SOLUTION FOR PHYSICS 4

(Midterm)

April 2013

1)

a) The frequency detected by an observer riding on submarine B as the subs approach each other:

$$f_B = \frac{v + v_B}{v - v_A} f_A = \frac{1533 + 9}{1533 - 8} . 1400 = 1415{,}6\ (Hz)$$

b) The frequency detected by an observer riding on submarine B as the subs recede from each other:

$$f_B = \frac{v - v_B}{v + v_A} f_A = \frac{1533 - 9}{1533 + 8} . 1400 = 1384{,}55\ (Hz)$$

2)

We have: Two adjacent natural frequencies of an organ pipe:

$$f_{n_2} - f_{n1} = \frac{n_2 v}{4L} - \frac{n_1 v}{4L} = (n_2 - n_1)\frac{v}{4L} = \frac{2v}{4L} = 2f_1 = 650 - 550 = 100$$

(Since $n_2 = n_1 + 2$)

$\Rightarrow f_1 = 50$ (Hz)

The length of the pipe:

$$L = \frac{v}{4f_1} = \frac{340}{4.50} = 1.7\ (m)$$

3)

We have:

$$\frac{I}{I_{max}} = \cos^2\left(\frac{\pi dy}{L\lambda}\right) = \cos^2\left(\frac{\pi dy}{L.\,600\,.\,10^{-9}}\right) = 0{,}81 \Rightarrow \frac{\pi dy}{L.600\,.\,10^{-9}} = 0{,}451 \Rightarrow \frac{dy}{L} = 8{,}613\,.\,10^{-8}$$

When the relative intensity at same location to 64% of the maximum intensity:

$$\frac{I}{I_{max}} = \cos^2\left(\frac{\pi dy}{Lc'}\right) = 64\%$$

$$\Leftrightarrow \frac{\pi dy}{L\lambda'} = 0{,}6435$$

$$\Leftrightarrow \frac{\pi}{\lambda'} .\ 8{,}613\,.\,10^{-8} = 0{,}6435$$

$\Rightarrow \lambda' = 0{,}42\ (\mu m)$

4)

a) The condition for first constructive interference of red bands

$$2nt_r = \left(1 + \frac{1}{2}\right)\lambda_r \Leftrightarrow 2\,.\,1{,}33\,.\,t_r = 1{,}5\,.\,680\,.\,10^{-9} \Rightarrow t_r = 3{,}834\,.\,10^{-7}(m)$$

The condition for first constructive interference of violet bands

$$2nt_v = \left(1 + \frac{1}{2}\right)\lambda_v \Leftrightarrow 2.1{,}33.t_v = 1{,}5\ .\ 420\ .\ 10^{-9} \Rightarrow t_v = 2{,}368\ .\ 10^{-7}(m)$$

We have: $\frac{x_r}{x_v} = \frac{t_r}{t_v} \Leftrightarrow \frac{x_r}{3} = \frac{3{,}834}{2{,}368} \Rightarrow x_r = 4{,}857\ (cm)$

b) The film thickness at the position of

+ Violet: $2nt_v = m\lambda_v \Rightarrow t_v = \frac{m\lambda_v}{2n}\ \{0{,}157\ (\mu m); 0{,}314(\mu m); 0{,}471(\mu m); \dots.\}$

+ Red: $2nt_r = m\lambda_r \Rightarrow t_v = \frac{m\lambda_r}{2n}\ \{0,\ 257(\mu m); 0{,}511(\mu m); 0{,}771(\mu m); \dots.\}$

c) The wedge angle of the film

$$sin\theta = \frac{t_v}{x_v} = \frac{2{,}368\ .\ 10^{-7}}{3\ .\ 10^{-2}} \Rightarrow \theta \approx 7{,}893.10^{-6}(rad)$$

June 2013

1)

a) The fundamental frequency of the pipe: $f_1 = \frac{v}{2L} = 594$

$\Rightarrow$ The length of the pipe:

$$L = \frac{v}{2f_1} = \frac{348}{2.594} \approx 0{,}3\ (m)$$

In case that one end is now closed:

b) The wavelength:

$$\lambda = \frac{4L}{n} = \frac{4.0{,}3}{n} = \frac{6}{5n}\ (n = 1{,}3{,}5, \dots)$$

c) The new fundamental frequency:

$$f_1 = \frac{v}{4L} = \frac{348}{4.\ 0{,}3} = 290\ (Hz)$$

2)

According to the Doppler's effect, we have:

$$f' = \frac{v - v_0}{v} f = \frac{344 - v_0}{344}\ .520 = 490$$

⇨ $v_0 = 19{,}84$ (m/s)

3)

The position of the first-order bright fringe of red light interference:

$$y_r = k_r \frac{L}{d}\lambda_r = \frac{\lambda_r L}{d}$$

The position of the first-order bright fringe of blue light interference:

$$y_b = k_b \frac{L}{d}\lambda_b = \frac{\lambda_b L}{d}$$

Therefore: The distance between the first-order bright fringes for the two wavelength:

$$d = y_r - y_b = (\lambda_r - \lambda_b)\frac{L}{d} = (660\ - 470).10^{-9}\frac{5}{0,3.10^{-3}} \approx 3,16\ (mm)$$

4)

a) The angular position: $sin\theta\ = m\frac{\lambda}{a}$

We have:

$$-1 \le sin\theta \le 1$$

$$\Leftrightarrow -1 \le m\frac{\lambda}{a} \le 1 \text{ ó } -\frac{a}{\lambda} \le m \le \frac{a}{\lambda} \Leftrightarrow -113,84 \le m \le 113,84$$

Since m is an integer number ⇨ m = {-113,-112,….,112,113} (not including m = 0)

Therefore: On a very large screen, there are totally 226 dark fringes

b) The most distant dark fringe from the central bright fringe ⇨ m = 113

Therefore:

$$sin\theta\ = m\frac{\lambda}{a} = 113\frac{\lambda}{a} = \frac{113\ .\ 585\ .\ 10^{-9}}{0,0666\ .\ 10^{-3}} = 0,99256$$

$\Rightarrow \theta \approx 83^0$

5)

a) We have: This lens is converging $\Rightarrow f\ = 12,5\ cm$

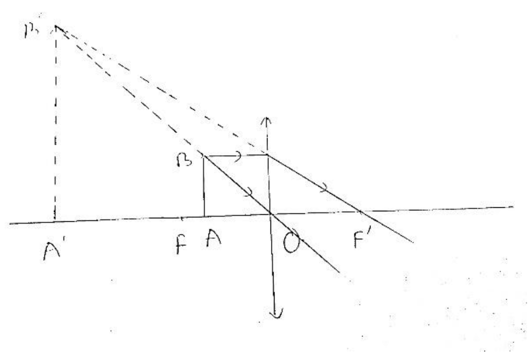
Virtual image : $q\ = -30\ cm$

$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$$

$$\Leftrightarrow \frac{1}{12,5} = \frac{1}{p} + \frac{1}{-30} \text{ ð } p = 8,82\ (cm)$$

The magnification: $M\ = \frac{h'}{h} = -\frac{q}{p} = \frac{30}{8,82} = 3,4$

Conclusion: The image is upright



July 2014

1)

a) The fundamental frequency:

$$f_1 = \frac{v}{4L} = \frac{348}{4.\ 2,4\ .\ 10^{-2}} = 3625\ Hz$$

The wavelength: $\lambda = \frac{4L}{n} = \frac{4.2,4.10^{-2}}{n} = \frac{0,096}{n}\ (n = 1,3,5,..)$

Since: $20 \leq\ f_1 \leq 20000 \Rightarrow$ This sound is audible

b) We have: Normal human can hear between 20 Hz and 20000 Hz

$$20 \leq nf_1 \leq 20000$$
$$\Leftrightarrow 20 \leq 3625n \leq 20000$$
$$\Leftrightarrow 5,5.10^{-3} \leq n \leq 5.517$$

Since n is an odd number => n = {1,3,5}

Therefore: The highest audible harmonic of this person's canal is the fifth harmonic

$$f_5 = \frac{5v}{4L} = \frac{5.348}{4.2,4.10^{-2}} = 18125\ (Hz)$$

2)

The wavelength: $\lambda = \frac{v}{f} = \frac{343}{688} = 0,4985(m)$

For the constructive interference : $\delta = d_1 - d_2 = k\lambda$

Since $d_1 + d_2 = AB \Rightarrow d_2 = AB\ - d_1$

Therefore: $d_1 = \frac{AB}{2} + \frac{k\lambda}{2}$

For the destructive interference : $\delta = d_1' - d_2' = \left(k + \frac{1}{2}\right)\lambda$

Since $d_1' + d_2' = AB \Rightarrow d_2' = AB\ - d_1'$

Therefore: $d_1' = \frac{AB}{2} + \left(k + \frac{1}{2}\right)\frac{\lambda}{2}$

The distance between constructive interference point and destructive interference point

$$\Delta d = d_1' - d_1 = \frac{AB}{2} + \left(k + \frac{1}{2}\right)\frac{\lambda}{2} - \frac{AB}{2} - \frac{k\lambda}{2} = \frac{\lambda}{4} = 0,1246\ (m)$$

Conclusion: You must walk 0,1246m toward speaker B to move to a point of destructive interference

3)

The angular position of first diffraction minima:

$$sin\theta = \frac{\lambda}{a}$$

Since $\theta = 90^0 \Rightarrow sin90^0 = \frac{\lambda}{a} = 1$

⇨ $a = \lambda = 580\ (nm)$

Conclusion: When $a = \lambda$, the central maximum completely fills the screen ⇨ Cannot see the fringe pattern

4)

We have: 15 fringes per centimeter

The distance between each fringe: $d = \frac{1cm}{Number\ of\ fringes} = \frac{10^{-2}}{15} = \frac{1}{1500}(m)$

The thickness of an abitrary bright fringe

$$2nt_1 = \left(m + \frac{1}{2}\right)\lambda$$

The thickness of the next bright fringe

$$2nt_2 = \left(m + 1 + \frac{1}{2}\right)\lambda$$

Therefore:

$$2n\Delta t = \left(m + 1 + \frac{1}{2}\right)\lambda - \left(m + \frac{1}{2}\right)\lambda = \lambda \Rightarrow \Delta t = \frac{\lambda}{2n} = \frac{546\ .\ 10^{-9}}{2}$$
$$= 273.10^{-9}(m)$$

The angle of the wedge:

$$sin\theta = \frac{\Delta t}{d} = \frac{273.10^{-9}}{\frac{1}{1500}} = 4{,}095.10^{-4} \Rightarrow \theta \approx 0{,}023^0$$

5)

The condition for bright fringes of interference:

$$dsin\theta = k\lambda ⇨ sin\theta = \frac{k\lambda}{d}$$

We have:

$$-1 \le sin\theta \le 1$$

$$⬄ \frac{-d}{\lambda} \le k \le \frac{d}{\lambda} ⬄ -19{,}8 \le k \le 19{,}8$$

Since k is an integer number ⇨ $k = \{-19, -18, \dots, 18, 19\}$

Conclusion: On a very large screen, there are totally 39 bright fringes that can be observed

b) The most distant bright fringe ⇨ $k = 19$

Therefore:

$$sin\theta = k\frac{\lambda}{d} = 19\frac{\lambda}{d} = \frac{19\ .\ 585\ .\ 10^{-9}}{0{,}0116\ .\ 10^{-3}} = 0{,}99256$$

$\Rightarrow \theta \approx 73{,}37^0$

July 2017

1)

a) According to the Doppler effect, when the train approaches the crossing

$$f' = \frac{v}{v - v_s}f = \frac{348}{348 - 20}.\ 440 = 466{,}82\ (Hz)$$

b) According to the Doppler effect, when the train has passed the crossing

$$f' = \frac{v}{v + v_s}f = \frac{348}{348 + 20}.440 = 416{,}08\ (Hz)$$

2)

The position of second-order maximum of blue light interference:

$$y_b = 2\frac{L}{d}\lambda_b$$

The position of minimum of another visible light interference:

$$y' = \left(k + \frac{1}{2}\right)\frac{L}{d}\lambda'$$

Since it locates at the same location of second-order maximum of blue light interference:

$$y' = y_b \Leftrightarrow \left(k + \frac{1}{2}\right)\lambda' = 2\lambda_b = 2.467 = 934 \Rightarrow \lambda' = \frac{934}{(k + \frac{1}{2})}$$

We have: $380 \le \lambda' \le 760 \Rightarrow 380 \le \frac{934}{\left(k+\frac{1}{2}\right)} \le 760 \Leftrightarrow 0{,}72 \le k \le 1{,}95$

$\Rightarrow k = 1$ (k is an interger)

Therefore: The wavelength of the visible light: $\lambda' = \frac{934}{(k+\frac{1}{2})} = \frac{934}{1+\frac{1}{2}} = 622{,}67\ (nm)$

Conclusion: That light is orange light

3)

We have: 15 fringes per centimeter

The distance between each fringe: $d = \frac{1cm}{Number\ of\ fringes} = \frac{10^{-2}}{15} = \frac{1}{1500}(m)$

The thickness of an abitrary bright fringe

$$2nt_1 = \left(m + \frac{1}{2}\right)\lambda$$

The thickness of the next bright fringe

$$2nt_2 = \left(m + 1 + \frac{1}{2}\right)\lambda$$

Therefore:

$$2n\Delta t = \left(m + 1 + \frac{1}{2}\right)\lambda - \left(m + \frac{1}{2}\right)\lambda = \lambda \Rightarrow \Delta t = \frac{\lambda}{2n} = \frac{546\,.\,10^{-9}}{2}$$
$$= 273.10^{-9}(m)$$

The angle of the wedge:

$$sin\theta = \frac{\Delta t}{d} = \frac{273.10^{-9}}{\frac{1}{1500}} = 4{,}095.10^{-4} \Rightarrow \theta \approx 0{,}023^0$$

4)

The grating spacing: $d = \frac{1cm}{Number\ of\ grooves} = \frac{10^{-2}}{5310} \approx 1{,}88(\mu m)$

The condition for the first order pricipal maxima of diffraction:

$$dsin\theta = \lambda$$

We have: $sin\theta \sim tan\theta = \frac{y}{L}$

Therefore:

$$d\frac{y}{L} = \lambda$$

⇨ $\lambda = d\frac{y}{L} = \frac{1{,}88\,.\,10^{-6}\,.\,0{,}488}{1{,}72} = 5{,}343\,.\,10^{-7}(m)$

2018

1)

a) When the car is behind the train, the frequency that the driver from the car observes from the train:

$$f_c{}' = \frac{v + v_c}{v + v_t}f_t = \frac{347 + 40}{347 + 20}.320 = 337{,}44\ (Hz)$$

b) When the car is in front of the train, the frequency that the train passenger observes from the car:

$$f_t{}' = \frac{v + v_t}{v + v_c}f_c = \frac{347 + 20}{347 + 40}.510 = 483{,}64\ (Hz)$$

2)

The two reflected waves from the line of contact are in phase (they both undergo the same phase shift), so the line of contact is at a bright fringe.

Condition for constructive interference:

$$2nt = m\lambda$$

=> $t = \frac{m\lambda}{2n}$

We have: $\frac{x}{t} = \frac{l}{h} \Rightarrow x = \frac{tl}{h} = \frac{m\lambda l}{2nh}$

$\Rightarrow x = \frac{m.500.10^{-9}.10.10^{-2}}{2.1{,}5.0{,}02.10^{-3}} = 0{,}833m\ (mm)$

$\Rightarrow x = 0{,}833\ (mm); 1{,}666\ (mm); 2{,}499\ (mm);$ ....

3)

a) The condition for maximum intensity:

$$\delta = d_1 - d_2 \approx 2dsin\theta = m\lambda$$

The first-order diffraction maximum:

$$2dsin\theta = \lambda$$

$$\Leftrightarrow d = \frac{\lambda}{2sin\theta} = \frac{0{,}154\,.\,10^{-9}}{2\,.\,sin34{,}5^{0}} = 0{,}1359\ (nm)$$

Because of the extremely small spacing d, it requires shorter wavelength (in X-rays) to observe diffraction pattern and determine the crystal's structure.

b) We have: $2dsin\theta = m\lambda \Rightarrow sin\theta = \frac{m\lambda}{2d}$

Condition for the incident angle:

$$0 \leq sin\theta \leq 1$$

$$\Leftrightarrow 0 \leq \frac{m\lambda}{2d} \leq 1 \Leftrightarrow \frac{-2d}{\lambda} \leq m \leq \frac{2d}{\lambda} ó\ 0 \leq m \leq 1{,}76 \Rightarrow$$

$$m = 1\ (Since\ m\ is\ an\ integer\ number)$$

Conclusion: There is only the interference maxima from these planes at $34{,}5^{0}$

4)

a) We have: Thin-lens equation for lens 1:

$$\frac{1}{f_1} = \frac{1}{p_1} + \frac{1}{q_1}$$

$$\Leftrightarrow \frac{1}{40} = \frac{1}{50} + \frac{1}{q_1} \Rightarrow q_1 = 200\ (cm)$$

Since $q_1 > 0 \Rightarrow$ This image is real

b) The distance between lens 1 and lens 2:

$$d = q_1 + p_2 = 200 + p_2 = 300 \Rightarrow p_2 = 100\ (cm)$$

Thin-lens equation for lens 2:

$$\frac{1}{f_2} = \frac{1}{p_2} + \frac{1}{q_2}$$

$$\Leftrightarrow \frac{1}{60} = \frac{1}{100} + \frac{1}{q_2} \Rightarrow q_2 = 150\ (cm)$$

April 2018

1)

a) The frequency of the sound measured by a stationary observer standing at the canyon wall

$$f_w = \frac{v}{v + v_a} f_a = \frac{343}{343 + 31{,}3}.\ 400 = 366{,}55\ (Hz)$$

b) The frequency of the reflected sound from the ambulance's siren as heard by the injured rock climber in the ambulance:

$$f_i = \frac{v - v_a}{v} f_w = \frac{343 - 31{,}3}{343}.366{,}55 = 333{,}1\ (Hz)$$

2)

We have: $\beta_1 - \beta_2 = 10log\frac{I_1}{I_0} - 10log\frac{I_2}{I_0} = 10log\frac{I_1}{I_2}$

Since: The intensity is inversely proportion to the square of the distance

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

Therefore: $\beta_1 - \beta_2 = 10\log\frac{r_2^2}{r_1^2} = 105 - 108 = -3$

$\Rightarrow r_2 \approx 0{,}707r_1$

Therefore: The distance between two friends from the loudspeaker on stage:

$$d = r_1 - r_2 = r_1 - 0{,}707r_1 = 0{,}293r_1 = 2{,}8$$

$\Rightarrow r_1 \approx 9{,}55\ (m); r_2 \approx 6{,}756\ (m)$

3)

We have: Condition for constructive interference:

$$2nt = \left(m + \frac{1}{2}\right)\lambda$$

$\Leftrightarrow 2t = \left(25 + \frac{1}{2}\right).516.\ 10^{-9} \Rightarrow t = 6,\ 579(\mu m)$

4)

a) The grating spacing: $d = \frac{1mm}{Number\ of\ grooves} = \frac{10^{-3}}{400} = 2{,}5(\mu m)$

The second-order angle of diffraction :

$$dsin\theta = 2\lambda \Leftrightarrow 2{,}5\,.10^{-6}sin\theta = 2\,.\ 541.10^{-9} \Rightarrow sin\theta = 0{,}4328$$

$\Rightarrow \theta \approx 25{,}64^0$

b) When the entire apparatus is immersed in water:

The wavelength: $\lambda' = \frac{\lambda}{n} = \frac{541\,.\,10^{-9}}{1{,}3333} = 405{,}75\ (nm)$

The new second-order angle of diffraction:

$$dsin\theta' = 2\lambda' \Leftrightarrow 2{,}5\,.\ 10^{-6}sin\theta' = 2\,.\ 405{,}75.10^{-9} \Rightarrow sin\theta' = 0{,}3246$$

$\Rightarrow \theta' \approx 18{,}94^0$

November 2018

1)

a) The frequency is detected by an observer on B as the submarines approach each other:

$$f_B = \frac{v + v_B}{v - v_A} f_A = \frac{1533 + 9}{1533 - 8} . 1400 = 1415{,}6\ (Hz)$$

b) We have: The reflected sound is equal to the incident sound: $f_B' = f_B$

Therefore: The frequency of the reflected sound detected by an observer on sub A:

$$f_A' = \frac{v + v_A}{v - v_B} f_B' = \frac{1533 + 8}{1533 - 9} . 1415{,}6 = 1431{,}39\ (Hz)$$

2)

a) The angle of the third-order maximum of the diffraction pattern:

$$d sin\theta = 3\lambda \Leftrightarrow d sin 32^0 = 3 \,.\, 500 \,.\, 10^{-9} \Rightarrow d \approx 2{,}83 (\mu m)$$

Number of rulings per centimeter = $\frac{1cm}{d} = \frac{10^{-2}}{2{,}83 \,.\, 10^{-6}} = 3532{,}79$

Conclusion: There are 3532 rulings per centimeter for the grating

b) We have: The condition for maximum intensity:

$$d sin\theta = m\lambda \Rightarrow sin\theta = \frac{m\lambda}{d}$$

We have:

$$-1 \leq sin\theta \leq 1$$

$$\Leftrightarrow -1 \leq \frac{m\lambda}{d} \leq 1 \Leftrightarrow \frac{-d}{\lambda} \leq m \leq \frac{d}{\lambda} \text{ ó } -5{,}66 \leq m \leq 5{,}66$$

Since m is an integer number $\Rightarrow m = \{-5, -4, -3, -2, -1{,}0{,}1{,}2{,}3{,}4{,}5\}$

Conclusion: There are 11 primary maximas that can be observed in this situation

3)

The position of bright fringes of green light interference:

$$y_g = k_g \frac{L}{d} \lambda_g$$

The position of bright fringes of blue light interference:

$$y_b = k_b \frac{L}{d} \lambda_b$$

Since a bright fringe of the green light coincides with a bright fringe of the blue light:

$$y_g = y_b \Leftrightarrow k_g \lambda_g = k_b \lambda_b \Rightarrow \frac{k_g}{k_b} = \frac{\lambda_b}{\lambda_g} = \frac{450}{540} = \frac{5}{6}$$

Therefore: The minimum distance:

$$d = y_b = y_g = 5 \frac{L}{d} \lambda_g = 5 . \frac{1{,}4}{0{,}105 \,.\, 10^{-3}} . 540 . 10^{-9} = 36\ (mm)$$

4)

a) Thin-lens equation for lens 1:

$$\frac{1}{f_1} = \frac{1}{p_1} + \frac{1}{q_1}$$

$$\Leftrightarrow \frac{1}{-26} = \frac{1}{12} + \frac{1}{q_1} \Rightarrow q_1 = -8{,}21\ (cm)$$

Thin-lens equation for lens 2:

$$\frac{1}{f_2} = \frac{1}{p_2} + \frac{1}{q_2}$$

Since $q_2 = \infty \Rightarrow \frac{1}{f_2} = \frac{1}{p_2} \Rightarrow p_2 = f_2 = 12\ (cm)$

The distance between lens 1 and lens 2:

$$d = q_1 + p_2 = -8{,}21 + 12 = 3{,}79\ (cm)$$