = \frac{(5)(343)}{(405+400)} = \underline{2.13 \text{ m/s}}$ (D)

15. $f = \frac{n}{2L}\sqrt{\frac{\tau_1}{\mu}} \Rightarrow n = \frac{2Lf}{\sqrt{\tau_1}}\sqrt{\mu}$ — ①

$f = \frac{n-1}{2L}\sqrt{\frac{\tau_2}{\mu}} \Rightarrow n-1 = \frac{2Lf}{\sqrt{\tau_1}}\sqrt{\mu}$ — ②

substitute ① in ②

$$\frac{2Lf}{\sqrt{\tau_1}}\sqrt{\mu} - 1 = \frac{2Lf}{\sqrt{\tau_2}}\sqrt{\mu}$$

$$\Rightarrow \sqrt{\mu} = \frac{1}{2Lf\left(\frac{1}{\sqrt{\tau_1}} - \frac{1}{\sqrt{\tau_2}}\right)}$$

or $$\boxed{\mu = \frac{1}{4L^2f^2\left(\frac{1}{\sqrt{\tau_1}} - \frac{1}{\sqrt{\tau_2}}\right)^2}} = 0.002388\ \frac{kg}{m}$$

(C)

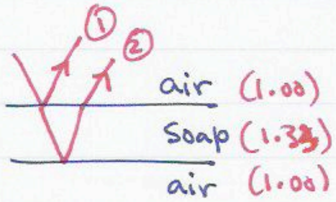
16. $f = \frac{v}{4L}n \underset{(n=1)}{\Rightarrow} L = \frac{v}{4f} = \frac{343}{(4)(138.1)} = 0.6209\ m$

$f = \frac{v}{2L}n \underset{(n=1)}{\Rightarrow} f = \frac{v}{2L} = \frac{343}{(2)(0.6209)} = \underline{276.2\ Hz}$

17. the $m=2$ bright falls at $\theta = 2.5°$

$d\sin\theta = m\lambda \Rightarrow \boxed{d = \frac{m\lambda}{\sin\theta}} = \frac{(2)(480\times10^{-9})}{\sin(2.5°)} = \underline{2.20\times10^{-2}\ mm}$

(E)

18. 

net phase shift of π ? YES

so: $2L = (m+\frac{1}{2})\lambda_n$ — bright

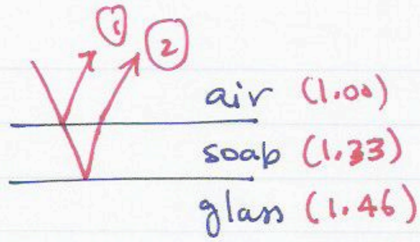
$2L = m\lambda_n$ — dark

we want

$$2L = (m+\tfrac{1}{2})\frac{\lambda}{n} \quad \text{with } m=0$$

(B)

$\therefore\ 2L = \frac{1}{2}\frac{\lambda}{n} \Rightarrow \boxed{L = \frac{\lambda}{4n}} = \frac{674\times10^{-9}}{(4)(1.33)} = \underline{126.7\ nm}$

19. 

net phase shift of π ? NO

so: $2L = m\lambda_n$ — bright

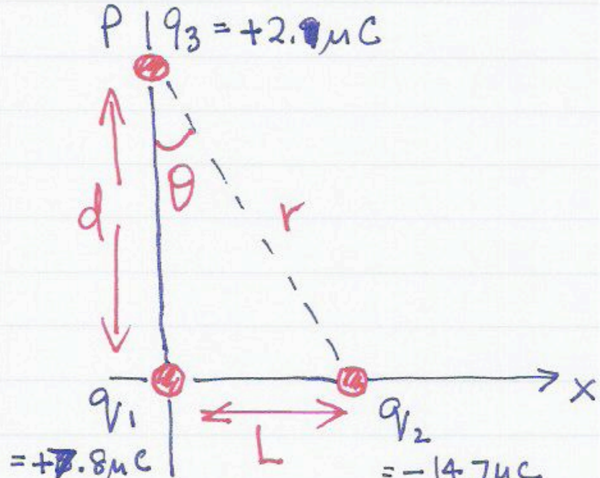
$2L = (m+\frac{1}{2})\lambda_n$ — dark

we want

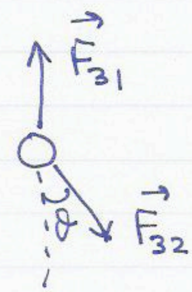
$$2L = m\frac{\lambda}{n} \Rightarrow \lambda = \frac{2nL}{m}$$

longest wavelength $\Rightarrow m=1$ $\therefore$ $\boxed{\lambda = 2nL}$ (B)

$$\lambda = (2)(1.33)(551) = \underline{1465.7\,nm}$$

20. 

FBD for the third charge



$$F_{3x} = F_{31x} + F_{32x} = 0 + \frac{k|q_3||q_2|}{r^2}\sin\theta = \frac{k|q_3||q_2|L}{r^3}$$

$$F_{3y} = F_{31y} + F_{32y} = \frac{k|q_3||q_1|}{d^2} - \frac{k|q_3||q_2|}{r^2}\cos\theta$$

$$= \frac{k|q_3||q_1|}{d^2} - \frac{k|q_3||q_2|\,d}{r^3}$$

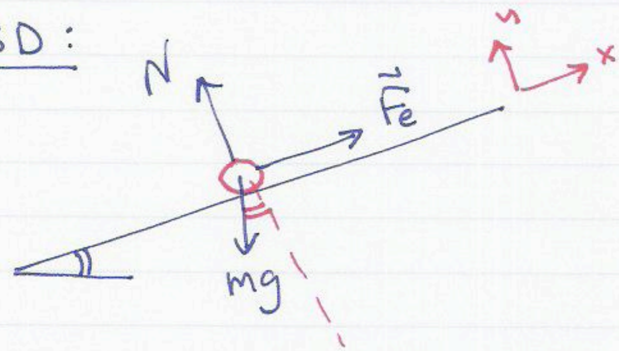
$$F_{3x} = \frac{(8.99\times10^9)(2.1\times10^{-6})(14.7\times10^{-6})(5.4)}{(5.4^2+10.1^2)^{3/2}} = 0.00099755\,N$$

$$F_{3y} = \frac{(8.99\times10^9)(2.1\times10^{-6})(7.8\times10^{-6})}{(10.1)^2} - \frac{(8.99\times10^9)(2.1\times10^{-6})(14.7\times10^{-6})(10.1)}{(5.4^2+10.1^2)^{3/2}}$$

$$= -0.0004222568\,N$$

$$F_3 = \sqrt{F_{3x}^2 + F_{3y}^2} = \underline{1.083\times10^{-3}\,N}$$ (A)

21. FBD:



place x-axis along the inclined plane

$$\Sigma F_x = 0 \Rightarrow \frac{k|q_1||q_2|}{l^2} - mg\sin\theta = 0$$

$$\Rightarrow \boxed{\sin\theta = \frac{k|q_1||q_2|}{mgl^2}}$$

$$\theta = \sin^{-1}\left(\frac{k|q_1||q_2|}{mgl^2}\right) = \sin^{-1}\left[\frac{(8.99\times10^9)(1.8\times10^{-7})(3.75\times10^{-8})}{(1.5\times10^{-3})(9.8)(0.108)^2}\right]$$

$$= \underline{20.73°} \quad \text{(A)}$$

22. $-x$ direction $\Rightarrow$ relative sign $+$

$\mu = 0.006$ kg/m $\quad \tau = 13.2$ N

$$\Rightarrow v = \sqrt{\tau/\mu} = 46.9 \text{ m/s}$$

$$k = \frac{2\pi}{\lambda} = \frac{2\pi}{2.0} = 3.14 \text{ m}^{-1}$$

$$\omega = vk = 147.4 \text{ s}^{-1}$$

amplitude $= y_m = 0.012$ m

$$\boxed{y_M = 0.012 \sin(3.14x + 147.4t)}$$