Delta Science Education

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HKDSE Physics

Core 3: Wave Motion

Chapter 6 Wave Nature of Light

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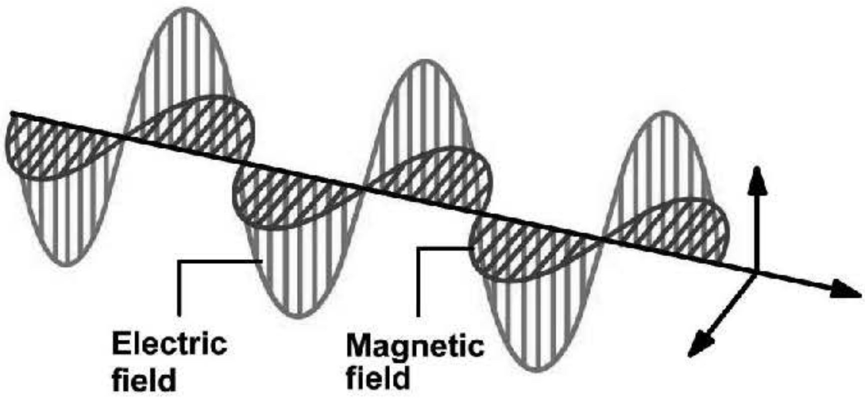
1. Electromagnetic Wave

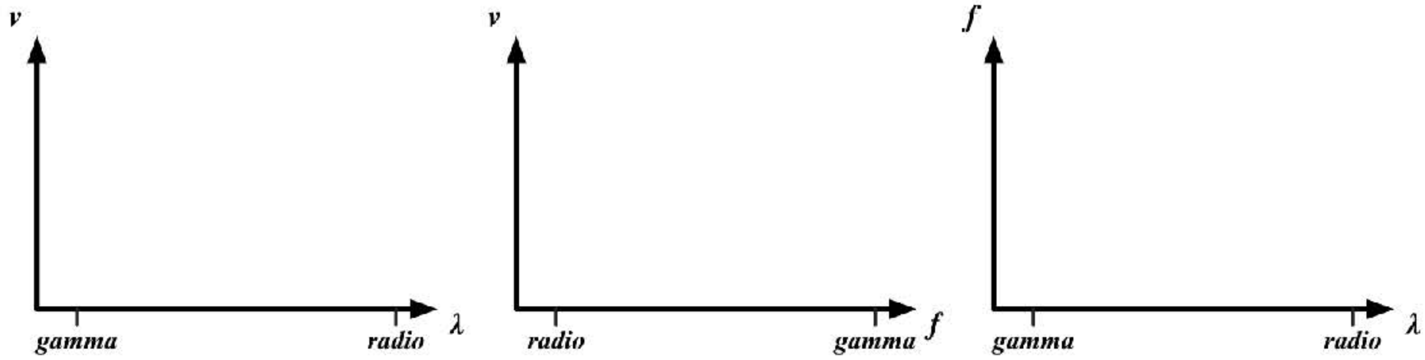
(1) Nature of Light

- Light is a kind of electromagnetic wave which can travel in vacuum.

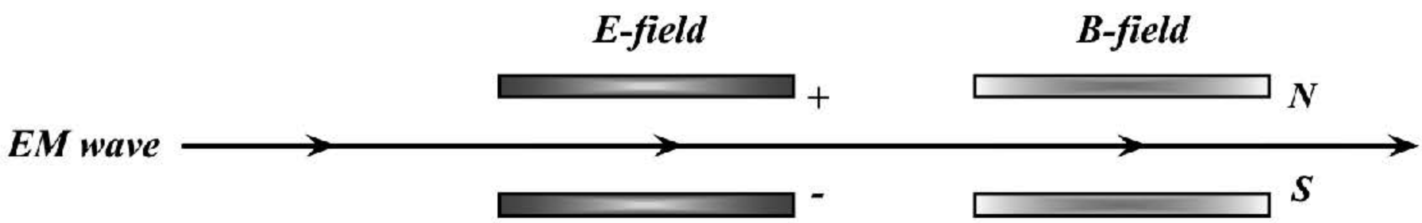
- All EM waves are transverse waves which is due to the oscillation of electric field and magnetic field.



- All EM waves travel with the same speed, 3×10^8 m s^{-1} in vacuum or in air.



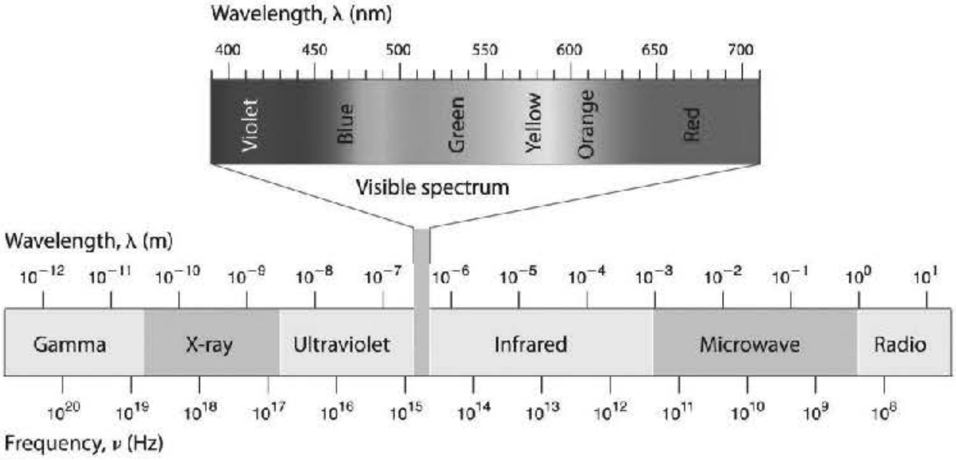
- All EM waves would not be deflected by Electric field or Magnetic field.



- All EM waves can show the following phenomena:

  - **Reflection**
  - **Refraction**
  - **Diffraction**
  - **Interference**

(2) The EM wave spectrum



(a)


(b)

Examples that you must fully understand

1. The frequency of an EM wave beam is in the order of 10^{15} Hz. What type of EM wave is it?

2. Which of the following combinations of wavelengths for infrared, red and violet lights is possible?

	Infrared	*Red light*	*Violet light*
(1)	***1×10^{-4} m***	***4×10^{-7} m***	***7×10^{-7} m***
(2)	***1×10^{-4} m***	***7×10^{-7} m***	***4×10^{-7} m***
(3)	***100 nm***	***700 nm***	***400 nm***

3. Which of the following statements concerning the electromagnetic waves is/are true?

(1) The speed of X-rays in vacuum is larger than that of radio waves.

(2) Microwaves can be deflected by magnetic field.

(3) Red light transmits faster in plastic than violet light.

(4) The wavelength of red light is longer than the of green light.

(5) Infra-red radiation is red in colour.

(6) UV can be seen by naked eyes.

4. Which of the following can prove that light is an EM wave?

(1) Light demonstrates interference.

(2) Light diffracts after passing through a slit.

(3) Light can travel in space.

(4) Light's speed in vacuum is 3×10^8 m s^{-1}.

(5) Light cannot be deflected by electric field.

5. Arrange the following EM waves in ascending order of their wavelengths.

   (1) X-rays
   (2) Radio waves
   (3) IR radiation
   (4) Visible light
   (5) Gamma radiation
   (6) Microwaves

6. Arrange the following EM waves in ascending order of their frequencies.

   (1) X-rays
   (2) Radio waves
   (3) Yellow light
   (4) IR radiation
   (5) UV rays
   (6) Blue light

7. The diagram shows part of the EM wave spectrum. Which of the following statements is/are correct?

X-rays	***P***	***Q***	***IR***

   (1) The wavelength of P is shorter than that of Q.
   (2) The speed of P in vacuum is smaller than that of Q.
   (3) Q can be deflected by a B-field.
   (4) Both P and Q need a medium to transmit.

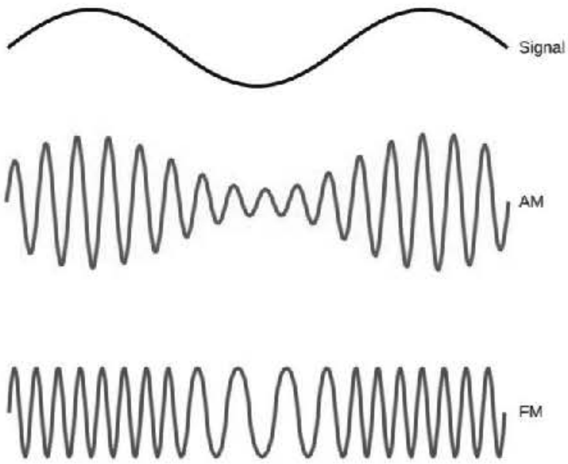
8. Which of the following shows the correct order of relative positions of five electromagnetic waves in the electromagnetic spectrum, in the order of decreasing wavelength?

   A. ***microwaves, infra-red, visible light, ultra-violet, X-rays***
   B. ***microwaves, ultra-violet, visible light, infra-red, X-rays***
   C. ***X-rays, infra-red, visible light, ultra-violet, microwaves***
   D. ***X-rays, ultra-violet, visible light, infra-red, microwaves***
   E. ***visible light, infra-red, microwaves, ultra-violet, gamma rays***

2. Radio waves

(1) Details of Radio waves

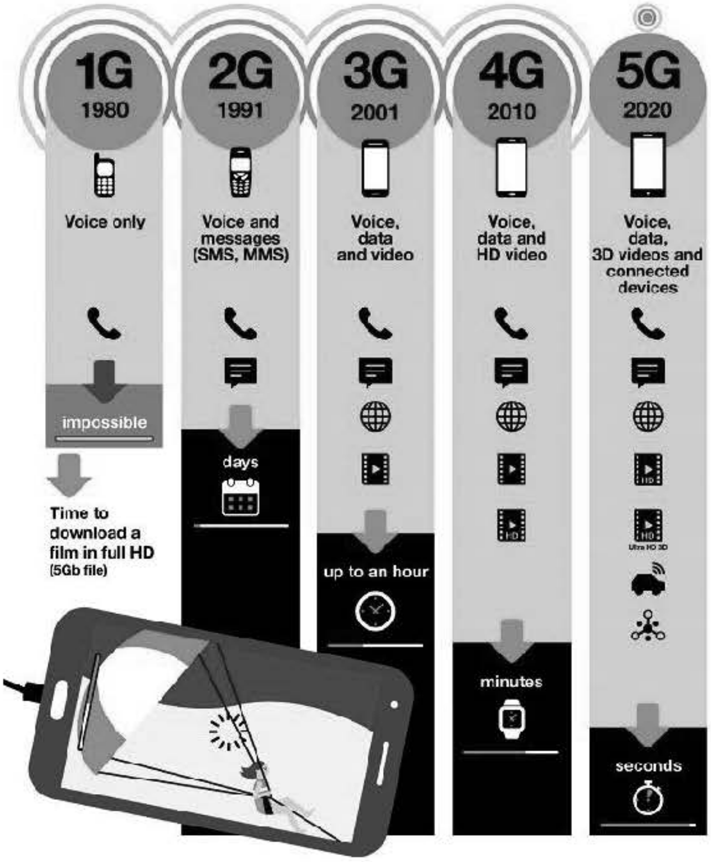
- Radio waves are mainly used for transmitting radio and TV signals.
- Radio waves are produced by oscillation of electrons and emitted by transmitters and they can be received by using antenna or aerial receiver.
- They can be broadcast by
  - Amplitude modulation (AM)
  - Frequency modulation (FM)



- According to the frequency, radio waves can be divided into a number of wavebends:
  - long waves (30 kHz to 300 kHz)
  - medium waves (300 kHz to 3 MHz)
  - short waves (3 MHz to 30 MHz)
  - very high frequency VHF (30 MHz to 300 MHz)
  - ultra high frequency UHF (300 MHz to 3 GHz)

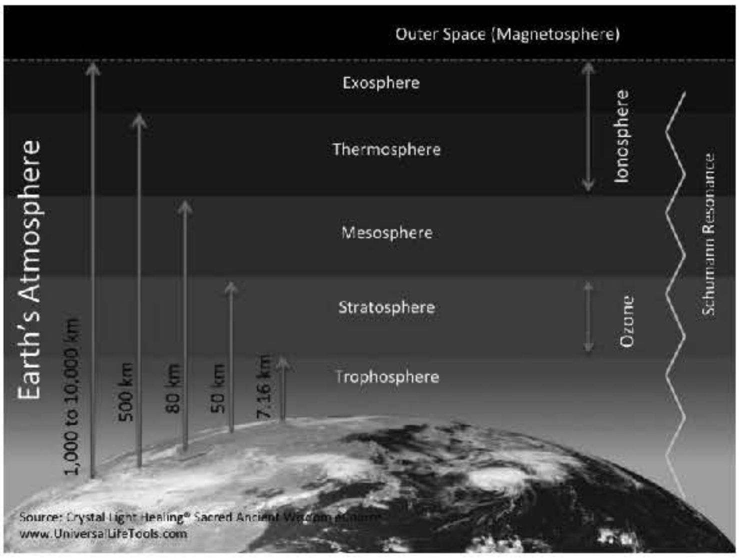
(2) Uses of Radio waves

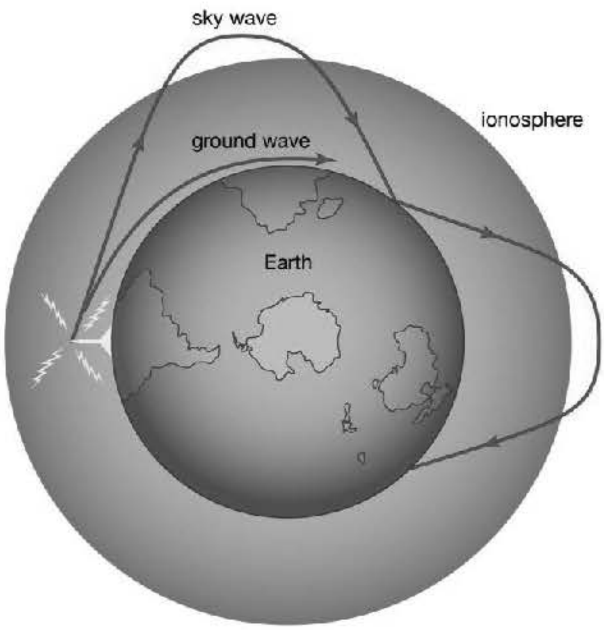
- **Radio broadcasting**
- **TV broadcasting**
- **Remote control of drones or toy cars**
- **Mobile phone communication**



(3) Reflection of Radio waves

- There is a part of the Earth's atmosphere full of ions, called ionosphere.
- The radio waves cannot penetrate through the ionosphere, instead, radio signals can be reflected by the ionosphere and propagate a very long distance.





(4) Diffraction and interference of Radio waves

- Due to the long wavelength of radio waves, they can diffract round obstacles and cover a large areas.
- As radio waves for TV signal have a higher frequency, shorter wavelength, it diffracts compared to radio waves for radio signal. As a result, the signal for radio is usually better than signal for TV.
- Destructive interference may occur when radio waves are reflected by low flying airplanes of other vehicles, resulting poorer signal temporarily.
- In order to avoid destructive interference of radio waves emitted from 2 nearby statins, the radio waves transmitted by them must have slightly different frequencies.

Examples that you must fully understand

1. 雷霆 881 broadcasts at the frequency of 88.1 MHz in Hong Kong Island, most of the Kowloon areas while in Sha Tin and Ma On Shan, it broadcasts at 89.2 MHz.

   (a) Calculate the wavelength of the radio wave Billy will receive if he listens to 雷霆 881 in Wanchai.

   (b) Which of the following statements is/are correct?

   (1) The radio signal in Central travels faster than that in Ma On Shan.

   (2) The signal is broadcasted at different frequencies so as to avoid interference.

   (3) The radio signal in Tsim Sha Tsui diffracts more round the high buildings than that in Sha Tin.

2. Mary finds that the TV signal reception is poorer than the radio signal. Why?

   Since the ______ of the TV waves is ______ than that of the radio waves, the TV waves ______ round obstacles, resulting in a poorer signal.

3. Joey lives in a house built between two transmitting stations (A and B). The distance between her house and station A is 3.95 km while the distance between her house and station B is 3.20 km.

   (a) How will the reception be affected if both of the stations transmits radio waves of frequency 600 kHz.

   As the ______ is equal to ______, the two signals will give ______ interference, resulting in poor signal.

   (b) What should the radio company do to avoid poor signal?

   The frequencies transmitted by the two stations should be ______ to avoid ______ of signals from 2 nearby stations.

3. Microwaves

(1) Details of Microwaves

- Microwaves can be considered as radio waves with shorter wavelength.
- Microwaves can be produced by a 3 cm-transmitter and received by a microwave receiver which is connected to a loudspeaker or a meter.

(2) Wave phenomena of microwaves

- **<u>Reflection</u>**: Microwaves cannot pass through metal and can be reflected by metal plate.
- **<u>Refraction</u>**: Microwaves change their speed and wavelength when they pass through different materials and thus refracted. A prism filled with paraffin oil can be an example.
- **<u>Diffraction</u>**: Microwaves can be diffracted when passing through a gap.
- **<u>Interference</u>**: A transmitter emits microwaves to two small slits or two transmitters emitting microwaves with same frequency act as two coherent sources.

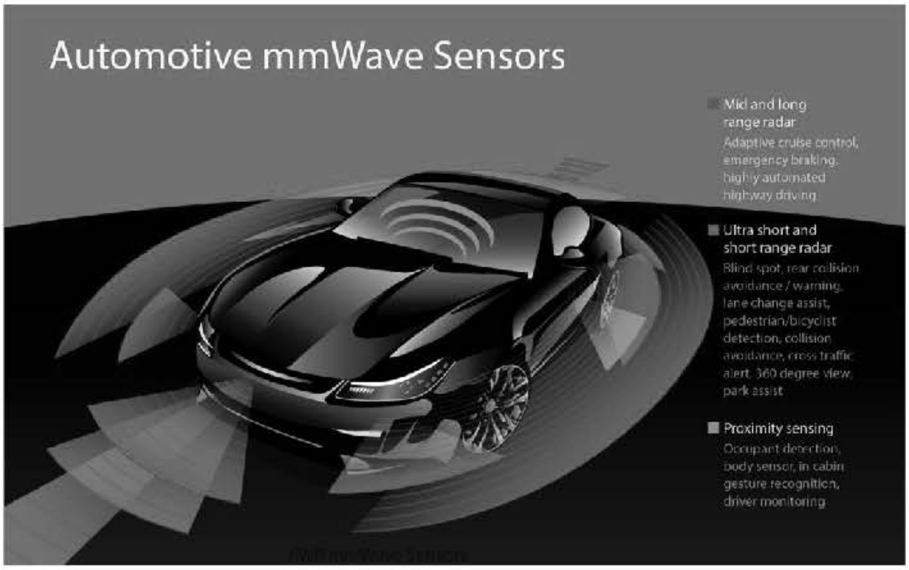
(3) Applications of microwaves

- **<u>Microwave oven:</u>**
  - *Microwaves can penetrate deep into the food.*
  - *Food absorbs microwave and is heated up shortly inside and on the surface.*

- **Radar:**

  - A microwave pulse is transmitted and reflected by an obstacle. Measuring the time the pulse received can know the distance of the obstacle.

  - Making a series of measurement can also find the obstacle's velocity.



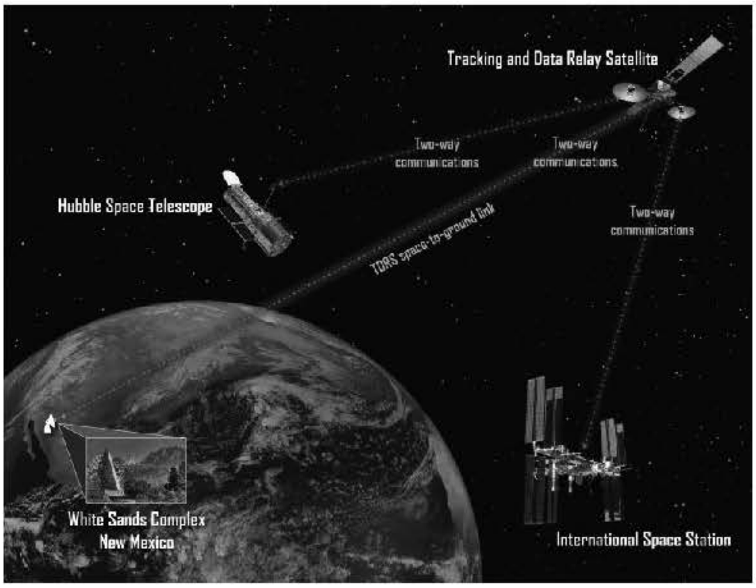
- **Radar speed gun:**

  - Similar to a radar, it can be used by police to measure the speed of moving vehicles.

- **Satellite communication:**

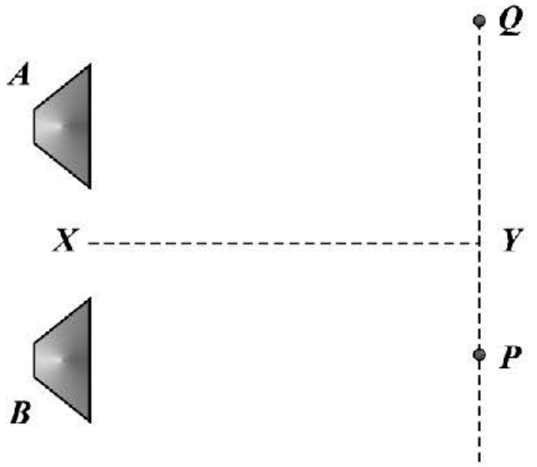
  - Microwaves can penetrate the atmosphere reaching the satellite.

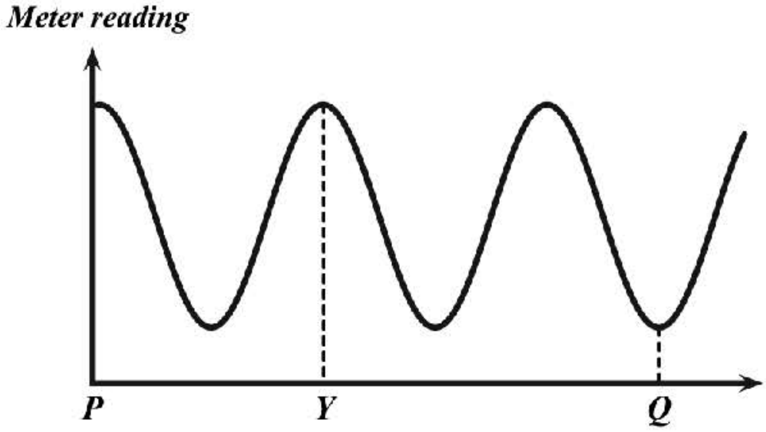
  - A concave collector is used to reflect and focus the microwave received to the collector.



Examples that you must fully understand

1. The figure below shows two transmitters A and B connected to the same signal generator emitting $3\ \mathrm{cm}$ microwaves. The receiver is connected to a meter detecting the intensity of the microwaves at different locations. The variation of the reading of the meter along PQ is shown.





(a) Explain why at point P, a maximum value of meter reading is observed while at point Q, a minimum value of meter reading is observed.

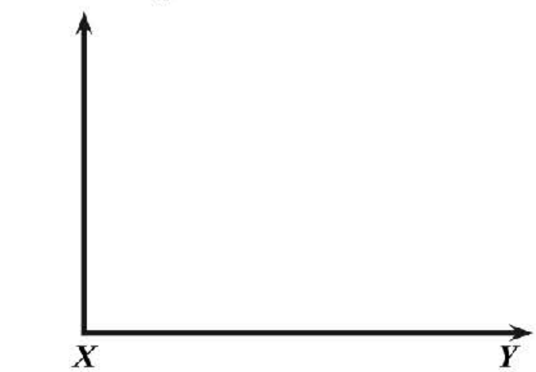
P is at a point of ______ while Q is at a point of ______ interference.

(b) If the distance between A and Q is $25\ \mathrm{cm}$, what is the distance between B and Q?

(c) Give two reasons to explain why the meter reading does not drop to zero at point Q.

Since the paths AQ and BQ are different, the ______ of the two waves reaching Q is different, therefore, destructive interference at Q is ______. Also, there are ______ of microwaves from the surrounding objects reaching the receiver at Q.

(d) Sketch a graph showing the variation of meter reading along XY and explain.

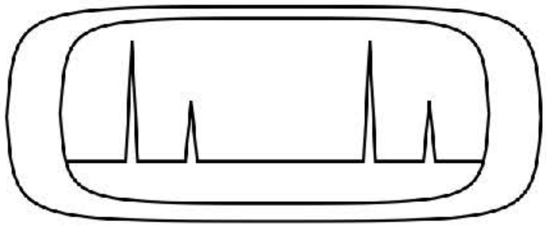


The meter reading is always ______ since ______ always occurs along XY as the path difference is always ______. However, the reading ______ with distance from X since ______.

(e) If the transmitter B is switched off, what is the effect on the meter reading at P and Q?

The ______ will ______, and the microwave energy will be redistributed. Therefore, the meter reading at P would ______ and that at Q would ______.

2. A radar sends a microwave pulse in every 0.40 s. At a certain instant, the receiver detects a UFO reflecting the first pulse after a time interval of 30 muis and the second pulse after a time interval of 28.7 muis.



(a) Calculate the speed of the UFO.

(b) Is the UFO approaching or receding?

Since the distance measured by the second pulse becomes ______, the UFO is ______ the radar.

(c) Explain why the reflected pulse has a smaller amplitude than the incident pulse.

Since the UFO can only reflect ______ incident microwave pulse.

3. Read the following passage about a stealth bomber.

There are a few features in a stealth bomber to hide from enemy sensors. The aircraft has to blend in with the background visually and its engine needs to be very quiet. Furthermore, its surface is particularly good at absorbing radio waves. Also, the large flat area on the top and the bottom of the aircraft reflect most incoming radio waves away from the radar station. In regard to infrared sensors which typically picks up on hot engine exhaust, all of the exhausts produced by a stealth bomber pass through cooling vents before releasing. With these designs, a stealth bomber is able to fly almost undetected.

(a) Explain how the bomber can hide from radar systems.

The surface of the bomber is good at ______ and the ______ can ______ most radio waves away from the radar.

(b) Explain how the bomber can hide away from infra-red detectors.

All the exhausts will be ______ so that the ______ will be reduced.

(c) State two other essential features to hide away from enemy detection.

The engine is very ______ and the bomber can blends in with the background visually.

4. Infra-red radiation

(1) Source of infra-red radiation

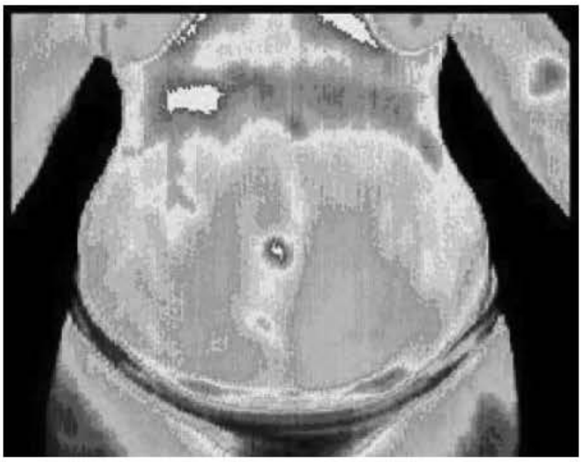
- Infra-red radiation is produced by all bodies at a temperature above absolute zero.
- The higher the temperature, the greater is the intensity of the infra-red radiation emitted.

(2) Characteristics of infra-red radiation

- Objects with black colour or rough surface are good absorbers or emitters of infra-red radiation.
- Objects with white colour and shiny surfaces are poor absorbers or emitter of infra-red radiations.
- Infra-red radiation can be detected by a blackened thermometer.

(3) Applications of infra-red radiation

- <u>Remote control in TV</u>
- <u>Auto-focus of camera</u>
  - Old camera auto-focus system emits infra-red radiation which is reflected by the object.
  - By measuring the time the camera receives the reflected infra-red radiation, the camera can calculate the distance of the object. The lens is then adjusted for focusing.
- <u>Detection of trapped survivors</u>
  - The temperature of survivors are higher than surrounding objects. Thus, the survivors emit infra-red radiation with stronger intensity.
  - This can be used to locate the survivors.
- <u>Night vision</u>
  - Night vision system can detect infra-red radiations emitted by objects and convert into visible light for human eyes to see.



- **Medical diagnosis**
  - Detecting the infra-red radiation emitted by a patient in different part of his/her body can be a means to help doctor diagnoses.
- **Domestic electric heaters**
- **Burglar alarm / motion sensors for lighting**
  - These systems detect the change of infra-red emission in an area to detect burglars or human activity.
- **Infra-red photography**
  - Infra-red photos, called thermographs, can show the details of temperature distribution.

Examples that you must fully understand

1. Which of the following statements concerning IR radiation is/are true?

   (1) IR radiation is red in colour.

   (2) At night, infra-red radiation can be seen by human eyes.

   (3) IR radiation has a lower frequency than red light.

   (4) IR travels slower in vacuum.

2. Which of the followings is/are applications of IR radiation?

   (1) To detect body temperature.

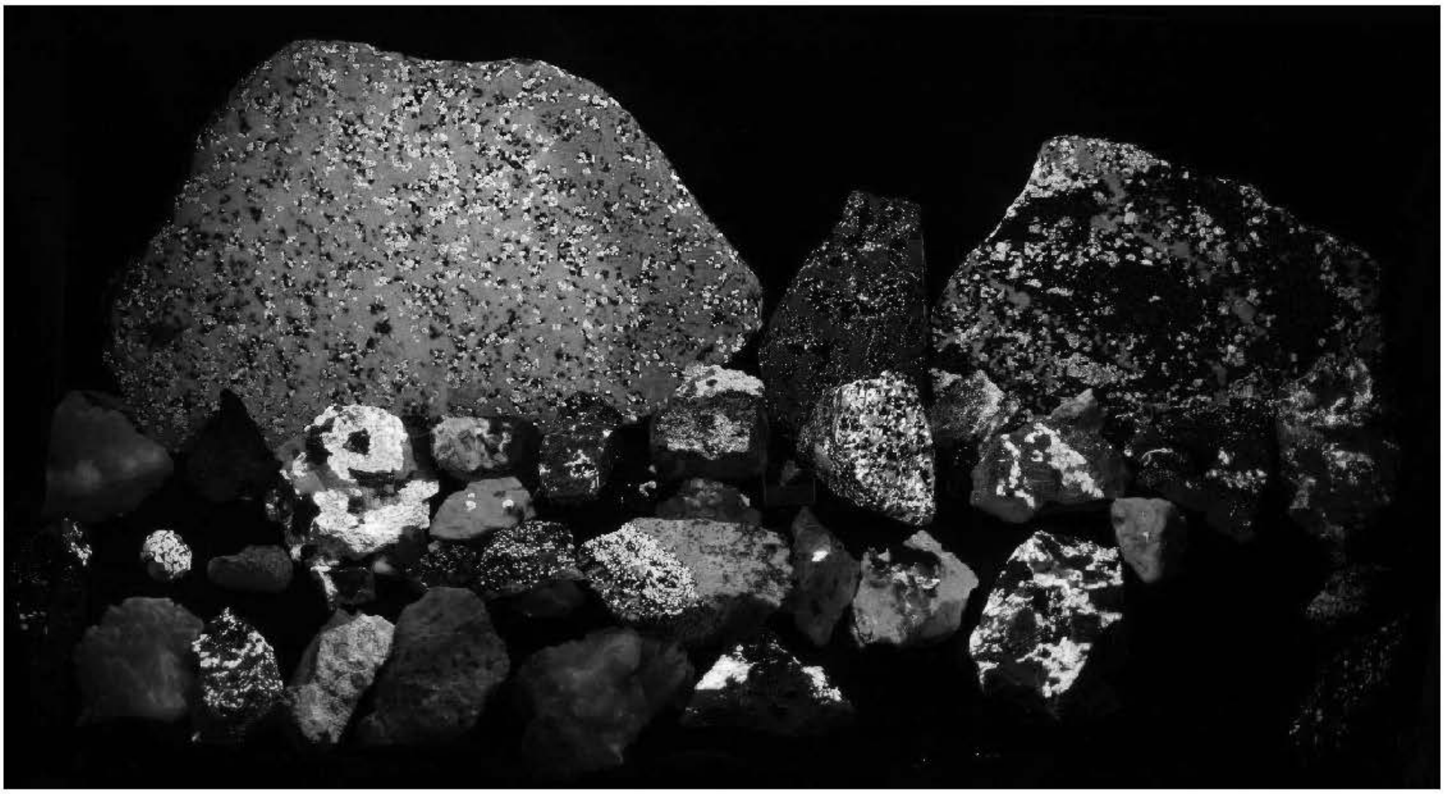
   (2) To communication with/between devices.

   (3) To be used in night vision.

5. Ultra-violet radiation

(1) Characteristics of Ultra-violet radiation

■ UV radiations can be produced by ultra-violet lamps and can be detected by fluorescent materials.



■ UV produced by the Sun are largely absorbed by the ozone layer in the atmosphere. However, some UV can still reach human body causing the following effects:

- **Inducing vitamin D production in the skin**
- **Leading to "sun-tan"**
- **Increasing the chance of having skin cancer**

(2) Applications of Ultra-violet radiation

■ <u>To sterilize drinking water</u>

- By destroying the DNA of bacteria and virus, UV can sterilize drink water.

■ <u>To identify real banknote</u>

Examples that you must fully understand

1. Which of the following is/are the harmful effect of using UV lamps to tan the skin?

   (1) UV radiation is absorbed by skin cells causing genetic change to affect the future generations.

   (2) UV radiation can penetrate deep the skin can kill the cells inside body.

   (3) UV radiation can damage body tissue by its strong heating effect.

   (4) Over exposure of UV can cause skin cancer.

2. Which of the followings is/are correct?

   (1) Our skin will not get burnt in a cloudy day.

   (2) Our skin will not get burnt under water.

   (3) Tanned skin is healthier.

   (4) If your skin doesn't feel hot, it means your skin is not burnt.

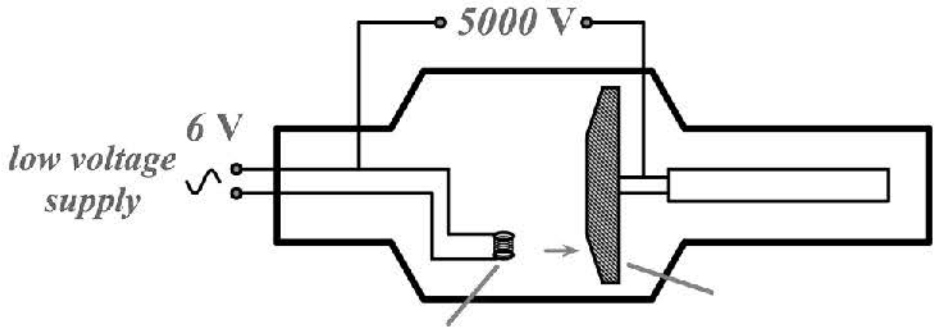
   (5) Out skin will not get burnt if taking rest during sun tanning.

   (6) Freckle and mole can be caused by UV light.

6. X-rays

(1) Generation of X-rays

- X-ray is produced when fast moving electrons hit a metal block.

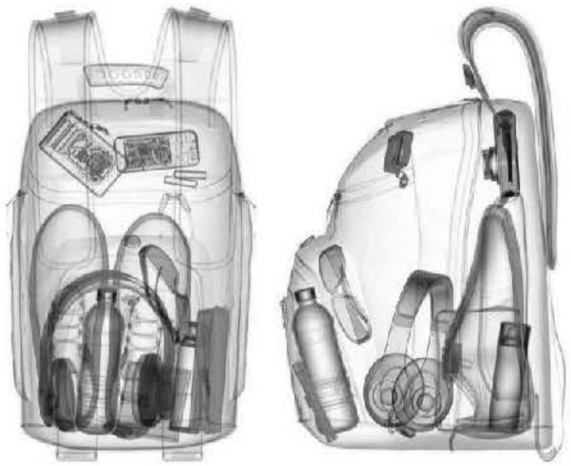


(2) Characteristics of X-rays

- X-rays have high penetrating power.
- X-rays can expose photographic film, making them dark.
- Over exposure to X-rays is dangerous and can cause cancer.

(3) Applications of X-rays

- <u>To help doctor diagnose diseases</u>
- <u>To detect forbidden objects in luggage</u>



7. Gamma rays

(1) Characteristics of Gamma rays

- Gamma rays are emitted from the decay of nucleus of radioactive isotopes.
- Gamma rays have extremely high penetrating power.

(2) Applications of Gamma rays

- <u>Radiotherapy to treat cancer cells</u>
- <u>Medical tracer for doctors to diagnoses</u>

Examples that you must fully understand

1. The SI unit of time, second, is defined as 9 192 631 770 times the period of the EM wave emitted from a caesium-133 atom.

   (a) What is the frequency of the radiation emitted from the caesium-133 atom?

   (b) What is the wavelength of the radiation emitted?

   (c) Before 1983, the SI unit of length, meter is defined as 1 650 763 times the wavelength of light emitted from a kypton-86 atom. What is the wavelength of this light?

2. Write down the appropriate type of EM waves that can:

   (1) be detected by human-body:

   (2) produce sun-tan:

   (3) pass through flesh:

   (4) pass through bones:

   (5) be reflected by the Earth's atmosphere:

   (6) not pass through the ozone layer:

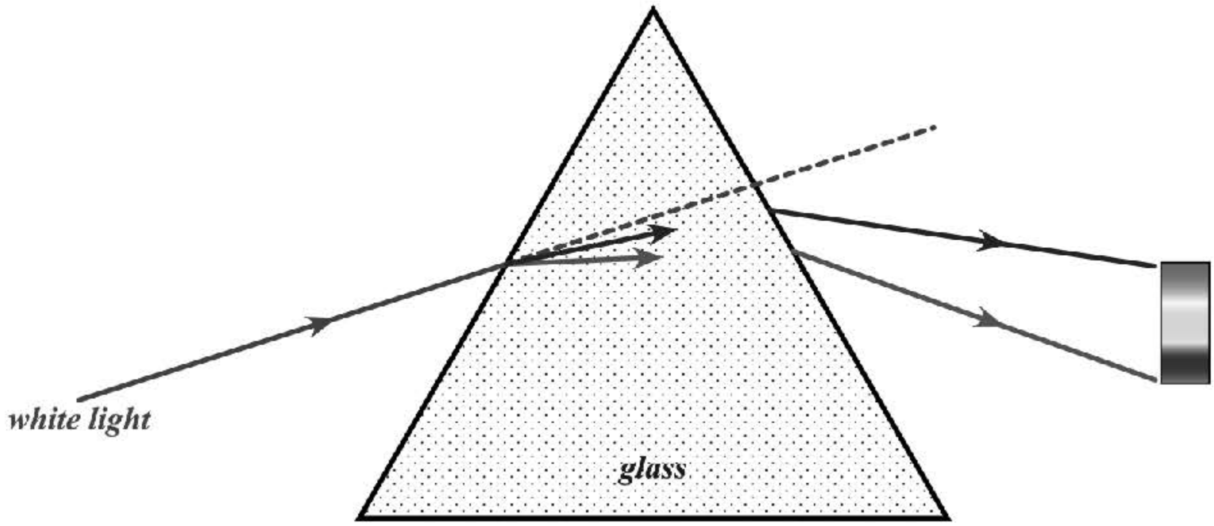
   (7) spread and cover most of the areas:

   (8) be used in heating food:

8. Visible light

(1) The spectrum of visible light

- White light consists of different colour of light. When white light passes through a glass triangular prism, it dispersed into different colours.



- The range of wavelength of visible light is from 400 nm (violet) to 700 nm (red).

Examples that you must fully understand

Which of the following statements concerning visible light is/are correct?

(1) Visible light enables human to see things.

(2) Visible light enables photo or video capturing.

(3) Photosynthesis makes use of visible light to make food for plants.

(4) When light travels from air to glass, the frequency remains unchanged.

(5) When light travels from air to glass, the speed of light is decreased.

(6) The wavelength of red light is longer than that of violet light.

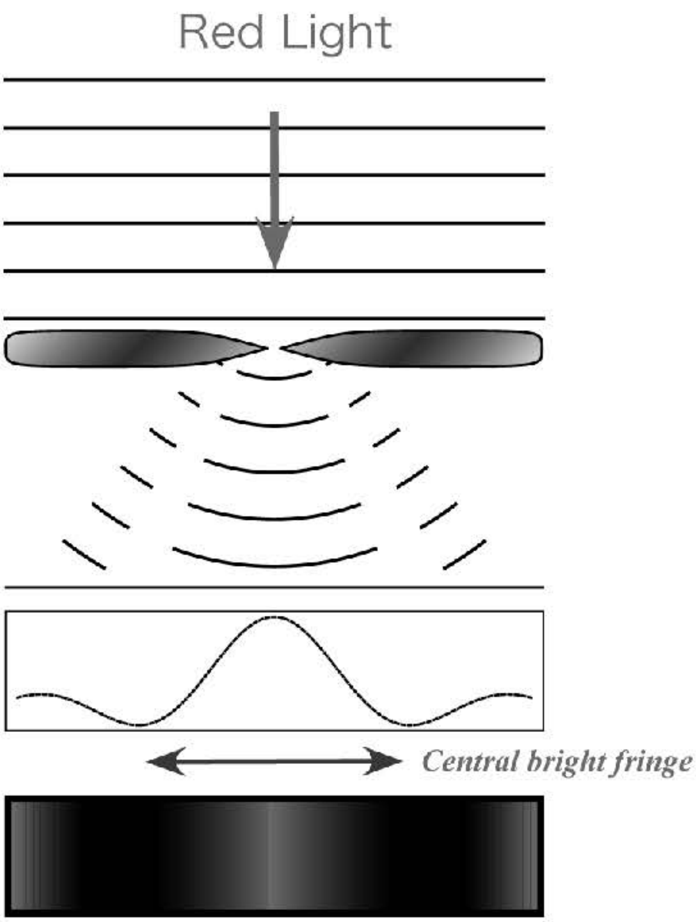
(7) The speed of red light in air is different from that of violet light in air.

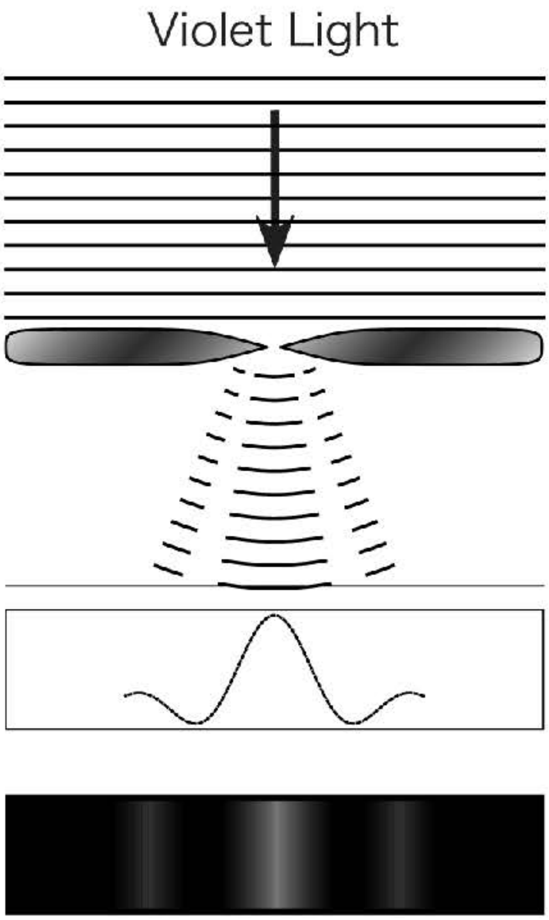
(8) The speed of red light in glass is different from that of violet light in glass.

(9) The refractive index for red light in glass is smaller than that of the violet light in glass.

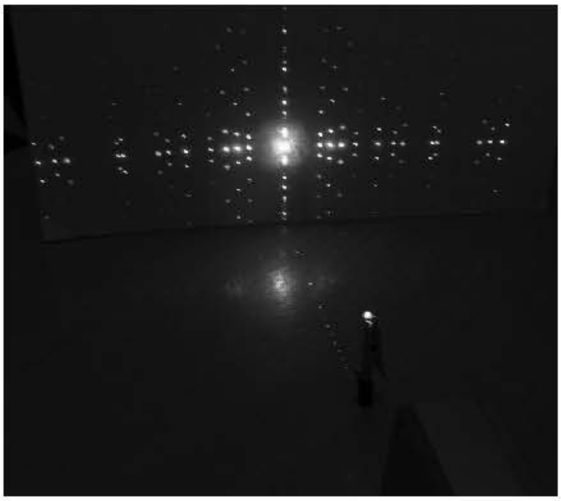
(2) Single slit diffraction of light

- As the wavelength of light is very short, light has a very small degree of diffraction. Therefore, the diffraction of light is not obvious in daily life.
- When a monochromatic light passes through a narrow single slit (~**0.01 mm** width), light spreads out and produce a diffraction pattern.
- The diffraction pattern of light is composed of a central bright fringe with a central band width and higher orders of minima and maxima.





- When white light passes through a single slit, the resultant pattern will be an overlap of diffraction patterns of different colours, as the degree of diffraction of different wavelengths of light is not the same.



Examples that you must fully understand

White light diffracted by a single slit falls on a screen. Which of the following statements is/are correct?

(1) The central bright fringe is wider for red light than for blue light.

(2) If the width of the slit is reduced, the width of central bright fringe would increase.

(3) The centre of the diffraction pattern is white.

(4) If the amplitude of light increases, the angle of diffraction increases.

(3) Interference of light

- Ordinary light source emits lights in a random manner. Therefore, two independent light sources do not have constant phase difference. As they are not coherent sources, no interference pattern can be observed.

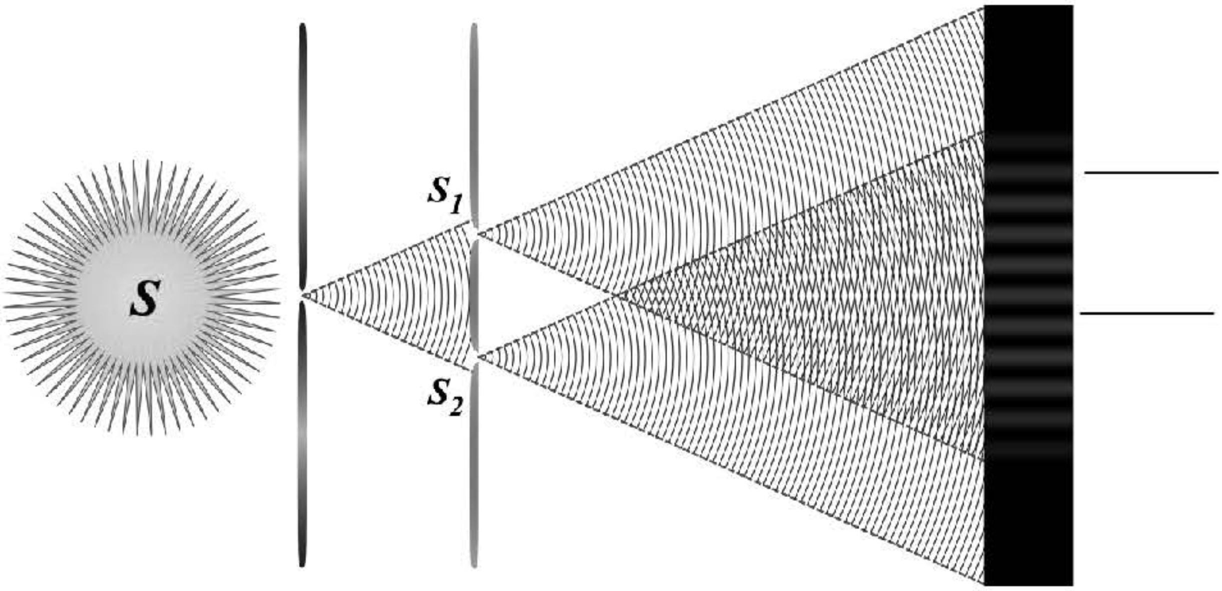
- Moreover, the wavelength of light is so short that the two sources must be very close to each other so as to obtain an observable interference pattern. But it is hard for two ordinary light sources to be close enough.

- Young solved the problem by using a single light source with a double slit.

9. Young's Double Slit Experiment

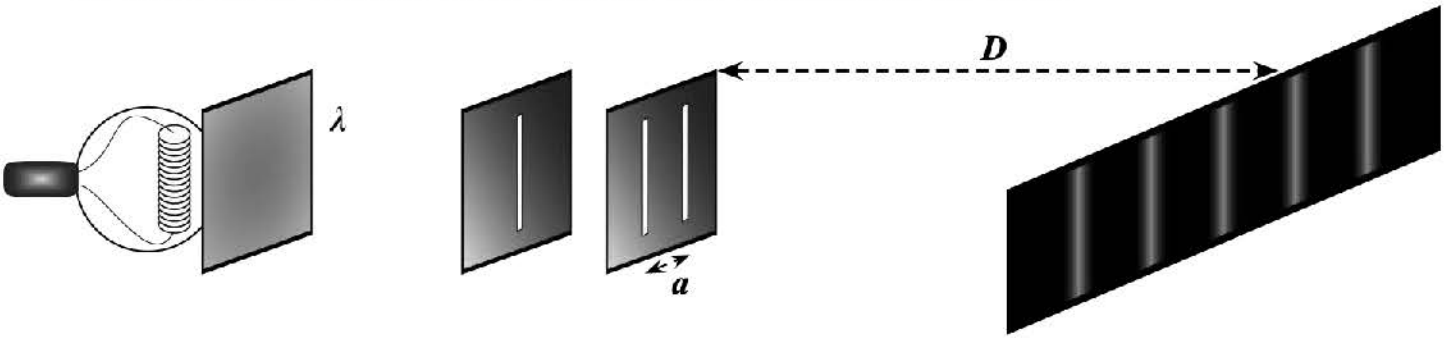
(1) The experimental set-up

- Young's experiment has a single light source S, a single slit and a double slit. The same wavefront from the single slit reaches the two close and narrow slits S_1 and S_2 to form 2 coherent point sources.



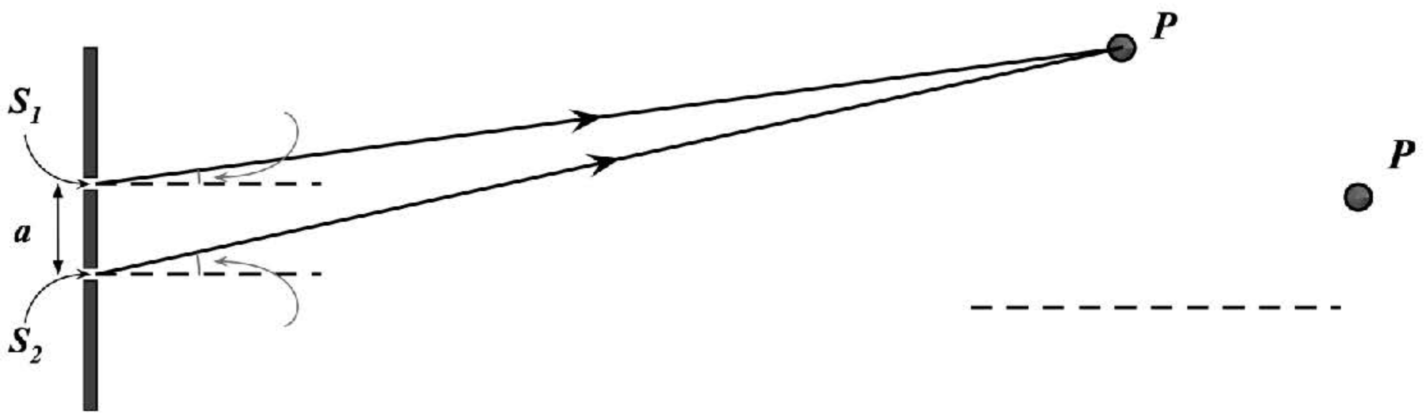
(2) The experimental set-up

- The filament of the light bulb should be parallel to the slit.
- Monochromatic light source should be used by placing a filter in front of the light bulb or by using sodium lamp or laser.
- The slits should be narrow so that light passing them can undergo diffraction.
- The double slits should be close enough and the screen should be placed at an appreciable distance from the slits to obtain an observable fringe pattern.
- The whole set-up should be shield so that no stray light falls onto the screen.

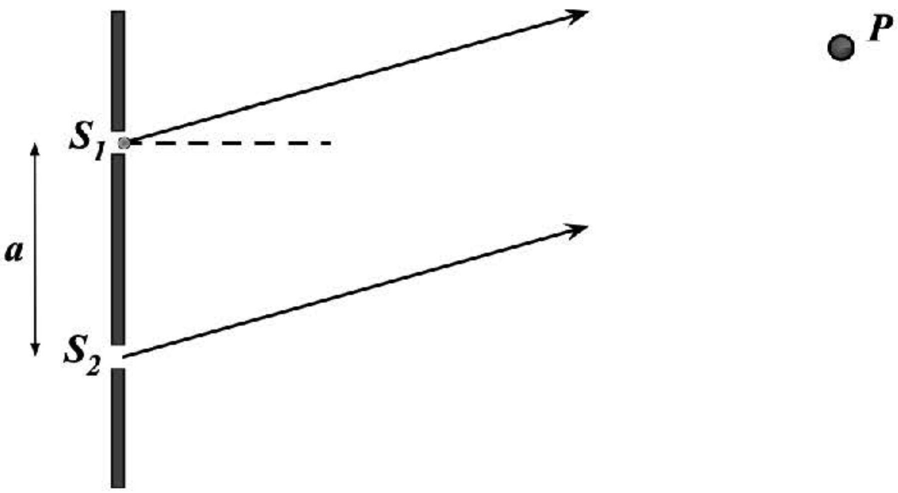


(3) Path difference of light

- Since the two slits are very close to each other (relative to the distance from the screen), the two light rays passing the slits can be treated as two parallel rays.



Approximated path difference in double slit experiment

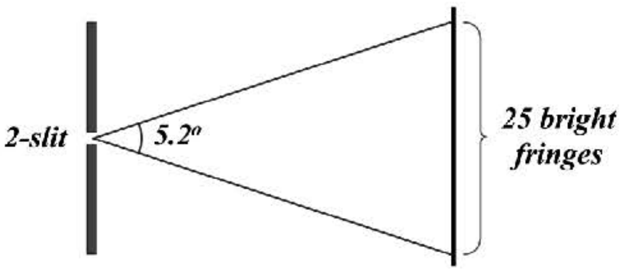


Constructive:

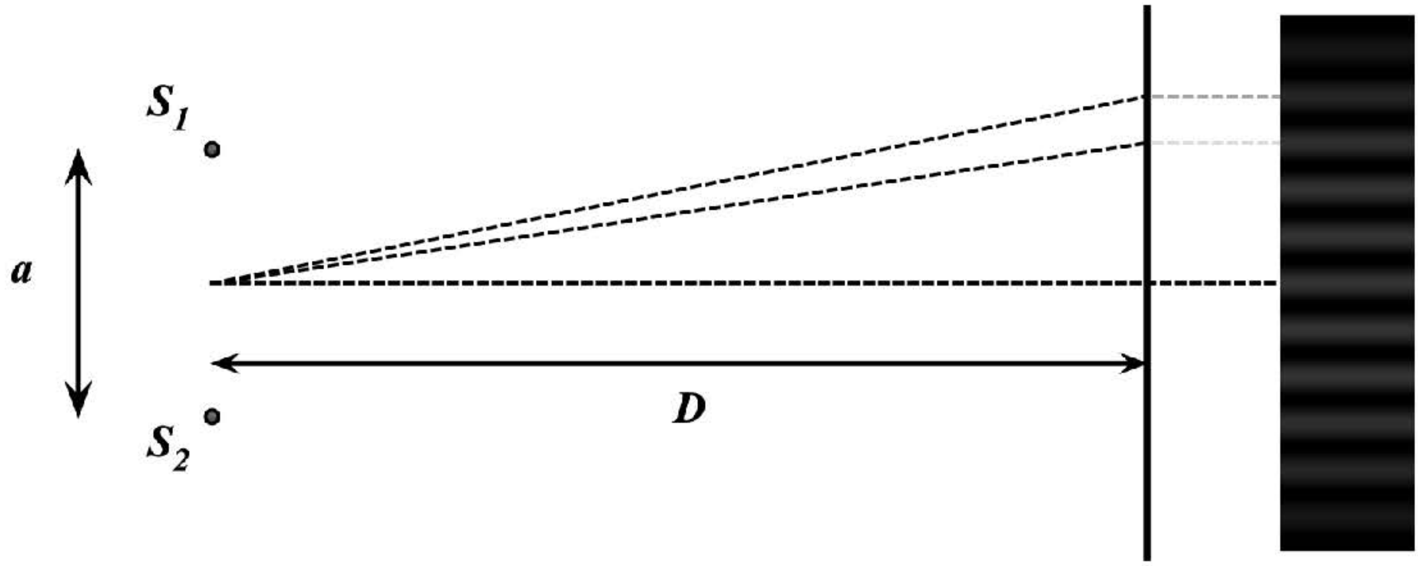
Destructive:

Examples that you must fully understand

In a Young's double slit experiment, the separation of the slits is 0.15 mm. when a monochromatic light source is used, 25 bright fringes are observed within an angular separation of 5.2° as shown in the figure below. Calculate the wavelength of the light source.



(4) Fringe separation



- Suppose the slit separation is a and the screen is placed at a distance D from the double-slit.
- If the angle theta is small, by small angle approximation:
- For the ***nth*** bright fringe:
- For the ***(n+1)th*** bright fringe:
- The fringe separation is therefore:

Equations for Double Slit Experiment	
Path difference	**Fringe separation**

Examples that you must fully understand

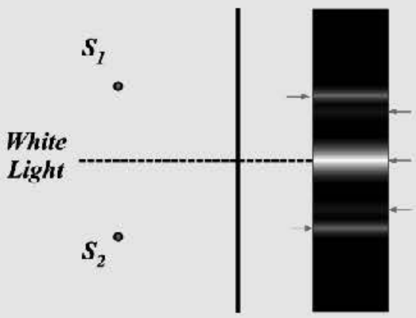
In a Young's double slit experiment, the separation between two slits is 0.1 mm and the screen is placed at 2 m away. The light source is emitting blue light of wavelength 4.6×10^{-7} m.

(a) Calculate the separation between two adjacent bright fringes on the screen.

(b) What is the separation between the first and the eighth dark fringes?

(c) What is the path difference at the 11^{th} dark fringe?

(5) Factors affecting the fringe pattern

(I) Slit separation	(II) Wavelength	(III) Distance
• • If the slit separation is too large (e.g. 1 mm), the fringe separation would be too small to be observed. • If the slit separation is too small (e.g. 0.01 mm), the fringe separation would be too large. The alternative bright and dark fringe patter can be hardly seen.	• • If white light is used, 	• • If the distance is too large, the bright fringes on the screen would be too dim to be observed.

Examples that you must fully understand

1. Violet light of wavelength $450\,\text{nm}$ is used in a Young's double-slit experiment.

   (a) If the path difference at a point, P on the screen from the two slits is $900\,\text{nm}$, which of the following statements is/are correct?

   (1) P is the second bright fringe.

   (2) P would become a dark fringe if another light of wavelength 600 nm is used.

   (3) If the distance of the screen from the double-slit is double, then point P on the screen would become a dark fringe.

   (4) If the separation between 2 slits is increased to 1 cm, no interference pattern can be observed.

   (b) Which of the following methods would result in a greater fringe separation on the screen?

   (1) Using a red light source of longer wavelength.

   (2) Using another double-slit with greater slit separation.

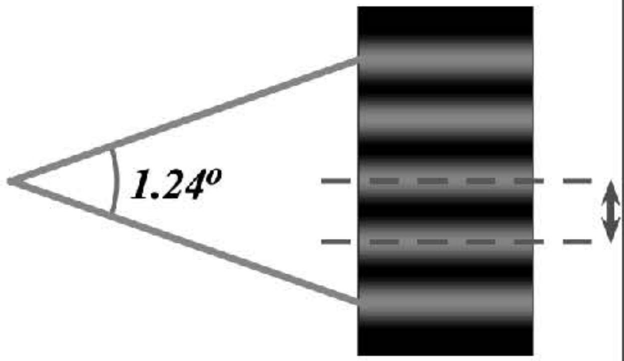
   (3) Using another double-slit with greater slit-width.

   (4) Increasing the separation between the light source and the double-slit.

   (5) Placing the whole set-up into water instead of air.

2. In a Young's double slit experiment, the separation of the slits is $0.12\,\text{mm}$. When a monochromatic light source is used, 5 bright fringes are observed within an angular separation of 1.24° subtended at the center of the 2 slits.

   (a) What is the angular separation between two adjacent bright fringes?



   (b) If the screen is placed at $1.5\,\text{m}$ from the 2-slit,

   (i) what is the separation between two adjacent bright fringes?

   (ii) if the length of the screen is $50\,\text{cm}$, what is the maximum order of the bright fringe that can be observed, provided that light diffracted from both slits can cover the whole screen.

(c) What is the wavelength of the light source?

(d) It is found that the second order maximum of this light coincides with the third order maximum of another light ray. Calculate the wavelength of this light ray.

(e) Explain what would be observed for each of the following:

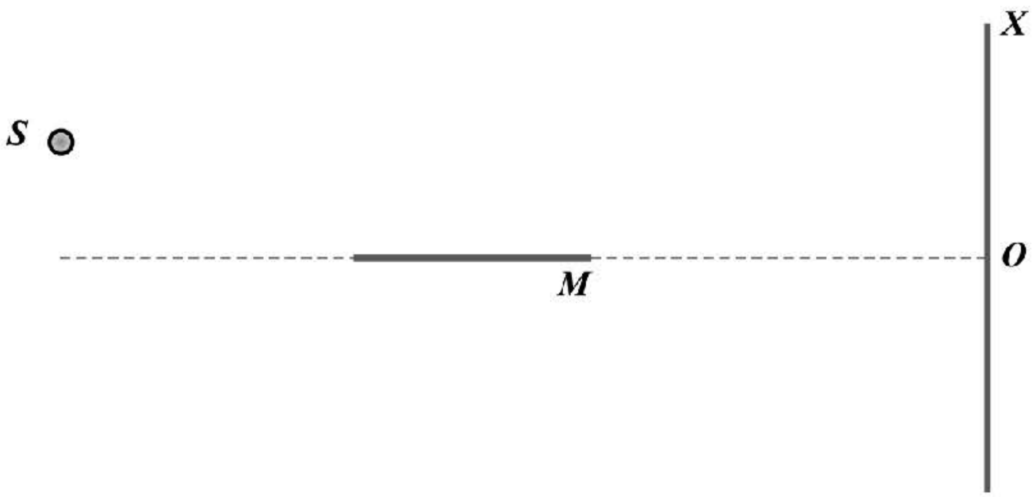
(i) The slit width of one of the slits is made several times narrower than the other slit.

As the amplitude of light from the two sources are [ ], destructive interference is [ ], interference cannot be observed since the [ ] between destructive and constructive interference [ ].

(ii) The slit widths of both slits are doubled but the slit separation remains unchanged.

The [ ] but [ ] will be observed since the diffraction at both slits is less [ ], as a result the [ ] decreases.

3. A plane mirror M is illuminated by monochromatic red light from a source S. An interference pattern is observed on the screen at a certain distance from the mirror. Which of the following statements about the interference pattern on the screen is / are correct?



(1) No interference pattern can be observed in the region OX on the screen.

(2) As the mirror M moves downward, the separation of the fringes decreases.

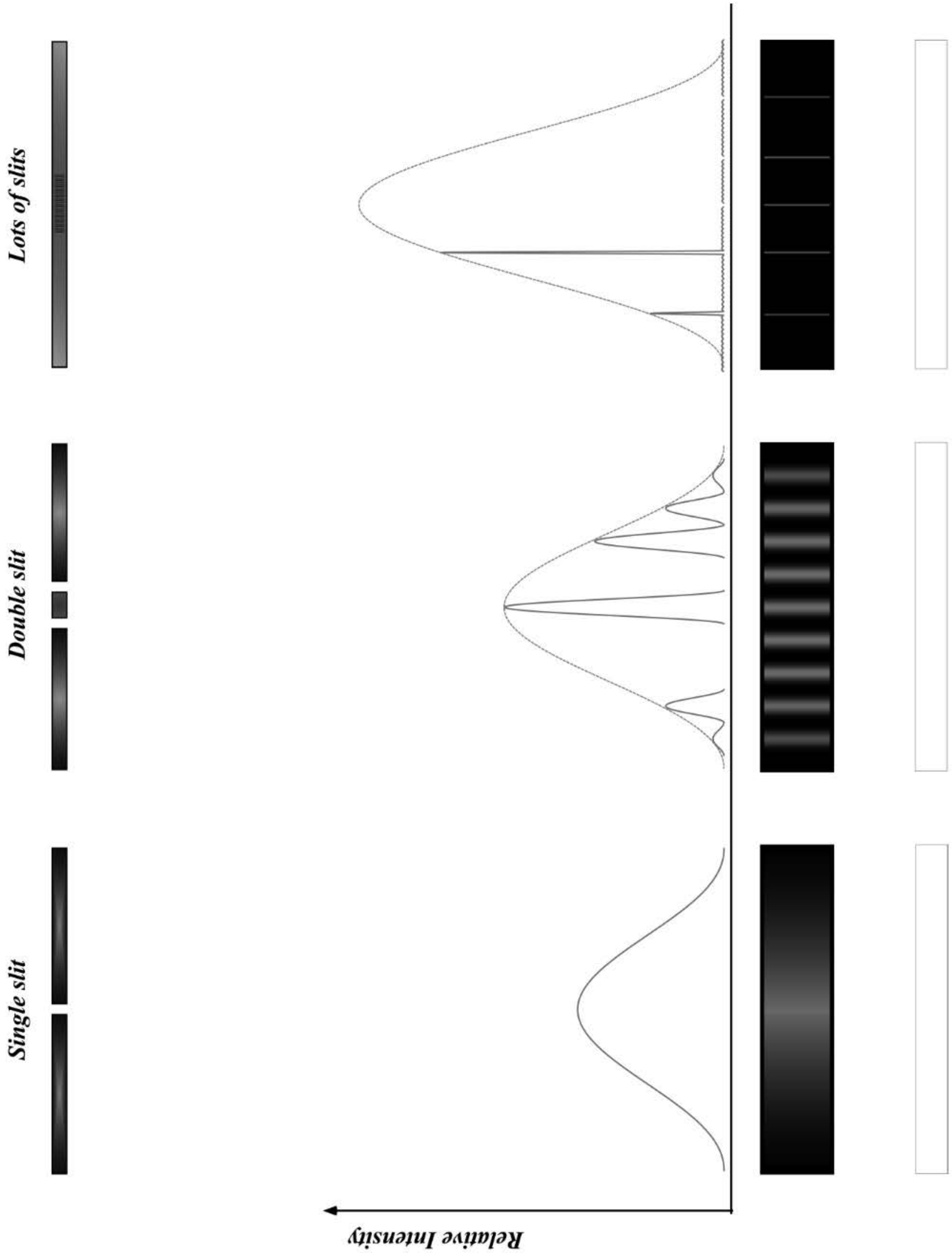
(3) As the mirror M moves horizontally away from the screen, the separation of the fringes increases.

(4) If monochromatic violet light is used, the separation of the fringes remains unchanged.

(5) A bright fringe would be observed at O.

10. Plane Transmission Grating

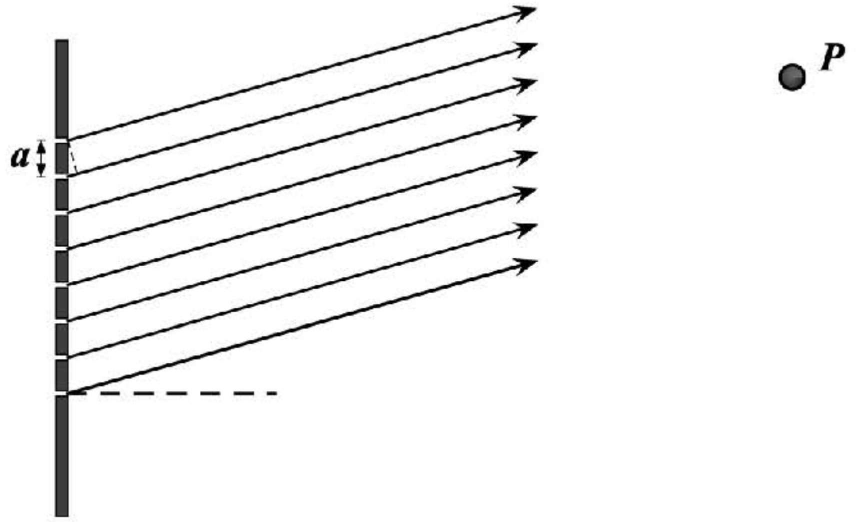
(1) Comparison between different number of slits



(2) Path difference in diffraction grating

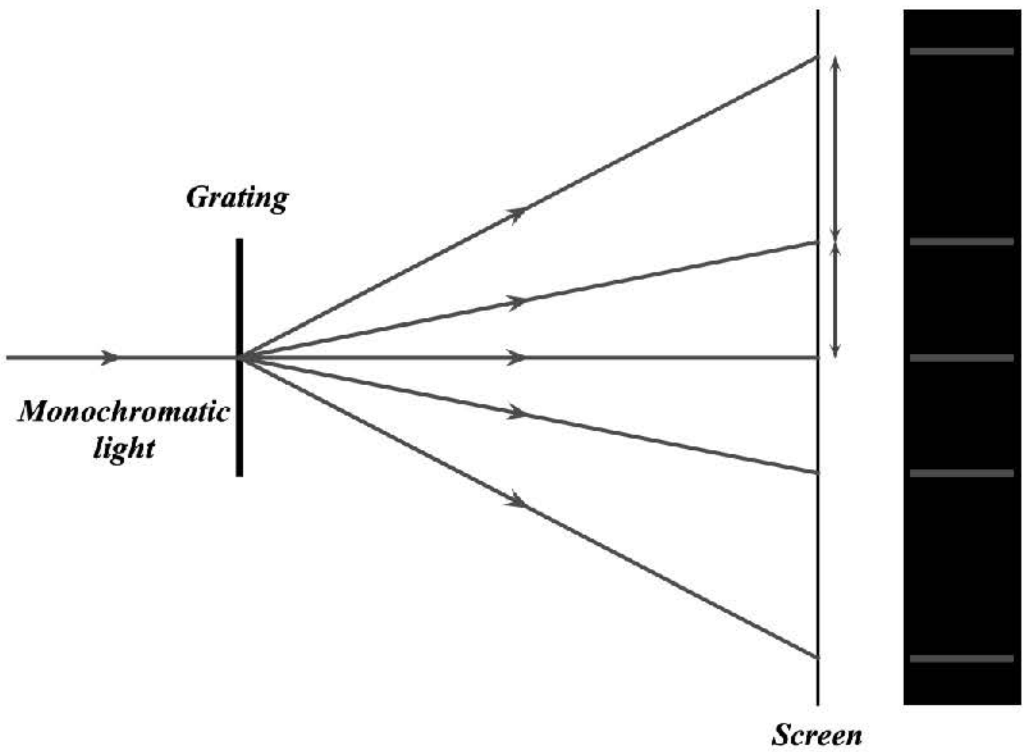
- In a (diffraction) grating, each narrow slit acts as a source of light.

Approximated path difference between any 2 adjacent slits



Bright Fringes:

Dark Fringes: NO need to consider



Examples that you must fully understand

1. The below 2 figures show the pattern observed by using multiple-slits. Which of the following statements is /are correct?

(1) ***The fringe separation in figure 1 is greater than that in figure 2.***

(2) ***The fringes in figure is sharper than that in figure 1.***

(3) ***Figure 2 has more number of slits.***

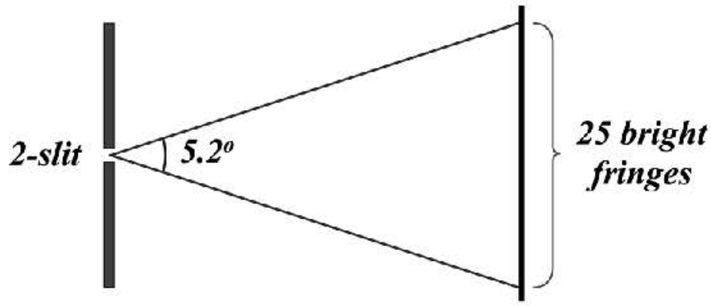
(4) ***The slit separation in figure 2 is smaller than that in figure 1.***

Figure 1

Figure 2

2. A transmission line grating has **600 rulings per millimeter**. When a monochromatic blue light source is used, it is found that the angle between the two first maxima is 28^o.

(a) Find the grating spacing and the wavelength of the light source.



(b) At what angle from the central line does the second order bright line occur?

(c) How many bright fringes totally can be observed?

(d) It is found that the third order of this monochromatic blue light is coincident with the second order of another monochromatic light source. Find the wavelength of this light source.

3. When blue light is passed through a diffraction grating, a pattern of maxima and minima is observed. Which of the following can increase the separation angle between the 2 first-order maxima?

   (1) Replace blue light with red light.

   (2) Increase the grating spacing.

   (3) Increase the number of grating lines per mm.

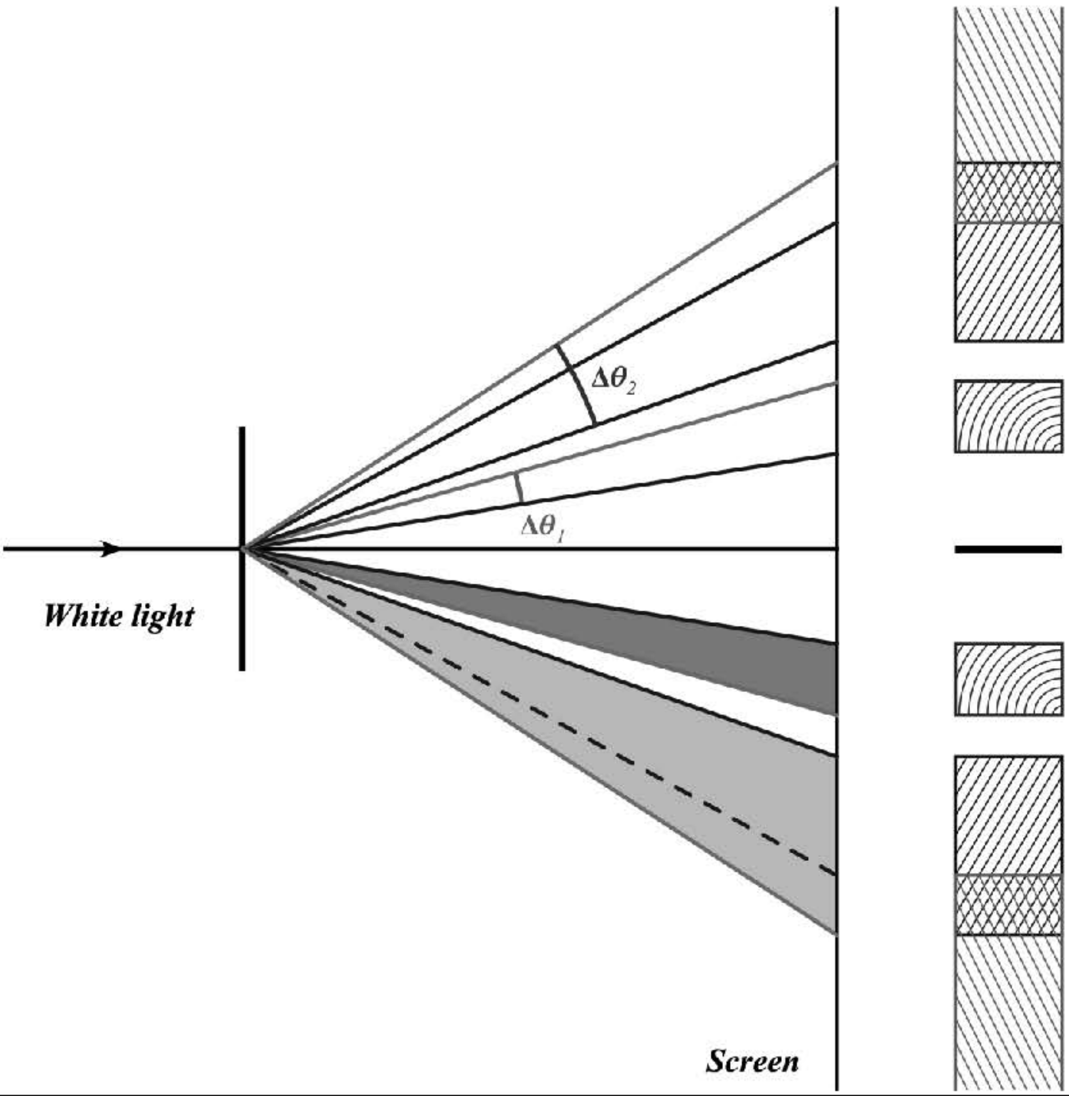
   (4) Increase the width of each slit.

   (5) Immerse the whole set-up into water.

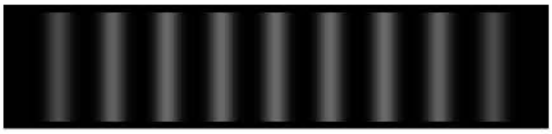
(3) Diffraction grating of white light

- Using white light in diffraction grating will produce a continuous spectrum and the zeroth order bright fringe is still white since every colour reaches here.

- The second order and the third order spectrum overlap:



(4) Advantages of using diffraction grating



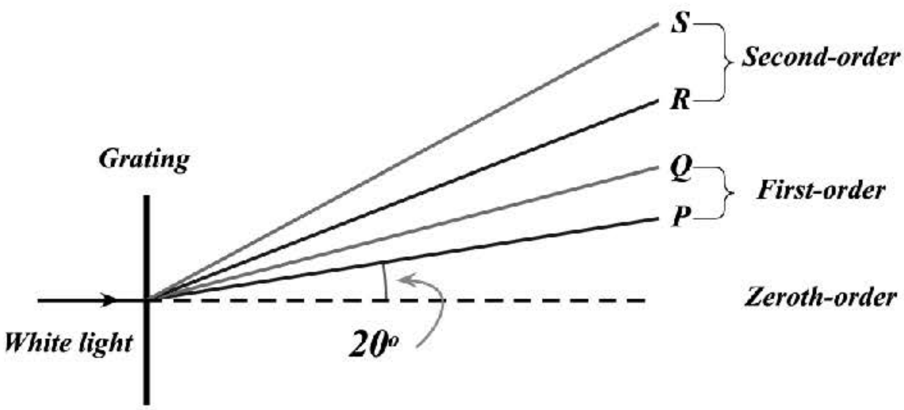
Double-slit Interference

Diffraction Grating

- The pattern of diffraction grating is sharper and brighter than a double-slit interference pattern.
- Since the slit separation in a diffraction grating is much smaller than that of a double-slit, the angular separation of the fringes is much larger. Thus the measurement of the angular separation or the fringe separation is much more accurate.

Examples that you must fully understand

1. A beam of white light is shone normally on a diffraction grating. The diagram below shows the spectra of the first two orders, which may not be drawn to scale. The first-order spectrum starts at an angle of 20° from the zeroth order. The respective angular separations between the two ends (red and violet) of a spectrum are α and β for the first- and second- order spectra. Which of the following statements are correct?

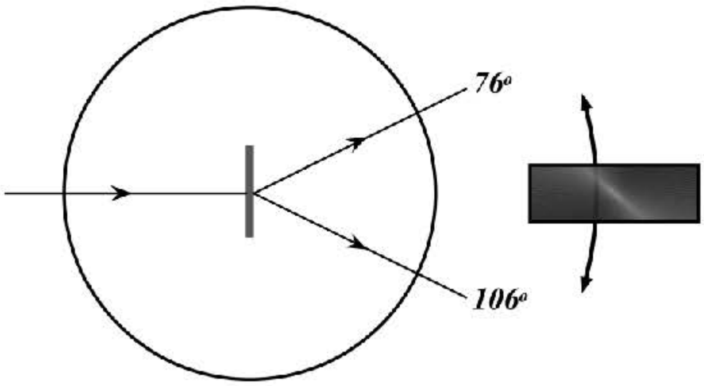


(1) In the first-order spectrum, P is the violet end.

(2) β is greater than α.

(3) There is no third-order spectrum.

2. A plane transmission grating is placed at the centre of a turntable of a spectrometer. The turntable has a circular protractor which can measure the positions of the fringes. A beam of monochromatic light is incident normally on the grating. The two angles for the first-order maximum are found to occur at a scale reading of 76^o and 106^o.



(a) If the diffraction grating has 400 lines per mm, what is the wavelength of the light source?

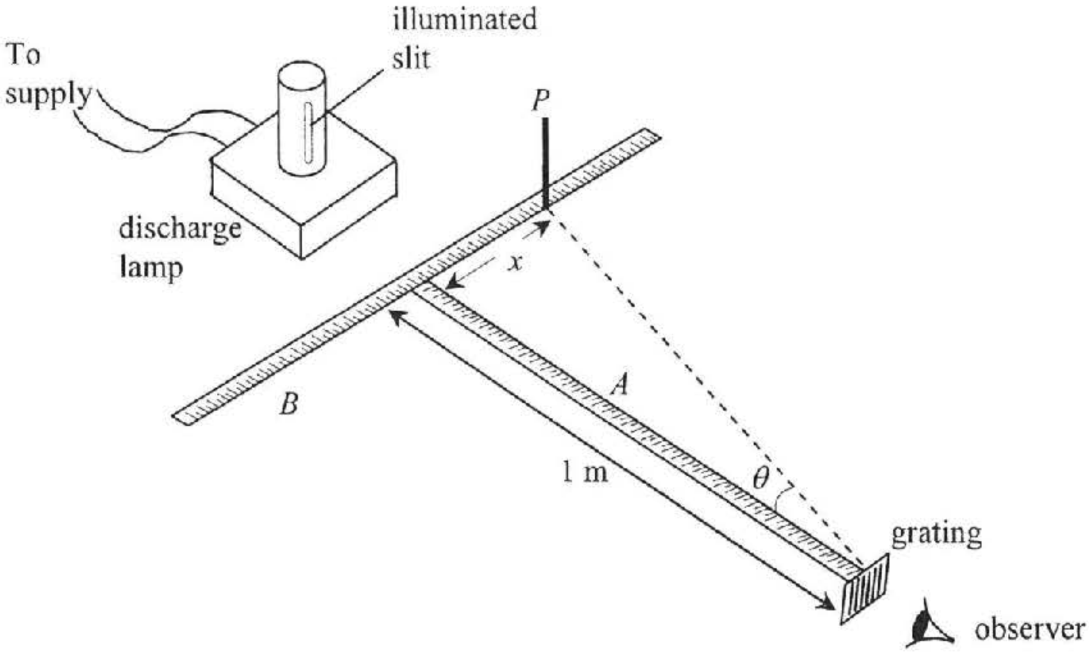
(b) What would be the angle between the two second-order maxima?

(c) What are the two possible scale readings for the third order maxima?

(d) Suppose blue light (450 nm) is used in this experiment. In order to produce fringes at the same positions, what should be the number of lines per cm be used?

3. Light of wavelength λ is incident normally on a diffraction grating with p lines per meter. The second-order diffraction maximum is at an angle of 24^o from the central position. For a second grating with $2p$ lines per meter illuminated normally by light of wavelength $3\lambda/5$, what is the angel between the first-order diffraction maximum and the central position?

4. The figure shows an experimental set-up to determine the wavelength of monochromatic light emitted from the vertical narrow slit of a discharge lamp. A, B are two mutually perpendicular meter rules on the bench with rule A pointing towards the lamp. A diffraction grating with vertical lines is placed at one end of rule A. A vertically mounted pin P is moved along rule B until the pint is in line with the diffracted image of the first-order to the observer. The corresponding distance x is measured for finding the diffraction angle θ.



(a) The grating has 6×10^5 lines per meter and x is found to be 0.37 m for the first-order image. Calculate the wavelength of the light from the lamp.

(b) Predict the position of the diffracted image of the second-order to the observer. State one advantage and one disadvantage of observing the second order compared with the first order.

ADV: The 2[nd] order has ______ angle. Thus measurement will be more ______.

DIS: The 2[nd] order is less ______. Thus it is more difficult to be ______.

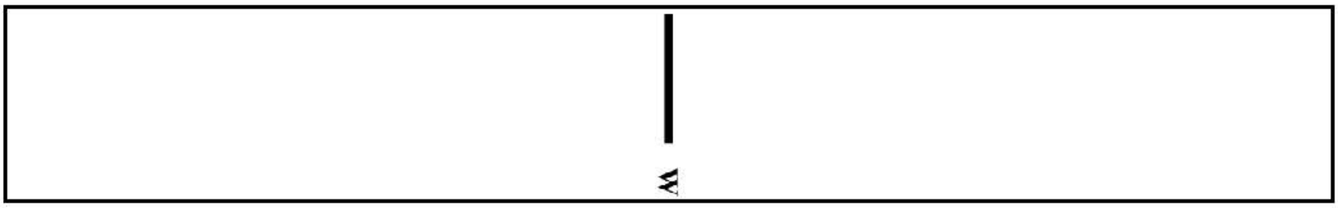
(c) It is preferred to place the discharge lamp several metres away, why?

The lamp would become a ______ which emits ______ light rays.

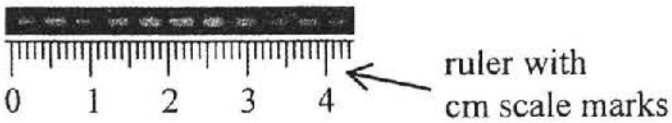
(d) In this experiment, the filament may not be well aligned along the metre rule near student A. Suggest one way to reduce the error.

[ ] the procedures with the [ ]. Take the [ ] value of x obtained from both sides to calculate the wavelength.

(e) If a source emitting white light is used, sketch the pattern seen by the observer on both sides of the source, up to the second order.



5. A laser beam is directed perpendicularly towards a double slit of separation $a = 0.3$ mm. The pattern of bright spots projected on a screen 1.8 m away from the slits is shown.



(a) Find the wavelength of the laser beam.

(b) Explain why the slit width has to be very narrow in order for the above pattern to be observed.

To ensure that the light through the 2 slits [ ] enough to [ ].

(c) Now, the double slit is replaced by a diffraction grating of 500 lines per mm.

(i) Find the separation between the central bright spot and first-order bright spot of the pattern on the screen for the same experimental settings.

(ii) Sketch the pattern up to the second-order, that you would expect to see on the screen when using this diffraction grating. A first-order bright spot has already been drawn for you.

centre of the pattern