HL Paper 1

Two galaxies with an angular separation at the observer of 5.0×10^{-4} radians are observed with a radio telescope. Both galaxies emit radio waves of wavelength $2.5 \times 10^{-2}\ \text{m}$.

The images of the galaxies are just resolved by the telescope. The diameter of the circular collecting dish of the telescope is

A. 61 m.

B. 50 m.

C. 30 m.

D. 25 m.

A diffraction grating is used to observe light of wavelength 400 nm. The light illuminates 100 slits of the grating. What is the minimum wavelength difference that can be resolved when the second order of diffraction is viewed?

A. 1 nm

B. 2 nm

C. 4 nm

D. 8 nm

A mass oscillates with simple harmonic motion (SHM) of amplitude x_o. Its total energy is 16 J.

What is the kinetic energy of the mass when its displacement is $\frac{x_0}{2}$?

A. 4 J

B. 8 J

C. 12 J

D. 16 J

Monochromatic light is incident on two identical slits to produce an interference pattern on a screen. One slit is then covered so that no light emerges from it. What is the change to the pattern observed on the screen?

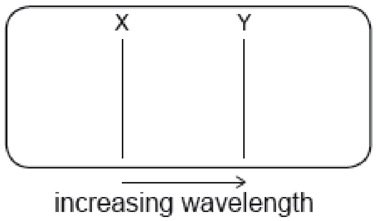
A. Fewer maxima will be observed.

B. The intensity of the central maximum will increase.

C. The outer maxima will become narrower.

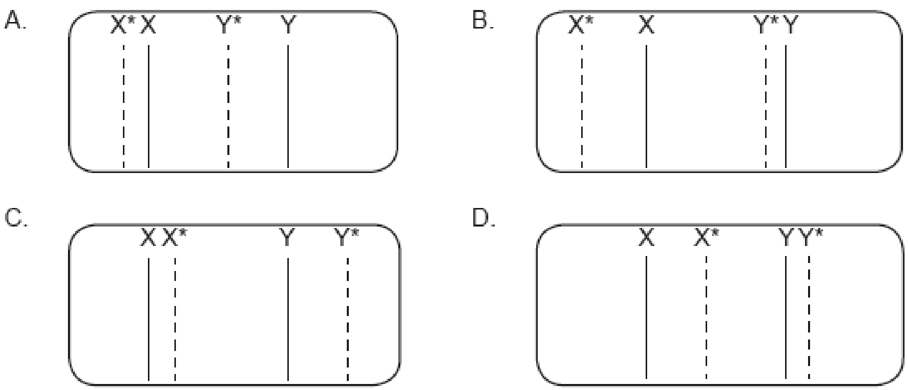
D. The width of the central maximum will decrease.

Two lines X and Y in the emission spectrum of hydrogen gas are measured by an observer stationary with respect to the gas sample.



The emission spectrum is then measured by an observer moving away from the gas sample.

What are the correct shifts X* and Y* for spectral lines X and Y?



Light of wavelength λ is incident normally on a diffraction grating that has a slit separation of $\frac{7\lambda}{2}$. What is the greatest number of maxima that can be observed using this arrangement?

A. 4
B. 6
C. 7
D. 9

Which of the following wave phenomena is associated with blood flow measurements?

A. Polarization

B. Diffraction

C. Refraction

D. Doppler effect

Monochromatic light of wavelength λ in air is incident normally on a thin film of refractive index *n*. The film is surrounded by air. The intensity of the reflected light is a minimum. What is a possible thickness of the film?

A. $\frac{\lambda}{4n}$

B. $\frac{3\lambda}{4n}$

C. $\frac{\lambda}{n}$

D. $\frac{5\lambda}{4n}$

Monochromatic light is incident on 4 rectangular, parallel slits. The first principal maximum is observed at an angle θ to the direction of the incident light. The number of slits is increased to 8 each having the same width and spacing as the first 4.

Three statements about the first principal maximum with 8 slits are

I. the angle at which it is observed is greater than θ

II. its intensity increases

III. its width decreases.

Which statements are correct?

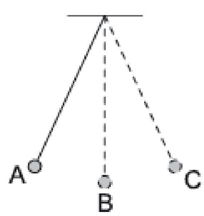
A. I and II only

B. I and III only

C. II and III only

D. I, II and III

A simple pendulum bob oscillates as shown.



At which position is the resultant force on the pendulum bob zero?

A. At position A

B. At position B

C. At position C

D. Resultant force is never zero during the oscillation

A pendulum oscillating near the surface of the Earth swings with a time period *T*. What is the time period of the same pendulum near the surface of the planet Mercury where the gravitational field strength is 0.4*g*?

A. $0.4T$

B. $0.6T$

C. $1.6T$

D. $2.5T$

A spring loaded with mass m oscillates with simple harmonic motion. The amplitude of the motion is A and the spring has total energy E. What is the total energy of the spring when the mass is increased to $3m$ and the amplitude is increased to $2A$?

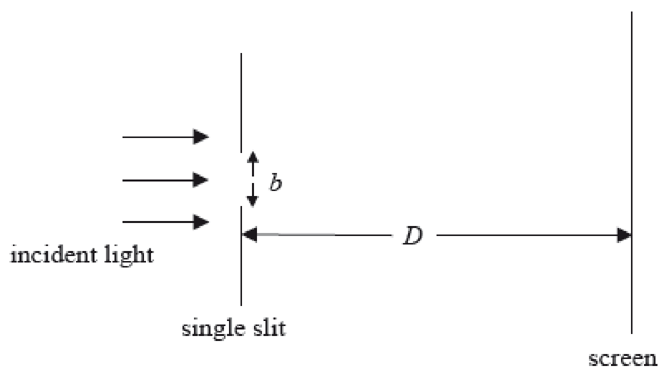
A. $2E$

B. $4E$

C. $12E$

D. $18E$

A beam of coherent light is incident on a single slit of width b. After passing through the slit, the light is incident on a screen at a distance D from the slit.



Which of the following changes, carried out separately, in respect of b and D will result in an increase in width of the first diffraction maximum formed on the screen?

	b	D
A.	decrease	increase
B.	increase	increase
C.	decrease	decrease
D.	increase	decrease

A parallel beam of coherent light of wavelength λ is incident on a rectangular slit of width d. After passing through the slit the light is incident on a screen a distance D from the slit where D is much greater than d. What is the width of the central maximum of the diffraction pattern as measured on the screen?

A. $\frac{2D\lambda}{d}$

B. $\frac{2d}{D\lambda}$

C. $\frac{D\lambda}{d}$

D. $\frac{d}{D\lambda}$

A single-slit diffraction experiment is performed using light of different colours. The width of the central peak in the diffraction pattern is measured for each colour. What is the order of the colours that corresponds to increasing widths of the central peak?

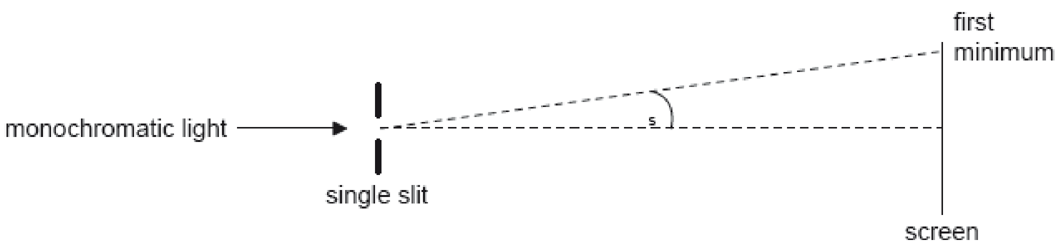
A. red, green, blue

B. red, blue, green

C. blue, green, red

D. green, blue, red

A beam of monochromatic light is incident on a single slit and a diffraction pattern forms on the screen.



What change will increase θ_s?

A. Increase the width of the slit

B. Decrease the width of the slit

C. Increase the distance between the slit and the screen

D. Decrease the distance between the slit and the screen

Green light is emitted by two point sources. The light passes through a narrow slit and is received by an observer. The images of the two sources just fail to be resolved. Which change allows for the images to be resolved?

A. Replacing the narrow slit with a circular aperture of same size.

B. Moving the two sources further from the aperture.

C. Using red light.

D. Using violet light.

A mass at the end of a vertical spring and a simple pendulum perform oscillations on Earth that are simple harmonic with time period *T*. Both the pendulum and the mass-spring system are taken to the Moon. The acceleration of free fall on the Moon is smaller than that on Earth. What is correct about the time periods of the pendulum and the mass-spring system on the Moon?

	Simple pendulum	Mass-spring system
A.	*T*	*T*
B.	greater than *T*	*T*
C.	greater than *T*	greater than *T*
D.	*T*	greater than *T*

A train travelling in a straight line emits a sound of constant frequency *f*. An observer at rest very close to the path of the train detects a sound of continuously decreasing frequency. The train is

A. approaching the observer at constant speed.

B. approaching the observer at increasing speed.

C. moving away from the observer at constant speed.

D. moving away from the observer at increasing speed.

A particle is oscillating with simple harmonic motion (shm) of amplitude x_0 and maximum kinetic energy E_k. What is the potential energy of the system when the particle is a distance $0.20x_0$ from its maximum displacement?

A. $0.20E_k$

B. $0.36E_k$

C. $0.64E_k$

D. $0.80E_k$

Which of the following experiments provides evidence for the existence of matter waves?

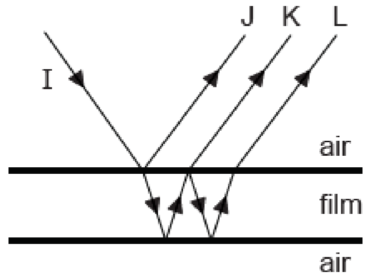
A. Scattering of alpha particles

B. Electron diffraction

C. Gamma decay

D. Photoelectric effect

A transparent liquid forms a parallel-sided thin film in air. The diagram shows a ray I incident on the upper air–film boundary at normal incidence (the rays are shown at an angle to the normal for clarity).



Reflections from the top and bottom surfaces of the film result in three rays J, K and L. Which of the rays has undergone a phase change of π rad?

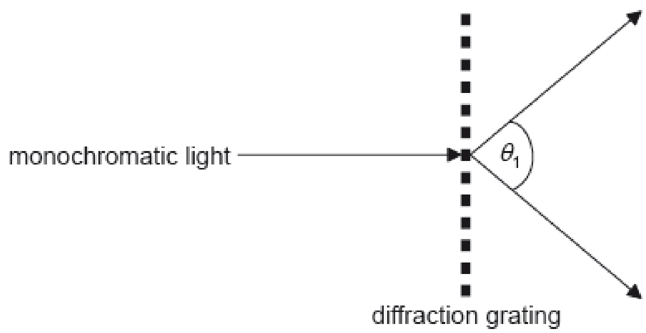
A. J only

B. J and L only

C. J and K only

D. J, K and L

A beam of monochromatic light is incident on a diffraction grating of N lines per unit length. The angle between the first orders is θ_1.



What is the wavelength of the light?

A. $\frac{\sin \theta_1}{N}$

B. $N \sin \theta_1$

C. $N \sin\left(\frac{\theta_1}{2}\right)$

D. $\frac{\sin\left(\frac{\theta_1}{2}\right)}{N}$

Two waves meet at a point. The waves have a path difference of $\frac{\lambda}{4}$. The phase difference between the waves is

A. $\frac{\pi}{8}$rad.

B. $\frac{\pi}{4}$rad.

C. $\frac{\pi}{2}$rad.

D. π rad.

A simple pendulum has mass M and length l. The period of oscillation of the pendulum is T. What is the period of oscillation of a pendulum with mass $4M$ and length $0.25l$?

A. $0.5T$

B. T

C. $2T$

D. $4T$

A source of sound approaches a stationary observer. The speed of the emitted sound and its wavelength, measured at the source, are ν and λ respectively. Which of the following is the wave speed and the wavelength, as measured by the stationary observer?

	Wave speed	Wavelength
A.	larger than v	larger than λ
B.	equal to v	larger than λ
C.	equal to v	less than λ
D.	larger than v	less than λ

A stationary source of sound emits sound of frequency f. A moving observer measures the sound as having the frequency f'. The observer is moving directly away from the source at a speed that is 30% of the speed of sound in air.

Which of the following gives the correct value for $\frac{f'}{f}$?

A. $\frac{7}{10}$

B. $\frac{10}{13}$

C. $\frac{13}{10}$

D. $\frac{10}{7}$

An object to be viewed by a microscope is irradiated with blue light. The reason for using blue light rather than light of a longer wavelength is to increase

A. diffraction.
B. interference.
C. resolution.
D. magnification.

The images of two sources are just resolved. Which of the following is a correct statement of the Rayleigh criterion for this situation?

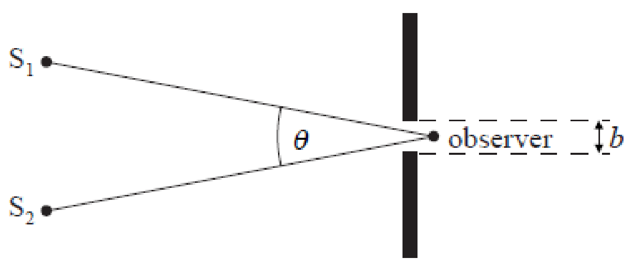
A. The central maximum of the diffraction pattern of one source must coincide with the central maximum of the diffraction pattern of the other source.

B. Light from the sources must pass through a circular aperture.

C. Light from the sources must be coherent.

D. The first minimum of the diffraction pattern of one source must coincide with the central maximum of the diffraction pattern of the other source.

Light of wavelength λ is emitted by two point sources. The light passes through a circular aperture of diameter *b* and is received by an observer. The angular separation of the sources from the observer's position is *θ*. The sources are **not** resolved by the observer. Which of the following mathematical relationships applies?



A. $\theta < 1.22\frac{\lambda}{b}$

B. $\theta > 1.22\frac{\lambda}{b}$

C. $\theta = 1.22\frac{\lambda}{b}$

D. $\theta = \frac{\lambda}{b}$

A car horn emits sound of frequency f. While the horn is sounding, the car moves in a straight line towards a stationary observer. The speed of the car is 0.10*v* where *v* is the speed of sound. What is the frequency of the sound of the horn heard by the observer?

A. $\frac{f}{0.90}$
B. 1.1 f
C. $\frac{f}{1.1}$
D. 0.90 f

A train is approaching an observer with constant speed

$$\frac{c}{34}$$

where *c* is the speed of sound in still air. The train emits sound of wavelength λ. What is the observed speed of the sound and observed wavelength as the train approaches?

	Speed of sound	Wavelength
A.	c	$\frac{33\lambda}{34}$
B.	$\frac{35c}{34}$	$\frac{33\lambda}{34}$
C.	c	λ
D.	$\frac{35c}{34}$	λ

A source emits sound of wavelength λ_0 and wave speed v_0. A stationary observer hears the sound as the source moves away. What are the wavelength of the sound and the wave speed of the sound as measured by the stationary observer?

	Wavelength	Wave speed
A.	less than λ_0	equal to v_0
B.	greater than λ_0	equal to v_0
C.	less than λ_0	less than v_0
D.	greater than λ_0	less than v_0

A siren on an ambulance emits sound of frequency *f*. The speed of sound in still air is *v*. What is the frequency of the sound observed when the ambulance travels at speed $\frac{v}{10}$ towards a stationary observer?

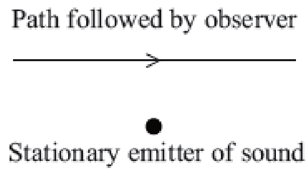
A. $\frac{f}{10}$

B. f

C. $\frac{11}{10}f$

D. $\frac{10}{9}f$

During a journey an observer travels at constant speed towards, and then goes beyond, a stationary emitter of sound.



The frequency of the sound as measured at the emitter is f. The frequency according to the observer

A. is always greater than f.

B. is always equal to f.

C. is always less than f.

D. varies during the journey.

A body moves with simple harmonic motion (SHM) with period T and total energy E_T. What is the total energy when the period of the motion is changed to $5T$ and the amplitude of the motion remains constant?

A. 0.04 E_T

B. 0.2 E_T

C. 5 E_T

D. 25 E_T

A sample of hydrogen on Earth emits a spectral line that is measured by an Earth observer to have wavelength 500 nm. The same spectral line is emitted by a galactic source that is moving away from Earth at speed of 0.1c. What is the wavelength of the galactic spectral line that will be measured by the Earth observer?

A. 50 nm
B. 450 nm
C. 550 nm
D. 5000 nm

Two coloured point sources are observed through an optical telescope. Which of the following colours for the sources would best allow their images to be resolved?

A. Blue
B. Green
C. Red
D. Yellow

Two point sources of light have an angular separation of θ, as measured by a distant observer. The light passes through a circular aperture of radius *r* just before reaching the observer. Which of the following conditions must be true for the two sources to be resolved?

A. $\theta < 0.61\frac{\lambda}{r}$

B. $\theta < 1.22\frac{\lambda}{r}$

C. $\theta \geq 0.61\frac{\lambda}{r}$

D. $\theta \geq 1.22\frac{\lambda}{r}$

A radio telescope has a circular collecting dish of diameter 5.0 m. It is used to observe two distant galaxies that are both emitting electromagnetic radiation of wavelength 20 cm. The images of the galaxies are just resolved by the telescope. What is the angle subtended by the galaxies at the telescope?

A. 0.05 rad

B. 0.3 rad

C. 5 rad

D. 30 rad

A source of sound moves away from an observer. The observed frequency of the sound differs from the frequency emitted by the source because the

A. observed wavelength of the sound is less than the emitted wavelength.
B. observed wavelength of the sound is greater than the emitted wavelength.
C. speed of sound relative to the observer has decreased.
D. speed of sound relative to the observer has increased.

Which of the following would be diffracted the most when incident on a slit of width 1 cm?

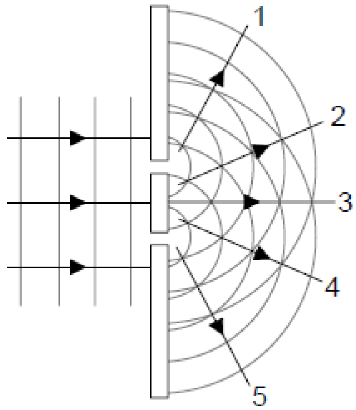
A. microwaves

B. red light

C. ultraviolet

D. X-rays

Blue light is incident on two narrow slits. Constructive interference takes place along the lines labelled 1 to 5.



The blue light is now replaced by red light. What additional change is needed so that the lines of constructive interference remain in the same angular positions?

A. Make the slits wider

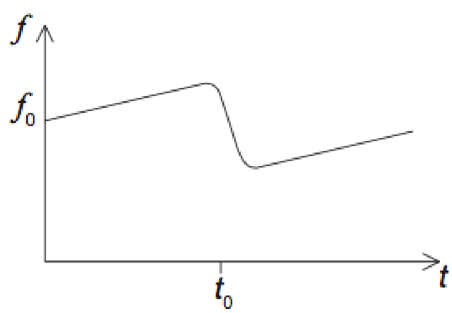
B. Make the slits narrower

C. Move the slits closer together

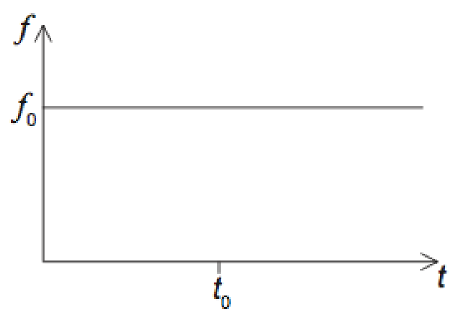
D. Move the slits further apart

A train moves at constant speed whilst emitting a sound wave of frequency f_0. At t=t_0 the train passes through a station. Which graph shows the variation with time t of the frequency f of the sound wave as measured by an observer standing on the station platform?

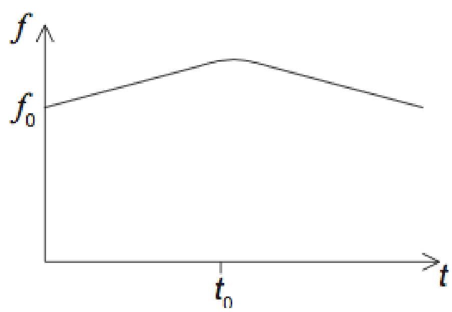
A.



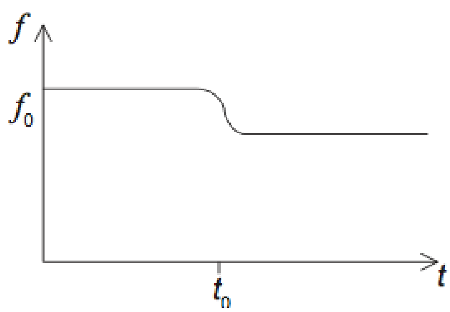
B.



C.



D.



A stationary sound source emits waves of wavelength λ and speed v. The source now moves away from a stationary observer. What are the wavelength and speed of the sound as measured by the observer?

	Wavelength	Speed
A.	longer than λ	equal to v
B.	longer than λ	less than v
C.	shorter than λ	equal to v
D.	shorter than λ	less than v

A parallel beam of monochromatic light of wavelength λ passes through a slit of width b. After passing through the slit the light is incident on a distant screen. The angular width of the central maximum is

A. $2\frac{\lambda}{b}$ radians.

B. $\frac{\lambda}{b}$ radians.

C. $2\frac{\lambda}{b}$ degrees.

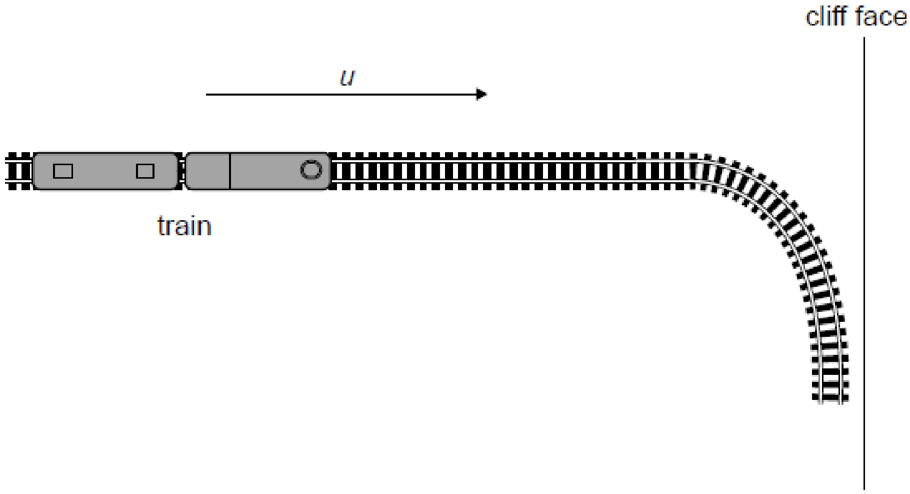
D. $\frac{\lambda}{b}$ degrees.

For fringes to be observed in a double-slit interference experiment, the slits must emit waves that are coherent.

What conditions are required for the frequency of the waves and for the phase difference between the waves so that the waves are coherent?

	Frequency of waves	Phase difference between waves
A.	same	variable
B.	same	constant
C.	constant difference	variable
D.	constant difference	constant

A train moving at speed u relative to the ground, sounds a whistle of constant frequency f as it moves towards a vertical cliff face.

C. 

The sound from the whistle reaches the cliff face and is reflected back to the train. The speed of sound in stationary air is *c*.

What whistle frequency is observed on the train after the reflection?

A. $\frac{(c+u)}{(c-u)} f$

B. (c + u)*f*

C. (c – u)*f*

D. $\frac{(c-u)}{(c+u)} f$

A radar speed gun is used to measure the speed of a car. The car is moving with speed *v* away from the gun.

The radar emits microwaves of frequency *f* and speed *c*. Which of the following is the frequency of the microwaves measured at the gun after reflection by the car?

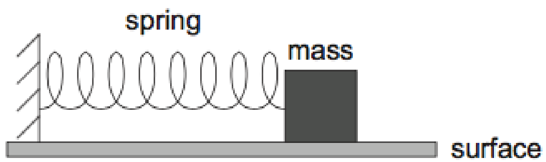
A. $f + \left(\frac{2v}{c} f\right)$

B. $f + \left(\frac{v}{c} f\right)$

C. $f - \left(\frac{2v}{c} f\right)$

D. $f - \left(\frac{v}{c} f\right)$

A mass is connected to a spring on a frictionless horizontal surface as shown.



The spring is extended beyond its equilibrium length and the mass executes simple harmonic motion (SHM). Which of the following is independent of the initial displacement of the spring?

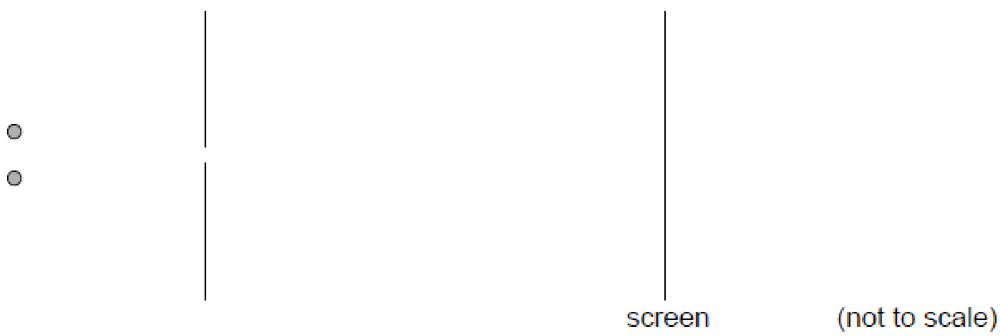
A. The angular frequency of the oscillation

B. The total energy of the mass

C. The average speed of the mass

D. The maximum kinetic energy of the mass

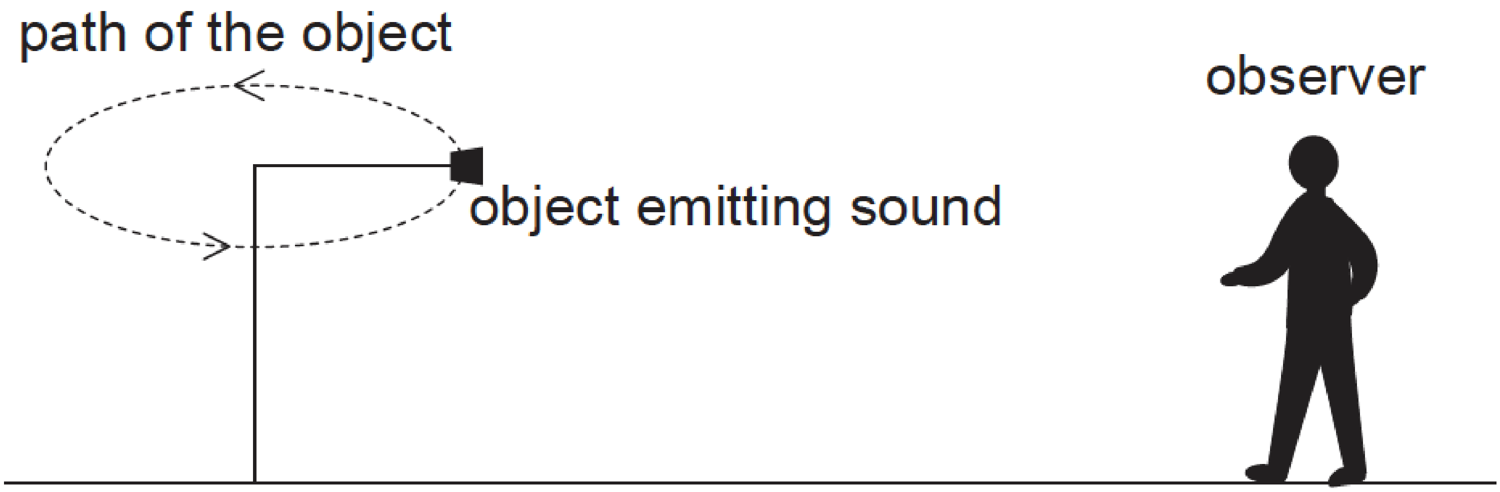
Two points illuminated by monochromatic light are separated by a small distance. The light from the two sources passes through a small circular aperture and is detected on a screen far away.



Two points illuminated by monochromatic light are separated by a small distance. The light from the two sources passes through a small circular aperture and is detected on a screen far away.

	Wavelength	Size of aperture
A.	increase	increase
B.	increase	decrease
C.	decrease	increase
D.	decrease	decrease

An object emitting a sound of frequency 100 Hz orbits in a horizontal circle at a rate of two revolutions per second.



An observer standing a short distance away from the object is able to hear the sound. Which of the following describes the sound the observer is able to hear?

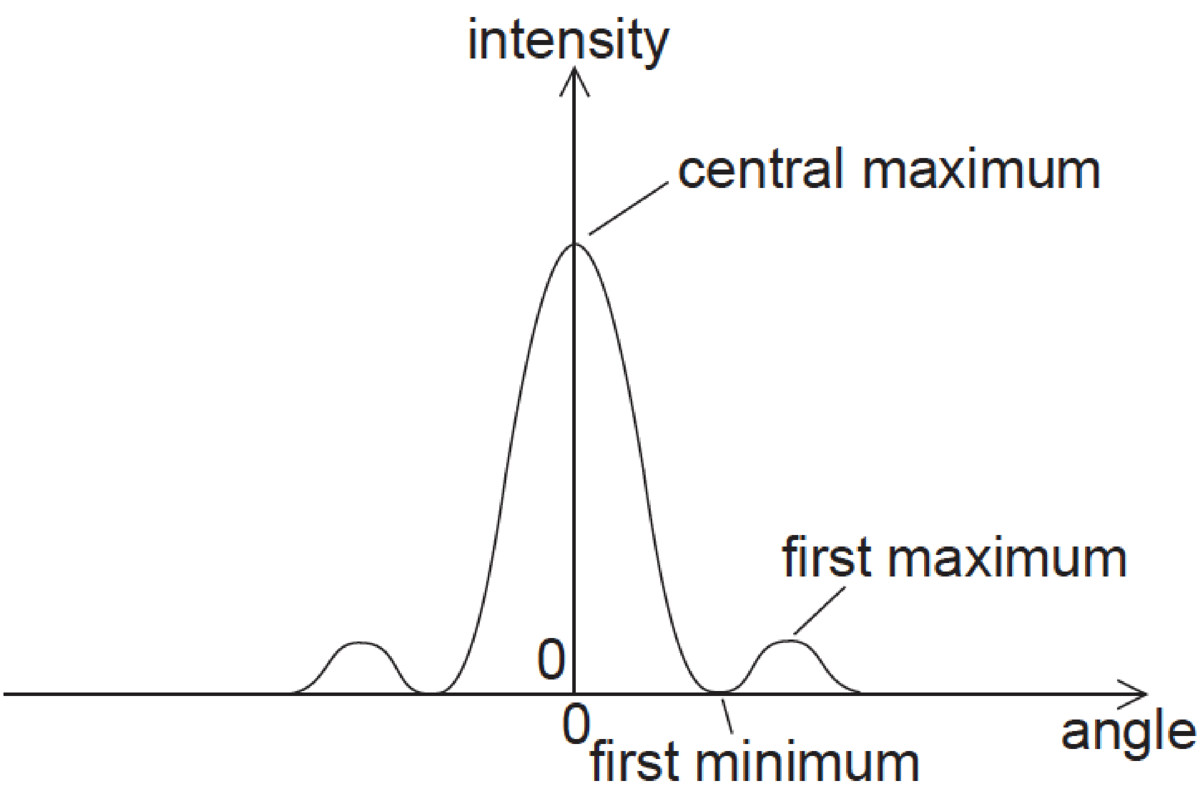
A. A sound of constant frequency but varying in amplitude

B. A sound of constantly varying frequency

C. A sound with a frequency of 50 Hz

D. A sound with a frequency of 200 Hz

The graph below shows the variation of the intensity of light with angle for the diffraction pattern produced when light is diffracted by a slit.



According to the Rayleigh criterion, when the diffraction patterns of two slits are just resolved

A. the first maximum of one diffraction pattern coincides with the central maximum of the other diffraction pattern.

B. the central maximum of one diffraction pattern coincides with the central maximum of the other diffraction pattern.

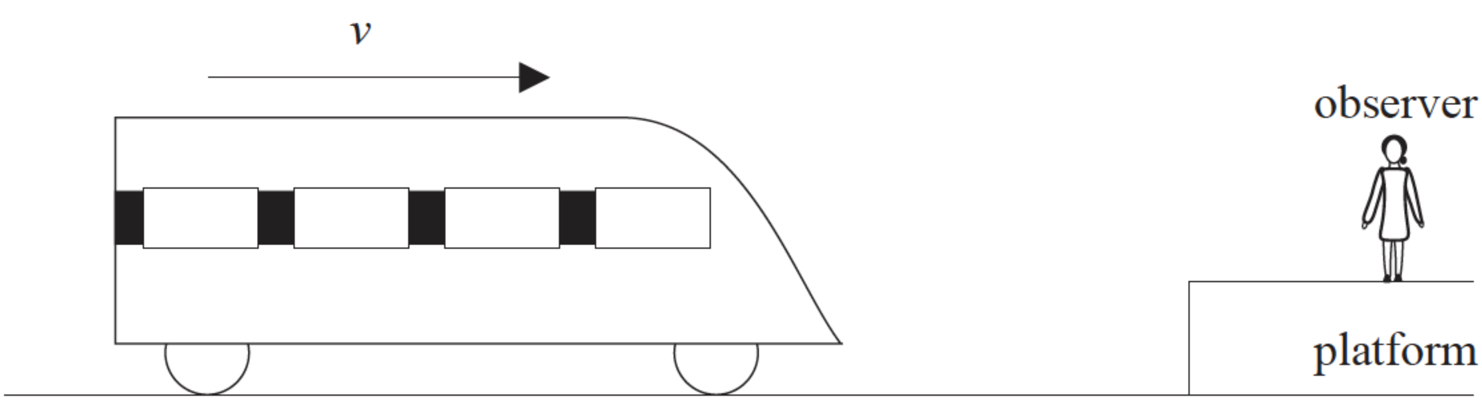
C. the first minimum of one diffraction pattern coincides with the central maximum of the other diffraction pattern.

D. the first minimum of one diffraction pattern coincides with the first minimum of the other diffraction pattern.

An optical instrument is used to observe an object illuminated with monochromatic light. Which of the following changes to the frequency of the light and to the aperture diameter of the optical instrument will increase the resolution of the image of the object formed by the instrument?

	Frequency	Aperture diameter
A.	increase	decrease
B.	decrease	decrease
C.	increase	increase
D.	decrease	increase

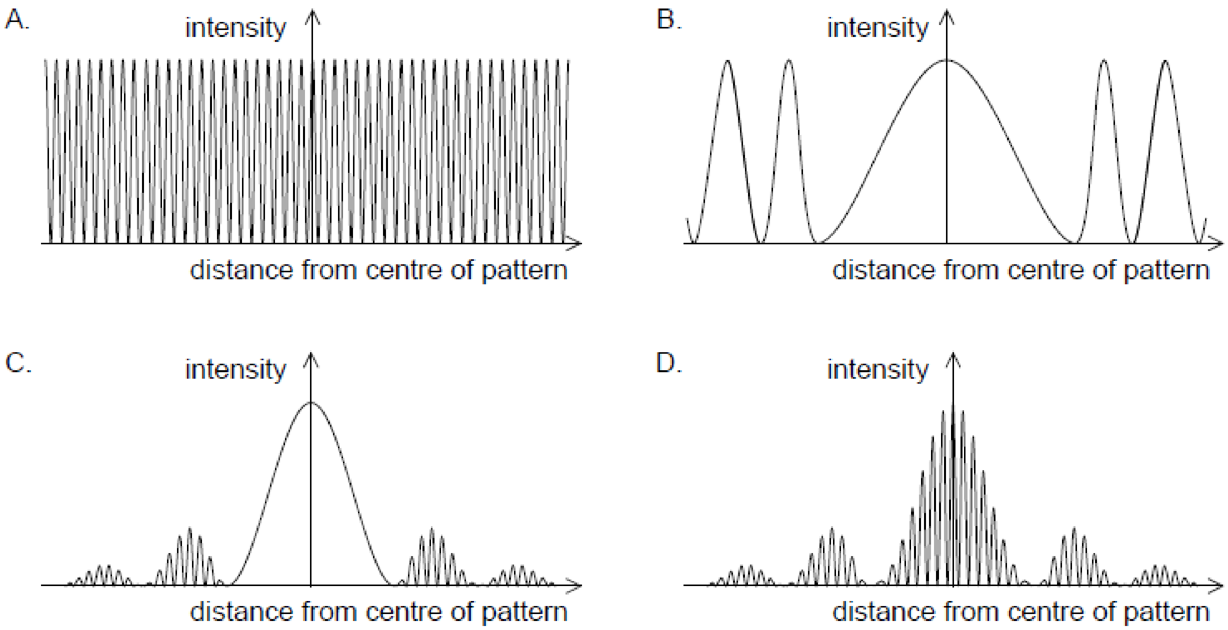
The diagram shows a train travelling in a straight line at constant speed v, as it approaches the platform of a station.



The whistle of the engine is emitting a sound of constant frequency. Which of the following is **not** true for the sound of the whistle heard by an observer on the platform?

A. A sudden change in frequency of the sound as the train passes the observer.
B. A sound of constant frequency as the train approaches the observer.
C. A sound of increasing frequency as the train approaches the observer and of decreasing frequency after the train has passed the observer.
D. A sound of constant frequency after the train has passed the observer.

Monochromatic light is incident on a double slit. Both slits have a finite width. The light then forms an interference pattern on a screen some distance away. Which graph shows the variation of intensity with distance from the centre of the pattern?



A coherent beam of light of wavelength λ is incident on a double slit. The width of the slits is small compared to their separation. An interference pattern is observed on a distant screen. O is the mid point of the screen.

There is a bright fringe at O and a bright fringe at P. Between O and P there are three dark fringes.

Which of the following is the path difference between the light from the two slits arriving at P?

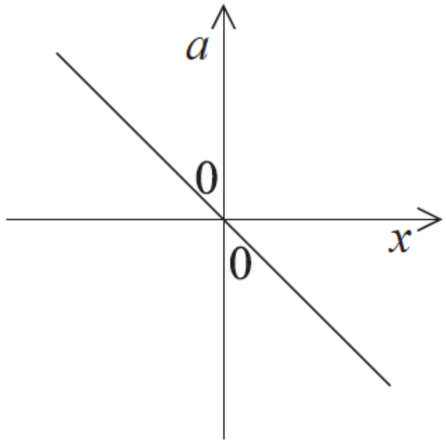
A. 1.5 λ
B. 2 λ
C. 3 λ
D. 4 λ

Light of wavelength λ_0 is emitted from a nearby galaxy. The light is received on Earth and the wavelength is measured to be λ where $\lambda<\lambda_0$. Which of the following correctly describes the speed and direction of motion of the galaxy?

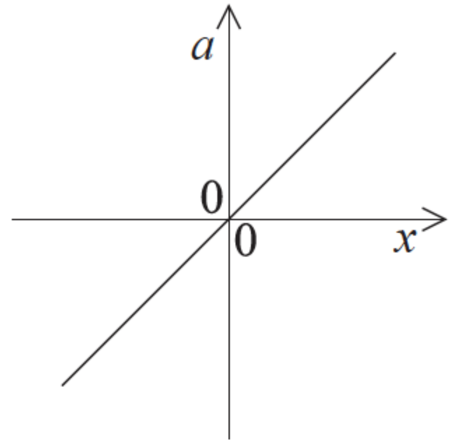
	Speed	Direction
A.	$\dfrac{\lambda_0 - \lambda}{\lambda_0}c$	towards earth
B.	$\dfrac{\lambda_0 - \lambda}{\lambda}c$	towards earth
C.	$\dfrac{\lambda_0 - \lambda}{\lambda_0}c$	away from earth
D.	$\dfrac{\lambda_0 - \lambda}{\lambda}c$	away from earth

An object undergoes simple harmonic motion. Which graph shows the relationship between the acceleration *a* and the displacement *x* from the equilibrium position?

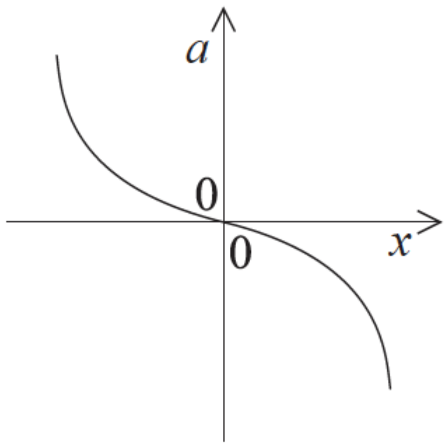
A.



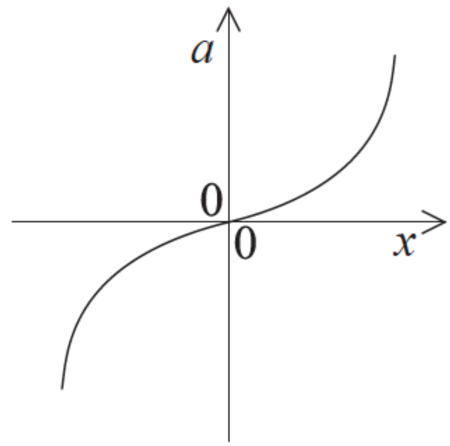
B.



C.



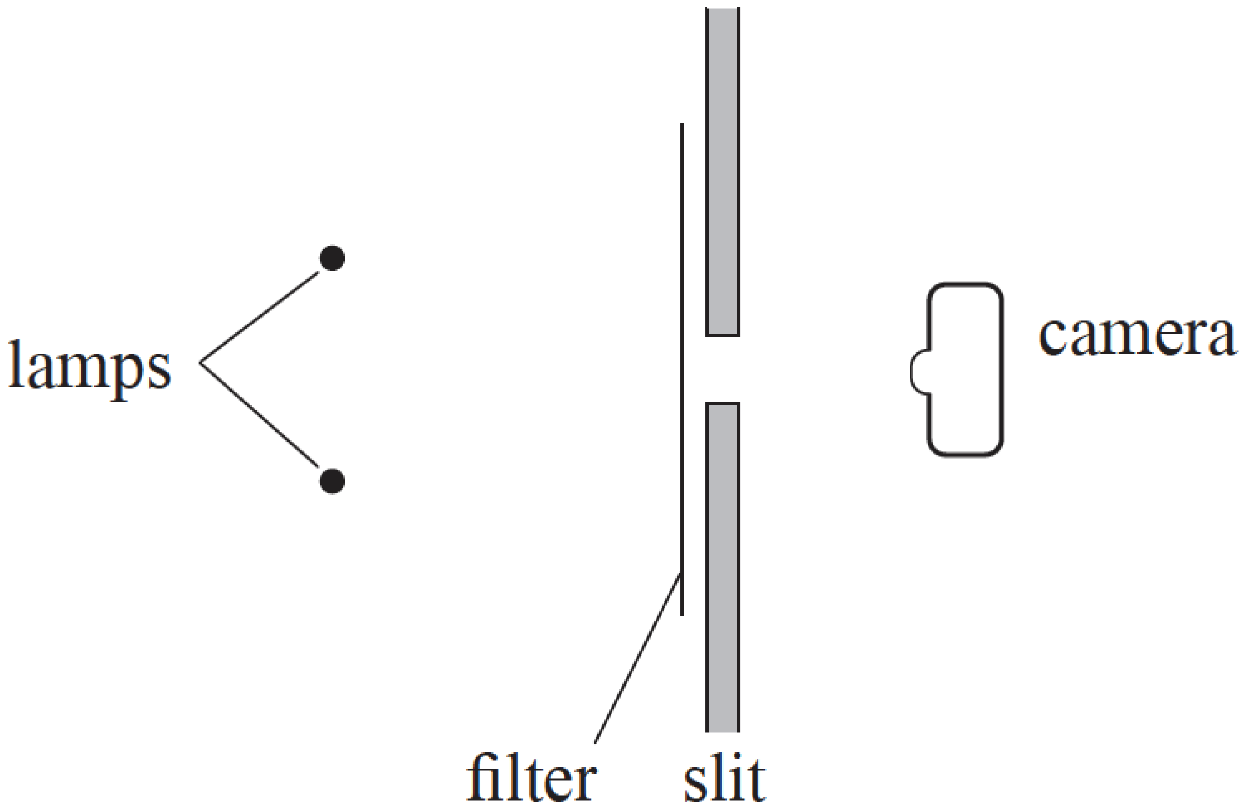
D.



A fire engine with its siren sounding approaches and passes a stationary observer. The frequency of the sound emitted by the siren is f_s. The frequency of the sound measured by the observer is f_o. Which of the following describes the relationship between f_o and f_s?

	Fire engine approaching observer	**Fire engine moving away from observer**
A.	$f_o > f_s$	$f_o < f_s$
B.	$f_o < f_s$	$f_o < f_s$
C.	$f_o > f_s$	$f_o > f_s$
D.	$f_o < f_s$	$f_o > f_s$

The diagram below shows two identical filament lamps separated by a small distance. Light from the lamps is incident on a narrow slit behind a green filter. The slit is parallel to the filament of each lamp. A photograph is taken of the lamps through the slit. The images of the filaments on the photograph are just resolved.



The green filter is replaced by a red filter and then by a violet filter. For each filter a photograph is taken of the lamps through the slit. Which of the following correctly describes the resolution of the images using a red and using a violet filter?

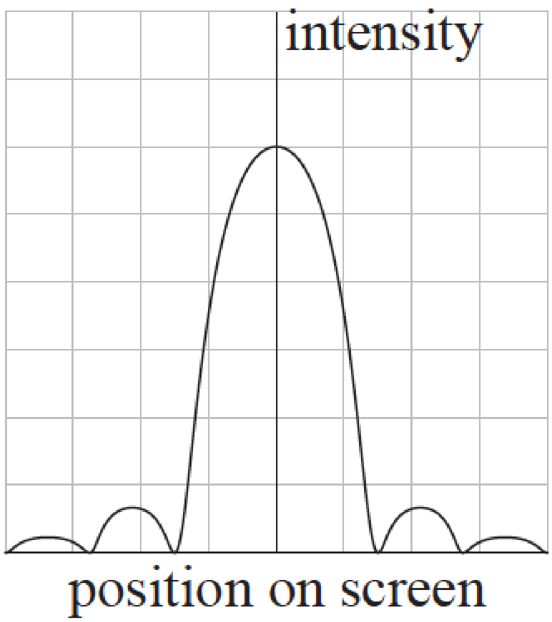
	Red filter	Violet filter
A.	resolved	resolved
B.	resolved	not resolved
C.	not resolved	resolved
D.	not resolved	not resolved

Radiation is incident on a single rectangular slit. The diffracted beam that emerges from the slit is incident on a screen. The slit width is then doubled and the wavelength of the radiation is also doubled. The intensity of the radiation remains the same.

Which of the following correctly describes the angular width of the central maximum of the diffracted beam and the total number of photons incident every second on the screen?

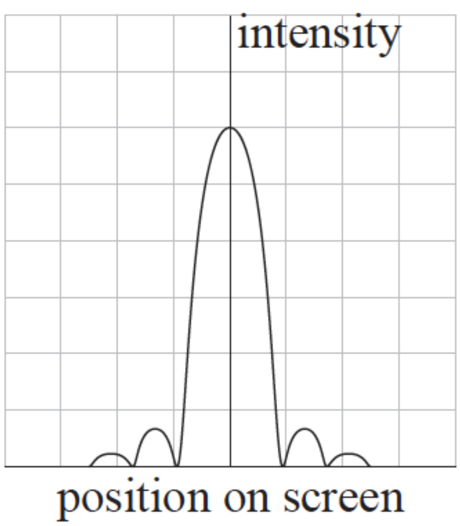
	Angular width of the central maximum	Number of photons incident every second on the screen
A.	unchanged	unchanged
B.	changed	unchanged
C.	unchanged	changed
D.	changed	changed

The intensity distribution of monochromatic light passing through a narrow slit and then incident on a screen is shown below.

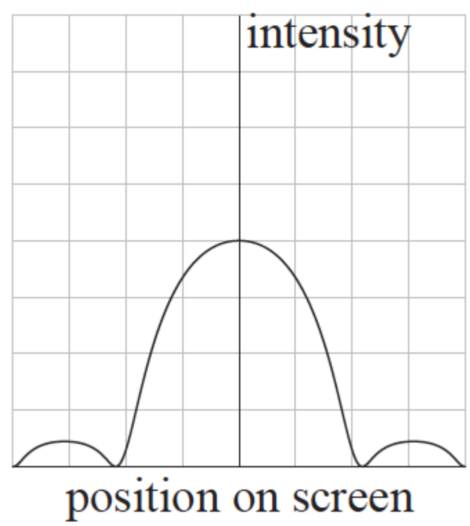


When the slit width is reduced which diagram shows the new intensity distribution? Diagrams are drawn to the same scale as the original.

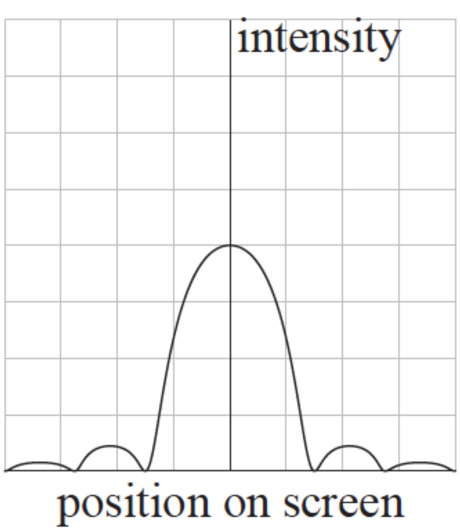
A.



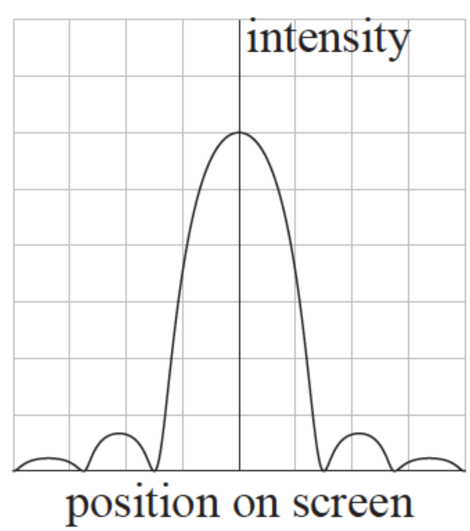
B.



C.

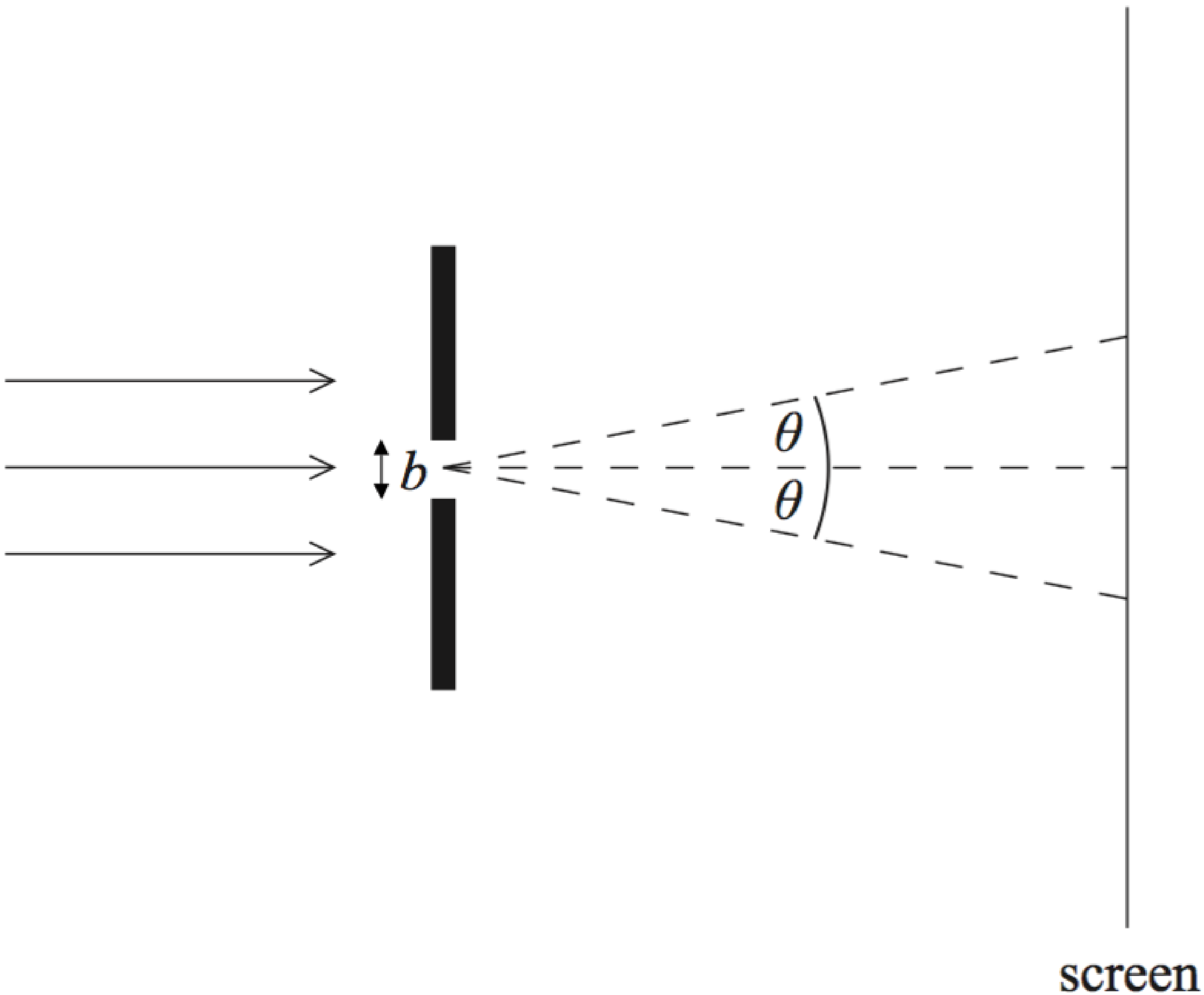


D.



A parallel beam of monochromatic light of wavelength λ passes through a slit of width *b* and forms a diffraction pattern on a screen far from the slit.

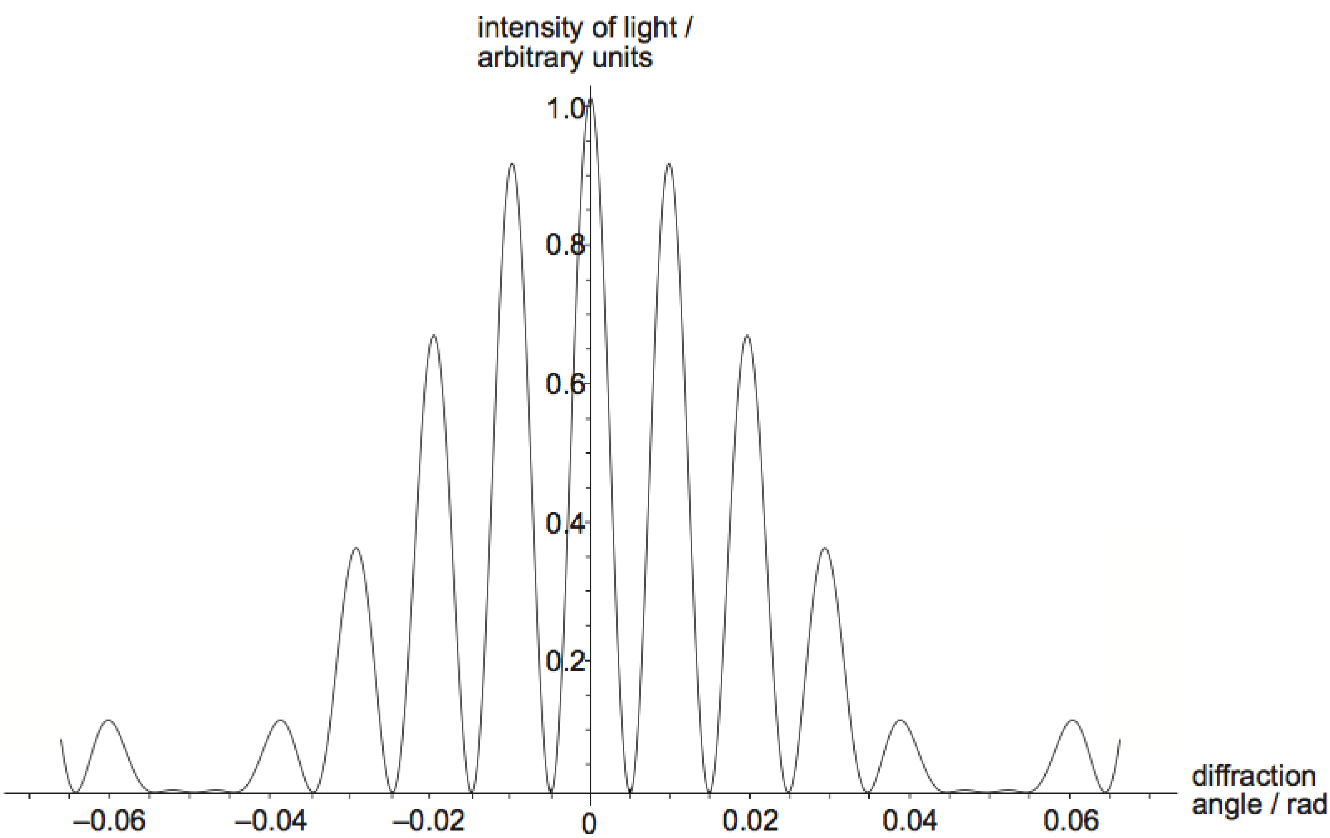
The angle at which the first diffraction minimum is formed is θ.



Which of the following changes in λ and b, carried out separately, will increase the value of θ?

	λ	b
A.	decrease	increase
B.	increase	increase
C.	decrease	decrease
D.	increase	decrease

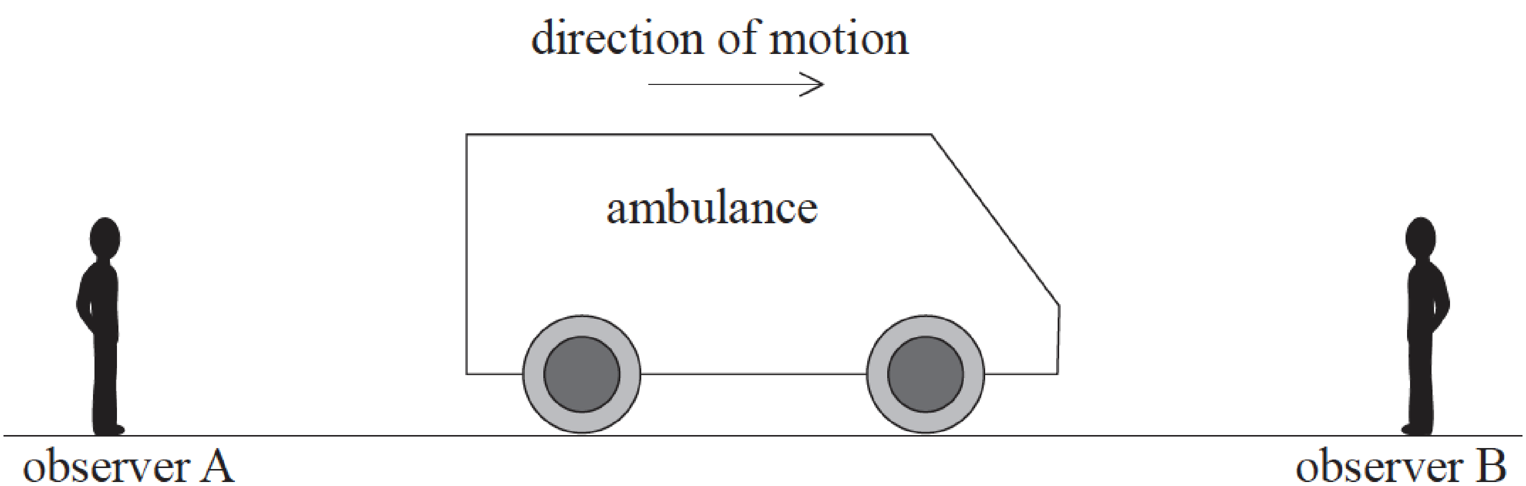
In a double-slit interference experiment, the following intensity pattern is observed for light of wavelength λ.



The distance between the slits is d. What can be deduced about the value of the ratio $\frac{\lambda}{d}$ and the effect of single-slit diffraction in this experiment?

	$\frac{\lambda}{d}$	Single-slit diffraction
A.	100	non-negligible
B.	0.01	non-negligible
C.	100	negligible
D.	0.01	negligible

An ambulance emits a sound of frequency *f* as it travels along a straight road between stationary observers A and B.

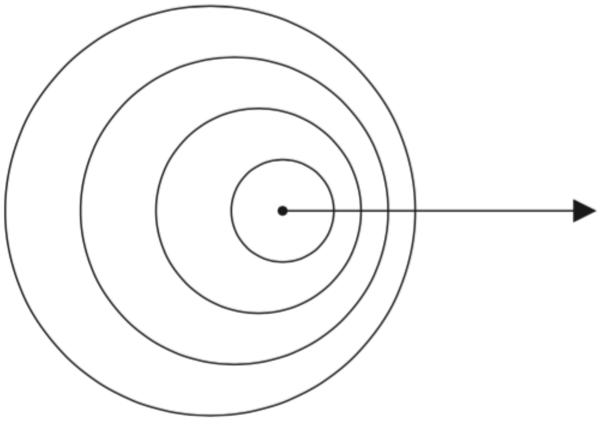


Which of the following shows how the frequency of the sound heard by each observer compares with *f*?

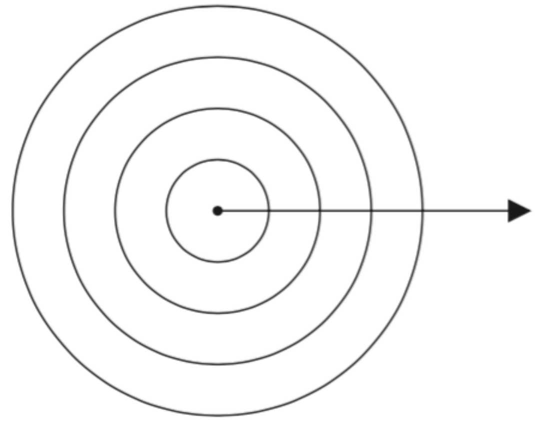
	Observer A	Observer B
A.	greater than f	greater than f
B.	greater than f	less than f
C.	less than f	greater than f
D.	less than f	less than f

A point source of sound is moving to the right at constant speed. The source emits sound waves of constant frequency. The speed of the source is less than the speed of sound. Which diagram correctly shows the wavefronts of the sound?

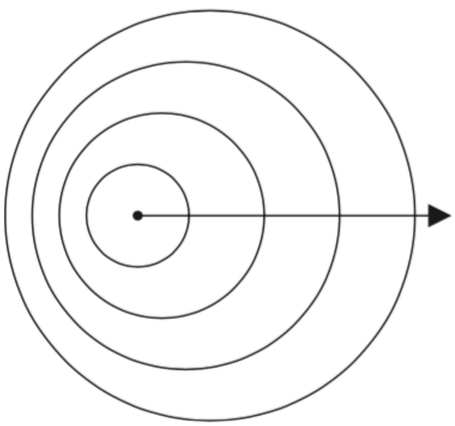
A.



B.



C.



D.