PHYS 1Cb

Spring 2014

Quiz 2 Key

Version A bedad beade

Version B ddebb edaea

Version C edbbe ddaae

Version D badee bedda

Detailed Solution

**Please note that the order of the questions differs among different test versions.*

1. What is the minimum thickness of a soap film (n=1.33) in which 550nm light will undergo constructive interference?

a) 400nm
b) 300nm
c) 200nm
d) 100nm

Ans. d

For soap film, constructive interference occurs when $2t = (m+0.5)\,\lambda_n$.

$\lambda_n = 550/1.33 = 413.5$ nm

$\therefore\ t = \frac{1}{2}\left(m + \frac{1}{2}\right) \times 413.5.$ Plugging in m = 0 gives t = 103.4 nm

d is the closet answer.

2. The movie "Patriot Games" has a scene in which CIA agents use spy satellites to identify individuals in a terrorist camp. Suppose that a minimum resolution for distinguishing human features is about 5cm. If the spy satellite's optical system is diffraction limited, what diameter mirror or lens is needed to achieve this resolution from an altitude of 100km? Assume a wavelength of 550nm.

a. 2000m
b. 200m
c. 20m
d. 2m
e. 0.2m

Ans. d

$$\theta_{min} = 1.22 \times \frac{\lambda}{D} = 1.22 \times \frac{550\times10^{-9}}{D} \qquad \therefore D = \frac{6.71\times10^{-7}}{\theta_{min}}$$

We can approximate θ_{min} to be $\theta_{min} \approx \frac{5\times10^{-2}}{100\times10^{3}} = 5 \times 10^{-7}\ rad$

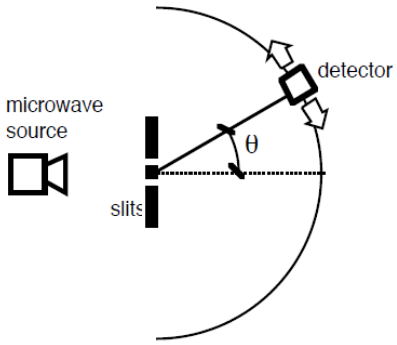
$\therefore$ D $= \frac{6.71\times10^{-7}}{\theta_{min}} = \frac{6.71\times10^{-7}}{5\times10^{-7}} = 1.34\ m$

The diameter of the lens must be greater than 1.34 m

d is the closest answer that is greater than this number.

3. Coherent microwave light with a frequency $f = 2.0 \times 10^{10}$ Hz is incident on a $d = 5.0$ cm double slit barrier, producing an interference pattern of a number of maxima and minima. A detector is free to swing around the full 180° in order to find the presence of interference maxima and minima. How many different maxima will this detector detect, as it is allowed to swing around the full 180°? (Include maxima on both sides of the centerline in your count.) Assume 3x10^8 m/s for the speed of light.

a. five.
b. four.
c. six.
d. ten.
e. seven.



Ans. e

For double-slit experiment, bright fringes appear at the angle that satisfies:

$\sin\theta_{mth,max} = \frac{m\lambda}{d}$ $\quad\therefore \theta_{mth,max} = \sin^{-1}(\frac{m\lambda}{d})$

where $\lambda = \frac{v}{f} = \frac{3\times10^{8}}{2\times10^{10}} = 0.015\ m$

Zeroth order maximum will be detected at $\theta = 0^{\circ}$, undoubtedly .

First order maximum will be detected at $\sin^{-1}\left(\frac{1\times0.015}{0.05}\right) = 17.5^{\circ}$

Second order maximum will be detected at $\sin^{-1}\left(\frac{2\times0.015}{0.05}\right) = 36.9^{\circ}$

Third order maximum will be detected at $\sin^{-1}\left(\frac{3\times0.015}{0.05}\right) = 64.2^{\circ}$

No higher orders of maxima exist because sine should be less than 1

Because of symmetry, we will also detect maxima with order -1, -2 and -3.

$\therefore$ Seven maxima will be detected (m= -3, -2, -1, 0, 1, 2, 3).

4. While standing on a crosswalk, you hear a frequency of 560Hz from an approaching police car. After the police car passes and is moving away from you, you hear a frequency of 480Hz. What is the speed of the police car ? (assume speed of sound = 331m/s)

a) 15 m/s
b) 25 m/s
c) 35 m/s
d) 45 m/s
e) 55 m/s

Ans. b

Assume that the speed of the police car is v_s , and it is producing a sound with frequency f.

When the car is approaching:

$$\frac{331}{331-v_s} \times f = 560$$

When the car is moving away:

$$\frac{331}{331+v_s} \times f = 480$$

By solving the equations above (you can do it by dividing the first one by the second one), we obtain v_s = 25.46 m/s

b is the closest answer.

5. A string, 2.0 meters in length, is fixed at both ends and tightened until a wave speed is 78m/s. What is the frequency of the standing waves shown in the figure below?

a) 40Hz
b) 100Hz
c) 200Hz
d) 300Hz
e) 500Hz

Ans. b

There are 6 "bubbles" on the string. It means that

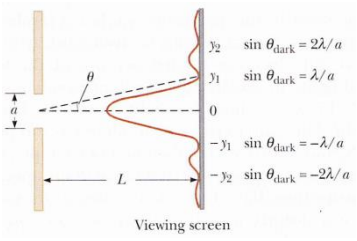
$$\mathrm{L} = 6 \times \frac{\lambda}{2} = 3 \times \lambda = 2 \rightarrow \lambda = \frac{2}{3}\, m$$

$$\therefore \mathrm{f} = \frac{v}{\lambda} = \frac{78}{\frac{2}{3}} = 117 \text{ Hz}$$

b is the closest answer.

6. Light of wavelength 540 nm is incident on a single slit of width 0.150 mm, and a diffraction pattern is produced on a screen that is 2.00 m from the slit. What is the width of the central bright fringe?

a. 0.720 cm.
b. 1.76 cm.
c. 2.88 cm.
d. 2.16 cm.
e. 1.44 cm.



Ans. e

From the figure above, the width of the central bright fringe is $2y_1$, and $2y_1 = 2L\ tan\theta_{1st,dark}$. And by small angle approximation,

$$2L\ tan\theta_{1st,dark} \approx 2L\ sin\theta_{1st,dark} = 2L\frac{\lambda}{a} = 2 \times 2 \times \frac{540 \times 10^{-9}}{0.15 \times 10^{-3}} = 0.0144\text{m}$$

∴The answer is 0.0144 m =1.44 cm

7. You are recreating Young's double-slit experiment in lab with red laser light (λ = 700 nm) as a source. You perform the experiment once with a slit separation of 4.5 mm and obtain an interference pattern on a screen a distance 3.0 m away. You then change the slit separation to 9.0 mm and perform the experiment again. In order to maintain the same interference pattern spacing as the first experiment, the new screen-to-slit distance should be changed to:

a. 1.5 meters.
b. 2.1 meters.
c. 4.2 meters.
d. 6.0 meters.
e. 12 meters.

Ans. d

The distance between 2 successive bright fringes in double-slit interference is

$$\Delta y_{\text{bright}} = y_{1st,max} \approx L\frac{\lambda}{d}$$

∴If d is doubled, we should double L to make the value of Δy_{bright} to be the same.

The answer is $2 \times 3 = 6$ m

8. Light with a wavelength of 450 nm shines through a telescope with a circular aperture diameter of 0.60 cm. Use Rayleigh's criterion to determine the limiting angle of resolution.

a. 9.2×10^{-5} rad.
b. 3.0×10^{-9} rad.
c. 1.3×10^{-4} rad.
d. 5.0×10^{-7} rad.
e. 7.5×10^{-5} rad.

Ans. a

$$\text{The limiting angle} = \theta_{min} = 1.22 \times \frac{\lambda}{D} = 1.22 \times \frac{450 \times 10^{-9}}{0.6 \times 10^{-2}} = 9.15 \times 10^{-5}\ rad$$

a is the closest answer.

9. A small flute 10.75cm long (open on one side, closed at the other) is played near a taut guitar string with fundamental frequency 600Hz. What is the lowest frequency that leads to standing waves on both instruments? (Assume speed of sound in air = 344 m/s)

a) 600Hz
b) there is no such frequency
c) 1200Hz
d) 1800Hz
e) 2400Hz

Ans. e

The guitar string as fundamental frequency 600 Hz means that this string has 2nd harmonic frequency 1200 Hz, 3rd harmonic frequency 1800 Hz and 4th harmonic frequency 2400 Hz.

For an open/closed air column, the fundamental wavelength is $4L = 0.43$ m

The fundamental frequency of the flute is $\frac{344}{0.43} = 800\ Hz$

Similarly, the flute has 2nd harmonic wavelength 0.14333 m, which gives 2nd harmonic frequency 2400 Hz

∴Only 2400 Hz can exist both on the flute and on the guitar string.

10. In an experiment to measure the wavelength of light using a double slit, it is found that the fringes are too close to easily count them. To spread out the fringe pattern, one could:

A) decrease the slit separation, d.
B) increase the slit separation, d.
C) increase the width of each slit, w.
D) decrease the width of each slit, w.
E) decrease the screen-to-slit distance, L.

Ans. a

The distance between 2 successive bright fringes in double-slit interference is

$\Delta y_{\text{bright}} = y_{1st,max} \approx L\frac{\lambda}{d}$

∴In order to increase Δy_{bright}, you can decrease the slit separation d.