Use the following data wherever necessary :

Speed of light in vacuum $c = 3 \times 10^8$ m s^{-1}

The following list of formulae may be found useful :

Fringe width in double-slit interference $\Delta y = \dfrac{\lambda D}{a}$

Diffraction grating equation $d \sin \theta = n \lambda$

Part A : HKCE examination questions

1. **< HKCE 1980 Paper II - 35 >**

An electromagnetic wave has a frequency of the order of 10^{16} Hz. What should be the type of the electromagnetic wave ? Given that the speed of light in vacuum is 3×10^8 m s^{-1}.

A. infra-red rays
B. visible light
C. ultra-violet rays
D. X-rays

2. **< HKCE 1981 Paper II - 23 >**

Given the following types of electromagnetic waves :

(1) radio waves
(2) yellow light
(3) green light

The waves listed in ascending order of their wavelengths are :

A. (1) , (3) , (2)
B. (2) , (1) , (3)
C. (3) , (1) , (2)
D. (3) , (2) , (1)

3. **< HKCE 1982 Paper II - 14 >**

Arrange the following electromagnetic waves in descending order of their wavelengths :

(1) visible light
(2) X-rays
(3) radio waves

A. (1) , (2) , (3)
B. (1) , (3) , (2)
C. (2) , (3) , (1)
D. (3) , (1) , (2)

4. **< HKCE 1983 Paper II - 18 >**

Which of the following statements about the properties of light is/are correct ?
(1) The speed of light in vacuum is independent of its wavelength.
(2) The wavelength of light will change when it enters a less dense medium.
(3) The frequency of light will change when it enters a less dense medium.
A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

5. **< HKCE 1983 Paper II - 21 >**

Given that the approximate wavelength of red light is 7×10^{-7} m, what is the approximate wavelength of an FM radio wave ?
A. 3×10^2 m
B. 3×10^{-3} m
C. 3×10^{-7} m
D. 3×10^{-9} m

6. **< HKCE 1985 Paper II - 22 >**

When light travels from air to glass, which of the following statements is/are true ?
(1) The speed of the light changes.
(2) The wavelength of the light increases.
(3) The frequency of the light remains unchanged.
A. (1) only
B. (2) only
C. (1) & (3) only
D. (2) & (3) only

7. **< HKCE 1985 Paper II - 23 >**

A short pulse of microwave travelling at 3×10^8 m s^{-1} was used to detect the position of a stationary weather balloon. It was found that the microwaves reflected from the balloon were picked up 2×10^{-4} s after the pulse had been emitted from the station. The distance of the balloon from the station was
A. 1.5×10^4 m
B. 3.0×10^4 m
C. 1.5×10^{12} m
D. 3.0×10^{12} m

8. **< HKCE 1985 Paper II - 24 >**

Which of the following is in the correct order of increasing wavelengths ?
A. infra-red rays, X-rays, radio waves
B. infra-red rays, radio waves, X-rays
C. X-rays, radio waves, infra-red rays
D. X-rays, infra-red rays, radio waves

9. **< HKCE 1986 Paper II - 26 >**

Which of the following is/are transverse wave(s) ?
(1) water waves
(2) sound waves
(3) X-rays
A. (1) only
B. (1) & (2) only
C. (1) & (3) only
D. (2) & (3) only

10. **< HKCE 1987 Paper II - 15 >**

Which of the following has the shortest wavelength ?

A. X-rays
B. Microwaves
C. Radio waves
D. Visible light

11. **< HKCE 1988 Paper II - 12 >**

visible light ↓

radio waves	micro-wave	*Y*	↓	ultra-violet	X-rays	gamma rays

The figure above shows the electromagnetic spectrum. Which of the following statements about *Y* is/are true ?

(1) The frequency of *Y* is lower than that of visible light.
(2) *Y* is emitted by hot bodies.
(3) *Y* can be deflected by electric and magnetic field.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

12. **< HKCE 1988 Paper II - 28 >**

If the speed of radio waves in air is v_1 and the speed of light in air is v_2, which of the following is correct ?

A. $v_2 > 2v_1$
B. $2v_1 > v_2 > v_1$
C. $v_1 = v_2$
D. $2v_2 > v_1 > v_2$

13. **< HKCE 1988 Paper II - 29 >**

When a light ray travels from air to water, how do the speed, the frequency and the wavelength change ?

	Speed	Frequency	Wavelength
A.	remains the same	remains the same	remains the same
B.	becomes smaller	becomes greater	remains the same
C.	becomes smaller	remains the same	becomes smaller
D.	becomes greater	remains the same	becomes smaller

14. **< HKCE 1989 Paper II - 13 >**

A pulse of microwave of speed 3×10^8 m s^{-1} is sent out to detect the position of a stationary weather balloon. The reflected microwave was picked up in 2×10^{-4} s after emission. What is the distance of the balloon from the station ?

A. 1.5×10^4 m
B. 3.0×10^4 m
C. 6.0×10^4 m
D. 1.5×10^{12} m

15. **< HKCE 1989 Paper II - 27 >**

Which of the following descriptions about the nature of light is/are correct ?

(1) The speed of light in a vacuum is independent of its wavelength.
(2) There cannot be total internal reflection when light is travelling from air to water.
(3) Light travels faster in glass than in air.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

16. **< HKCE 1989 Paper II - 28 >**

Arrange the following in ascending order of wavelengths.

(1) X-rays
(2) Microwaves
(3) Visible light
(4) Ultra-violet rays

A. (1), (2), (3), (4)
B. (2), (3), (4), (1)
C. (1), (4), (3), (2)
D. (2), (1), (3), (4)

17. **< HKCE 1990 Paper II - 29 >**

Infra-red	*P*	*Q*	*X*-rays

The diagram shows part of the electromagnetic spectrum. Which of the following statements is/are true ?

(1) The wavelength of *P* is longer than that of *Q*.
(2) The velocity of *P* in a vacuum is smaller than that of *Q*.
(3) *Q* can be deflected by an electric field.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

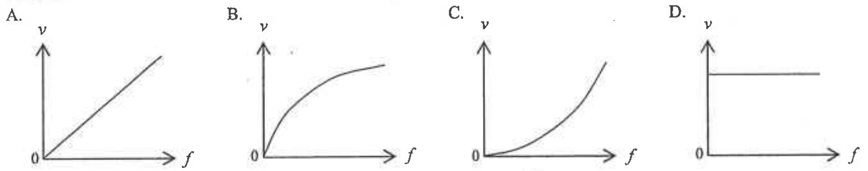
18. **< HKCE 1990 Paper II - 11 >**

What happens to the wavelength and frequency of a ray of light if it passes from water to air ?

	Wavelength	Frequency
A.	increases	decreases
B.	decreases	remains unchanged
C.	remains unchanged	increases
D.	increases	remains unchanged

19. **< HKCE 1991 Paper II - 25 >**

Which of the following graphs correctly shows the variation of speed v against frequency f of the electromagnetic waves in vacuum ?



20. **< HKCE 1992 Paper II - 28 >**

Which of the following is an application of microwaves in everyday life ?

A. Radar
B. Carbon-14 dating
C. Radiotherapy
D. Detecting cracks in railway track

21. < HKCE 1992 Paper II - 27 >

Given that the wavelengths of visible light range from 4×10^{-7} m to 7×10^{-7} m, which of the following combinations of wavelengths for infrared, red and violet lights is possible ?

	Infrared	Red light	Violet light
A.	1×10^{-4} m	7×10^{-7} m	4×10^{-7} m
B.	1×10^{-7} m	7×10^{-7} m	4×10^{-7} m
C.	1×10^{-4} m	4×10^{-7} m	7×10^{-7} m
D.	1×10^{-7} m	4×10^{-7} m	7×10^{-7} m

22. < HKCE 1993 Paper II - 26 >

Which of the following statements is/are true ?
(1) Light is a transverse wave.
(2) Light does not undergo diffraction.
(3) Light transmits energy.

A. (2) only
B. (3) only
C. (1) & (2) only
D. (1) & (3) only

23. < HKCE 1993 Paper II - 24 >

A radio station broadcasts at a frequency of 94 MHz. Find the wavelength of the radio waves.

A. 0.31 m
B. 3.19 m
C. 31.91 m
D. 3191 m

24. < HKCE 1994 Paper II - 22 >

Which of the following statements concerning infra-red radiation is correct ?

A. Infra-red is red in colour.
B. Infra-red can be detected by a Geiger-Muller counter.
C. Infra-red can be used to sterilize drinking water.
D. Warm objects emit infra-red.

25. < HKCE 1994 Paper II - 21 >

Arrange the following electromagnetic waves in ascending order of frequencies.
(1) X-rays
(2) Ultra-violet rays
(3) Radio waves

A. (1), (2), (3)
B. (2), (1), (3)
C. (3), (1), (2)
D. (3), (2), (1)

26. < HKCE 1996 Paper II - 28 >

Which of the following is **not** an application of the corresponding electromagnetic wave ?

	Electromagnetic wave	Application
A.	Ultra-violet	Camera autofocusing
B.	Infra-red	Detecting survivors buried in landslides
C.	Microwaves	Satellite communication
D.	X-rays	Detecting weapons hidden in suitcases

27. < HKCE 1996 Paper II - 26 >

X-rays	*P*	Visible light	*Q*	Microwaves

Part of the electromagnetic spectrum is shown above. Which of the following statements is/are correct ?
(1) *P* is ultra-violet and *Q* is infra-red.
(2) The wavelength of *P* is shorter than that of *Q*.
(3) The speed of *P* in vacuum is higher than that of *Q*.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

28. < HKCE 1997 Paper II - 26 >

Which of the following is an application of ultra-violet radiation ?

A. Camera auto-focusing
B. Detecting cracks in railway tracks
C. Detecting survivors buried in landslides
D. Sterilization of drinking water

29. < HKCE 1999 Paper II - 24 >

Which of the following equipment emit(s) waves which are electromagnetic in nature ?
(1) a television remote control
(2) a microwave oven
(3) an ultrasonic scanner for examining foetuses (babies not yet born)

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

30. < HKCE 2000 Paper II - 25 >

Scientists have discovered that ozone molecules in the earth's atmosphere are being destroyed. Which of the following electromagnetic waves is mainly responsible for causing hazard to human health as a result of the damaging of the ozone layer ?

A. gamma radiation
B. visible light
C. infra-red
D. ultra-violet

31. < HKCE 2002 Paper II - 27 >

Which of the following is/are the reason(s) for **not** over-using ultra-violet lamps to produce a suntan effect ?
(1) Ultra-violet radiation is highly penetrating and will damage body tissue.
(2) Ultra-violet radiation has a strong heating effect and will damage body tissue.
(3) Over exposure to ultra-violet radiation may cause skin cancer.

A. (2) only
B. (3) only
C. (1) & (2) only
D. (1) & (3) only

32. **< HKCE 2003 Paper II - 30 >**

The photograph shows a digital video camera recorder. The recorder has a night-shot function of capturing images in the dark. Which of the following electromagnetic waves is employed by the recorder in capturing images in the dark ?

A. radio waves
B. infra-red
C. ultra-violet
D. X-rays

33. **< HKCE 2004 Paper II - 24 >**

A ship is equipped with certain devices. Which device is **not** an application of electromagnetic waves ?

A. the radar system
B. the sonar system
C. the infra-red system for night navigation
D. the wireless telecommunication system

34. **< HKCE 2005 Paper II - 16 >**

Which of the following shows the correct order of the 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

35. **< HKCE 2007 Paper II - 17 >**

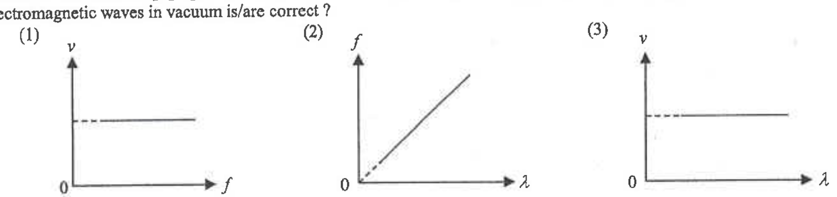
Which of the following phenomena demonstrate(s) that light is an electromagnetic wave ?

(1) Light bends when it travels across a boundary from one medium into another.
(2) Light reflects when it meets a polished metal surface.
(3) Light can travel from the Sun to the Earth.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

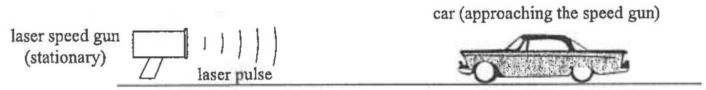
36. **< HKCE 2009 Paper II - 16 >**

Which of the following graphs showing the relationship among velocity (v), frequency (f) and wavelength (λ) of electromagnetic waves in vacuum is/are correct ?



A. (1) only
B. (2) only
C. (1) & (3) only
D. (2) & (3) only

37. **< HKCE 2010 Paper II - 37 >**



In the figure, a laser speed gun is used to check for speeding. A car is approaching the speed gun. The speed gun emits a laser pulse. The speed gun receives the reflected pulse from the car after 3.6×10^{-7} s. After 0.2 s, the speed gun emits another laser pulse. The speed gun receives the reflected pulse from the car after 3.1×10^{-7} s. What is the estimated speed of the car ? Given that speed of the laser pulse is 3×10^8 m s^{-1}.

A. 15.0 m s^{-1}
B. 20.1 m s^{-1}
C. 37.5 m s^{-1}
D. 40.2 m s^{-1}

38. **< HKCE 2011 Paper II - 13 >**

Compare the time taken for the following waves to travel a distance of 100 m.

T_1 Water waves with frequency 0.5 Hz and wavelength 2 m
T_2 Sound waves travelling at 340 m s^{-1}
T_3 Microwaves emitted by an artificial satellite

The time taken in **descending** order is

A. $T_1 > T_2 > T_3$
B. $T_2 > T_3 > T_1$
C. $T_3 > T_2 > T_1$
D. $T_1 > T_3 > T_2$

Part B : HKAL examination questions

39. **< HKAL 1981 Paper I - 43 >**

In Young's double slit experiment, which of the following can increase the separation of the interference fringes on the screen ?

(1) Increase the distance between the double slits and the screen.
(2) Increase the wavelength of the light.
(3) Increase the distance between the light source and the double slits.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

40. **< HKAL 1989 Paper I - 22 >**

When light of wavelength λ is incident normally on a diffraction grating with p lines per millimetre, the second-order maximum is at an angle θ from the central position. When light of wavelength $5\lambda/4$ is incident normally on another grating with $3p$ lines per millimetre, the first-order maximum is formed at an angle ϕ from the central position. Which of the following relations is correct ?

A. $\sin \phi = (5 \sin \theta) / 12$
B. $\sin \phi = \sin (5\theta / 12)$
C. $\sin \phi = \sin (15\theta / 4)$
D. $\sin \phi = (15 \sin \theta) / 8$

41. < HKAL 1995 Paper IIA - 14 >

In Young's double-slit experiment, which of the following combinations of monochromatic light, the slit-separation and the slit-to-screen distance would produce the greatest fringe separation on the screen ?

	Monochromatic light	Slit-separation	Slit-to-screen distance
A.	red light	1 mm	1 m
B.	red light	1 mm	2 m
C.	red light	2 mm	1 m
D.	blue light	1 mm	2 m

42. < HKAL 1996 Paper IIA - 12 >

When light travels from glass to air, the emergent light would show an increase in

(1) frequency.
(2) wavelength.
(3) velocity.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

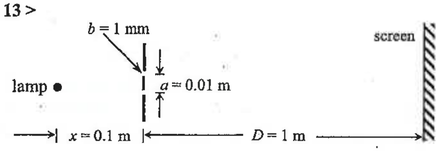
43. < HKAL 1997 Paper IIA - 15 >

In a Young's double-slit experiment, the light source gives out a monochromatic light of wavelength 400 nm. If the path difference of light from the two slits X and Y at point P on the screen is 3000 nm, which of the following is/are correct ?

(1) At point P, the 7th dark fringe is observed.
(2) If the light source is moved closer to the slits, the fringe separation on the screen will increase.
(3) If light of wavelength 500 nm is used, point P will become a bright fringe.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

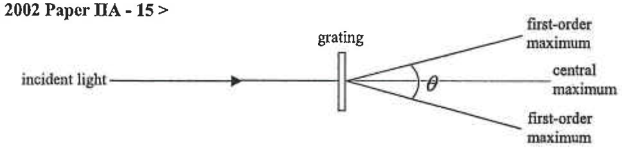
44. < HKAL 2001 Paper IIA - 13 >



A student prepares a double-slit interference experiment as shown. a is the slit separation and b is the slit width. However, no interference fringe can be observed on the screen. Which of the following improvements should be taken ?

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

45. < HKAL 2002 Paper IIA - 15 >



When a monochromatic light passes through a diffraction grating, a pattern of maxima and minima is observed as shown. Which of the following combinations would produce the largest angle θ between the two first-order maxima ?

	Grating (lines per mm)	Colour of light used
A.	200	green
B.	200	red
C.	400	green
D.	400	red

46. < HKAL 2003 Paper IIA - 19 >

A plane diffraction grating having a ruling of 5000 lines per cm. When monochromatic light of wavelength 500 nm is incident normally onto it, which of the following descriptions is/are correct ?

(1) The spacing between the rulings is 2000 nm.
(2) The second-order maximum occurs at an angle of 30° from the central line.
(3) There is no third-order maximum in the diffracted pattern.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

47. < HKAL 2004 Paper IIA - 11 >

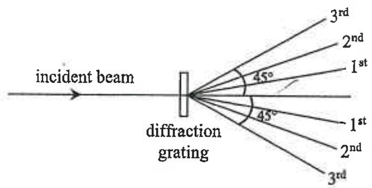
In a Young's double-slit experiment, a monochromatic light source is used. Which of the following methods would increase the fringe separation on the screen ?

(1) Use a monochromatic light source of longer wavelength.
(2) Use a double slit with greater slit separation.
(3) Use a double slit with larger slit width.

A. (1) only
B. (1) & (2) only
C. (2) & (3) only
D. (1), (2) & (3)

48. < HKAL 2007 Paper IIA - 10 >

A beam of monochromatic light is incident normally on a diffraction grating. The third-order maxima are found at angles of 45° from the central line. What is the highest order of diffracted maximum that can be observed ?



A. 3rd order
B. 4th order
C. 5th order
D. 6th order

49. < HKAL 2007 Paper IIA - 11 >

In a Young's double-slit experiment, monochromatic light of wavelength 550 nm is used. The fringes are formed on a screen placed at 1.0 m from the double slits. If the separation between the first and the fifth dark fringes is 5.0 mm, calculate the slit separation of the double slits.

A. 0.3×10^{-4} m
B. 1.1×10^{-4} m
C. 4.4×10^{-4} m
D. 5.5×10^{-4} m

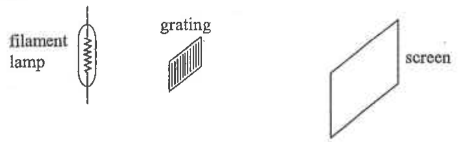
50. < HKAL 2011 Paper IIA - 15 >

Which of the following statements about a transmission diffraction grating are correct when monochromatic light is incident onto the grating ?

(1) The grating produces diffraction pattern on both sides of the central line.
(2) The angle of diffraction of the same order is directly proportional to the wavelength of the incident light.
(3) A grating with smaller grating spacing gives greater diffracted angle of the first maxima.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

51. < HKAL 2012 Paper IIA - 13 >



A student used the above set-up to produce a diffraction pattern on a screen. The filament lamp gives out white light. It was found that part of the second-order spectrum overlapped with the third-order one. The student suggested the following changes to eliminate the overlapping so as to obtain a pure second-order spectrum. Which of the following may be possible ?

(1) Move the screen closer to the grating.
(2) Replace the grating by one with smaller grating spacing.
(3) Insert a single slit between the filament lamp and the grating.

A. (1) only
B. (2) only
C. (3) only
D. None of the above

Part C : Supplemental exercise

52. A diffraction grating ruled with 500 lines per mm is illuminated normally by white light. If the wavelengths for yellow light and violet light are 600 nm and 400 nm respectively, which of the following statements are correct ?

(1) In the first order spectrum, the violet end is closer to the central bright fringe than the red end.
(2) The second-order image of yellow light coincides with the third-order image of violet light.
(3) There is no fourth-order image for violet light.

A. (1) & (2) only
B. (1) & (3) only
C. (2) & (3) only
D. (1), (2) & (3)

53. Which of the following correctly gives the order of magnitude of the wavelengths of infra-red radiation and ultra-violet radiation in air ?

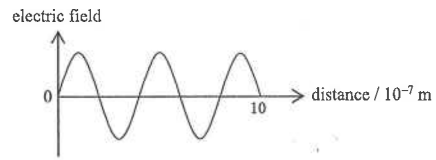
	Infra-red radiation	ultra-violet radiation
A.	10^{-2} m	10^{-8} m
B.	10^{-5} m	10^{-8} m
C.	10^{-2} m	10^{-10} m
D.	10^{-5} m	10^{-10} m

54. Two identical monochromatic light sources cannot give interference pattern. The reason(s) is/are

(1) the two light sources have different amplitudes.
(2) the two light sources have different frequency.
(3) the two light sources do not have constant phase relationship.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

55.



The above figure shows how the electric field of a monochromatic light wave varies with distance in air. Which description about the colour of the light and its frequency is correct ?

	colour	frequency / Hz
A.	violet	5.0×10^{14}
B.	violet	7.5×10^{14}
C.	orange	5.0×10^{14}
D.	orange	7.5×10^{14}

56. A diffraction grating of 4000 lines per cm is placed at a distance of 0.75 m from a screen. A monochromatic light is directed perpendicularly onto the grating. The two second-order fringes on the screen are at a separation of 68.6 cm. Calculate the wavelength of the monochromatic light.

A. 460 nm
B. 520 nm
C. 545 nm
D. 572 nm

Part D : HKDSE examination questions

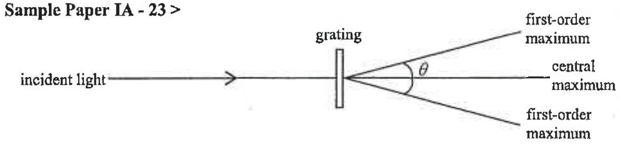
57. < HKDSE Sample Paper IA - 20 >

A Young's double-slit experiment was performed using a monochromatic light source. Which change would result in a greater fringe separation on the screen ?

(1) Using monochromatic light source of longer wavelength
(2) Using double slit with greater slit separation
(3) Using double slit with larger slit width

A. (1) only
B. (1) & (2) only
C. (2) & (3) only
D. (1), (2) & (3)

58. **< HKDSE Sample Paper IA - 23 >**



When monochromatic light is passed through a diffraction grating, a pattern of maxima and minima is observed as shown. Which combination would produce the largest angle θ between the first-order maxima ?

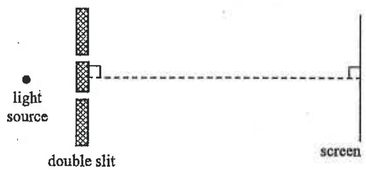
	Grating (lines per mm)	Colour of light used
A.	200	blue
B.	200	red
C.	400	blue
D.	400	red

59. **< HKDSE Practice Paper IA - 23 >**

Yellow light of wavelength 590 nm is incident normally on a diffraction grating with 400 lines per mm. Find the difference in angular positions for the third order and the fourth order bright fringes.

A. 13.7°
B. 25.7°
C. 45.1°
D. 70.7°

60. **< HKDSE Practice Paper IA - 22 >**



In a Young's double slit experiment, a monochromatic light source of wavelength 600 nm is used. The fringe separation is 5 mm on the screen. If the slit separation is halved and a monochromatic light source of wavelength 450 nm is used instead, what is the new fringe separation ?

A. 1.9 mm
B. 3.3 mm
C. 7.5 mm
D. 13.3 mm

61. **< HKDSE Practice Paper IA - 16 >**

Which of the following phenomena demonstrates that light is an electromagnetic wave ?

A. Light carries energy.
B. Light reflects when it meets a polished metal surface.
C. Light bends when it travels across a boundary from one medium into another.
D. Light can travel from the Sun to the Earth.

62. **< HKDSE 2012 Paper IA - 19 >**

Which of the following statements is INCORRECT ?

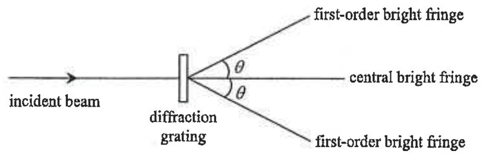
A. In air, the wavelength of infra-red radiation is shorter than that of ultra-violet radiation.
B. Visible light travels faster in air than in glass.
C. Microwaves travel at the speed of light in a vacuum.
D. Both light and sound exhibit diffraction.

63. **< HKDSE 2012 Paper IA - 20 >**

For a diffraction grating of 600 lines per mm, the diffracted red light (657 nm) coincides with the diffracted violet light (438 nm) at an angle of diffraction of 52°. What are the respective orders of the diffracted red light and violet light ?

	red	violet
A.	2	3
B.	3	4
C.	3	2
D.	4	3

64. **< HKDSE 2013 Paper IA - 23 >**

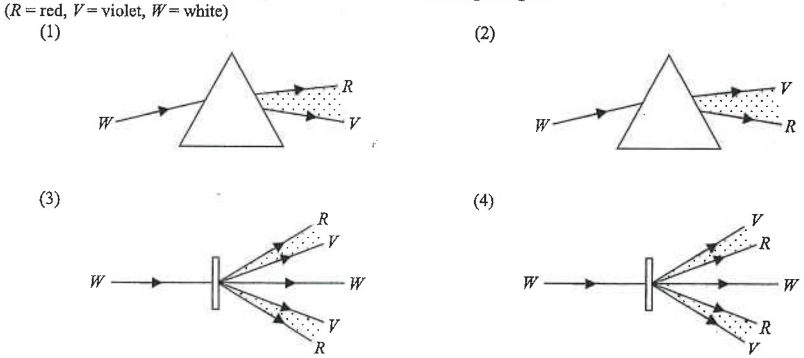


When monochromatic light passes through a diffraction grating, a pattern of bright fringes is formed. Which arrangement would produce the greatest angle θ between the central and first-order bright fringes ?

	grating (lines per mm)	colour of light
A.	400	green
B.	400	blue
C.	200	green
D.	200	blue

65. **< HKDSE 2015 Paper IA - 17 >**

Which diagrams below correctly show the spectra formed from white light by a glass prism and a diffraction grating respectively ? It is known that red light travels faster than violet light in glass.
(R = red, V = violet, W = white)



A. (1) & (3) only
B. (1) & (4) only
C. (2) & (3) only
D. (2) & (4) only

66. **< HKDSE 2015 Paper IA - 20 >**

Which of the following gives the order of magnitude of the wavelengths of ultra-violet radiation and microwave in a vacuum ?

	ultra-violet radiation	microwave
A.	10^{-8} m	10^{-2} m
B.	10^{-8} m	10^{-5} m
C.	10^{-10} m	10^{-2} m
D.	10^{-10} m	10^{-5} m

67. **< HKDSE 2016 Paper IA - 19 >**

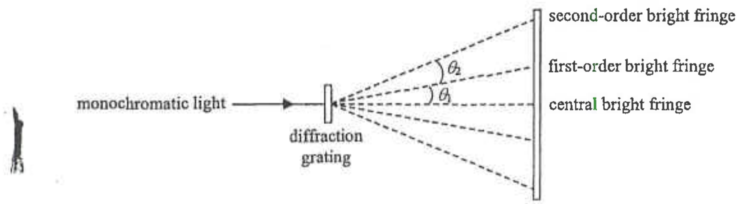
Diffraction will occur when light

(1) passes through a pinhole.
(2) passes by a sharp edge.
(3) passes through a slit.

A. (1) only
B. (2) only
C. (3) only
D. (1), (2) & (3)

68. **< HKDSE 2017 Paper IA - 20 >**

The figure below shows some of the bright fringes formed when monochromatic light passes through a diffraction grating.



Which of the following is/are correct ?

(1) $\theta_1 = \theta_2$
(2) The maximum order of bright fringe is 4 if $\theta_1 = 20°$.
(3) θ_1 will decrease if the experiment is performed in water but not in air.

A. (1) only
B. (3) only
C. (1) & (2) only
D. (2) & (3) only

There is question in next page

M.C. Answers

1. C	11. C	21. A	31. B	41. B
2. D	12. C	22. D	32. B	42. D
3. D	13. C	23. B	33. B	43. B
4. C	14. B	24. D	34. A	44. D
5. A	15. C	25. D	35. B	45. D
6. C	16. C	26. A	36. C	46. C
7. B	17. A	27. C	37. C	47. A
8. D	18. D	28. D	38. A	48. B
9. C	19. D	29. C	39. C	49. C
10. A	20. A	30. D	40. D	50. B
51. D	61. D	71. C		
52. A	62. A	72. A		
53. B	63. A			
54. B	64. A			
55. B	65. A			
56. B	66. A			
57. A	67. D			
58. D	68. B			
59. B	69. D			
60. C	70. A			

M.C. Solution

1. C

$v = f\lambda$

$\therefore$ $(3 \times 10^8) = (10^{16})\,\lambda$ $\therefore$ $\lambda = 3 \times 10^{-8}$ m

$\therefore$ The wave is in the range of ultra-violet rays.

2. D

Wavelengths in ascending order are : green light, yellow light, radio waves

69. <HKDSE 2019 Paper IA-19>

70. <HKDSE 2019 Paper IA-22>

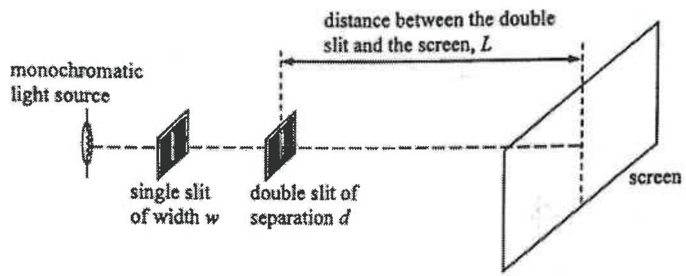
71. <HKDSE 2020 Paper IA-14>

A light beam consisting of wavelengths λ_1 and λ_2 is incident normally on a diffraction grating. The third-order diffraction of wavelength λ_1 coincides with the fourth-order diffraction of wavelength λ_2 in the resulting pattern. If λ_1 is 680 nm, find λ_2.

A. 510 nm
B. 680 nm
C. 907 nm
D. It cannot be determined because the grating spacing is unknown.

72. <HKDSE 2019 Paper IA-15>

The figure shows a typical set-up of Young's double slit experiment.



Which combination below is the best setting for displaying an observable fringe pattern on the screen ?

	w	d	L
A.	0.1 mm	1 mm	10 m
B.	0.1 mm	1 mm	1 m
C.	1 mm	0.1 mm	1 m
D.	1 mm	0.1 mm	0.1 m

3. D

Wavelengths in descending order are : radio waves, visible light, X-rays

4. C

✓ (1) Speed of light depends on medium only.

✓ (2) Change in medium results in change of speed, thus give the change in wavelength.

× (3) Frequency must remain unchanged during refraction.

5. A

The wavelength of FM radio wave is the order of 10^2 m.

6. C

✓ (1) From air to glass, speed of light would decrease.

× (2) When speed decreases, wavelength would also decrease, by $v = f\lambda$.

✓ (3) Frequency must be unchanged during refraction.

7. B

By $d = \frac{1}{2}vt$

$\therefore\ d = \frac{1}{2}(3 \times 10^8)(2 \times 10^{-4}) = 3 \times 10^4$ m

8. D

× A. wavelength of infra-red rays > wavelength of X-rays

× B. wavelength of radio waves > wavelength of X-rays

× C. wavelength of radio waves > wavelength of infra-red rays

✓ D. it is the correct ascending order of wavelengths

9. C

Sound wave is the only example of longitudinal wave.

10. A

Wavelength of X-rays is shorter than microwaves, radio waves and visible light

11. C

✓ (1) Frequency decreases towards the left

✓ (2) *Y* is infra-red which is emitted by hot or warm bodies

× (3) Electromagnetic waves cannot be deflected by electric field or magnetic field.

12. C

Both radio waves and visible light are electromagnetic waves, they have the same speed,

$\therefore\ v_1 = v_2$.

13. C

Speed : Speed decreases when light travels from air to water

Frequency : Frequency remains unchanged when light travels from one medium to another medium

Wavelength : Wavelength decreases when light travels from air to water, by $v = f\lambda$.

14. B

$d = \frac{1}{2}vt = \frac{1}{2}(3 \times 10^8)(2 \times 10^{-4}) = 3 \times 10^4$ m

15. C

✓ (1) Speed of light depends on medium.

✓ (2) Total internal reflection can only occur when light travels from a denser medium to a less dense medium, e.g. from water to air.

× (3) Light travels slower in glass than in air.

16. C

The correct ascending order of wavelengths :

gamma rays, X-rays, ultra-violet, visible light, infra-red, microwave, radio waves.

17. A

✓ (1) Wavelength decreases towards the right of the spectrum, thus *P* has longer wavelength.

× (2) All electromagnetic waves travel with the same velocity in vacuum.

× (3) Electromagnetic waves cannot be deflected by an electric field.

18. D

Wavelength : Speed of light increases when it travels from water to air, by $v = f\lambda$, wavelength also increases.

Frequency : Frequency must remain unchanged when light travels from one medium to another medium.

19. D

Speeds of all the electromagnetic waves are the same and do not depend on the frequency of the wave.

20. A

✓ A. Radar uses microwaves to send pulses to detect flying objects.

× B. Carbon-14 dating uses β radiation.

× C. Radiotherapy uses γ-rays.

× D. Detecting cracks in railway track uses ultrasound.

21. A

Infrared : Wavelength is longer than that of visible light, thus it should be 1×10^{-4} m

Red light : Red light has the longest wavelength among the range of visible light, thus it is 7×10^{-7} m

Violet light : Violet light has the shortest wavelength among the range of visible light, thus it is 4×10^{-7} m

22. D

✓ (1) Light is a type of transverse wave.

× (2) All waves, including electromagnetic waves, posses all phenomena of waves, including diffraction.

✓ (3) Light wave carries light energy.

23. B

$v = f\lambda$

$\therefore\ (3 \times 10^8) = (94 \times 10^6)\ \lambda$

$\therefore\ \lambda = 3.19$ m

24. D

× A. Infra-red is invisible.

× B. Geiger-Muller counter can only detect α, β or γ radiation, but not infra-red radiation.

× C. Ultra-violet is used to sterilize drinking water.

✓ D. Warm or hot bodies emit infra-red radiation.

25. D

Frequencies in ascending order are :

radio waves, ultra-violet rays, X-rays

26. A

Infra-red radiation OR ultrasonic wave can be used for camera autofocusing.

27. C

✓ (1) Ultra-violet is between X-rays and visible light while infra-red is between microwaves and visible light

✓ (2) Wavelength increases towards the right of this spectrum, thus wavelength of *P* is shorter.

× (3) All electromagnetic waves travel with same speed in vacuum

28. D

× A. Camera autofocusing : both ultrasound or infra-red radiation can be used

× B. Detecting railway cracks : use ultrasound

× C. Detecting survivors : use infra-red radiation

✓ D. Sterilize drinking water : use ultra-violet radiation

29. C

✓ (1) Remote control : Infrared radiation

✓ (2) Oven : Microwave

× (3) Scanning foetuses : ultrasonic waves – sound waves with frequency higher than 20000 Hz

30. D

Ozone layer in the atmosphere can absorb most of the ultra-violet radiation from the sun
so that the intensity of the ultra-violet radiation reaching the Earth's surface is much reduced
and causes less hazard to human being, as over-exposure to ultra-violet radiation may cause skin cancer.

31. B

× (1) The penetrating power of ultra-violet radiation is not high enough to penetrate through the human body (X-rays and gamma radiation can penetrate through human body)

× (2) Ultra-violet radiation does not have heating effect (Infra-red has heating effect)

✓ (3) Ultra-violet radiation has sun-tan effect and over-exposure may cause skin cancer

32. B

Infra-red can enable the images to be captured in the dark.

33. B

✓ A. The radar system makes use of microwave which is an electromagnetic wave.

× B. The sonar system makes use of ultrasound which is NOT an electromagnetic wave.

✓ C. The infra-red system makes use of infra-red radiation which is an electromagnetic wave.

✓ D. The wireless telecommunication system makes use of radio wave which is an electromagnetic wave.

34. A

The electromagnetic wave spectrum in order of decreasing wavelength :

① radio waves
② microwaves
③ infra-red
④ visible light
⑤ ultra-violet
⑥ X-rays
⑦ gamma rays

35. B

× (1) This can only shows that wave has refraction.

× (2) This can only shows that wave has reflection.

✓ (3) Since the space between the Sun and the Earth is vacuum,
this can show that light is an electromagnetic wave that can travel in vacuum.

36. C

✓ (1) Speed v of electromagnetic waves is independent of the frequency f, thus it is a horizontal line.

× (2) As the velocity is constant, by $v = f\lambda$,
the frequency f and the wavelength λ should be inversely proportional, thus the graph should be a curve.

✓ (3) Speed v of electromagnetic waves is independent of the wavelength λ, thus it is a horizontal line.

37. C

Initial distance of the car $= \frac{1}{2} \times (3 \times 10^8) \times (3.6 \times 10^{-7}) = 54$ m

Final distance of the car $= \frac{1}{2} \times (3 \times 10^8) \times (3.1 \times 10^{-7}) = 46.5$ m

Speed of the car $= \dfrac{\Delta d}{\Delta t} = \dfrac{54 - 46.5}{0.2} = 37.5 \text{ m s}^{-1}$

38. A

Speed of water waves < speed of sound waves < speed of microwaves

Time to travel a distance of 100 m $= \dfrac{100 \text{ m}}{\text{speed of the wave}}$

Thus, the smaller the speed, the longer is the time taken $\therefore\ T_1 > T_2 > T_3$

39. C

✓ (1) By $\Delta y = \dfrac{\lambda D}{a}$ $\therefore\ D\uparrow \Rightarrow \Delta y\uparrow$

✓ (2) By $\Delta y = \dfrac{\lambda D}{a}$ $\therefore\ \lambda\uparrow \Rightarrow \Delta y\uparrow$

× (3) Separation between fringes is independent of the distance between the light source and the double slits, thus Δy is unchanged.

40. D

As $d \sin\theta = n\lambda$

$\therefore\ (\dfrac{10^{-3}}{p})\sin\theta = (2)\lambda$ and $(\dfrac{10^{-3}}{3p})\sin\phi = (1)\dfrac{5\lambda}{4}$

$\therefore\ \dfrac{(1/p)}{(1/3p)} \cdot \dfrac{\sin\theta}{\sin\phi} = \dfrac{(2)}{(1)} \dfrac{\lambda}{(5\lambda/4)}$ $\therefore\ \sin\phi = \dfrac{15}{8}\sin\theta$

41. B

By $\Delta y = \dfrac{\lambda D}{a}$

Monochromatic light : $\lambda\uparrow \Rightarrow \Delta y\uparrow$ $\therefore$ red light

Slit-separation : $a\downarrow \Rightarrow \Delta y\uparrow$ $\therefore$ 1 mm

Slit-to-screen distance : $D\uparrow \Rightarrow \Delta y\uparrow$ $\therefore$ 2 m

42. D

× (1) Frequency remains unchanged during refraction

✓ (2) For light : $v_{glass} < v_{air} \Rightarrow \lambda_{glass} < \lambda_{air}$

✓ (3) For light : $v_{glass} < v_{air}$

43. B

× (1) $\Delta = 3000 \text{ nm} = \dfrac{3000}{400}\lambda = 7.5\lambda$ $\therefore\ P$: 8th dark fringe

× (2) The fringe separation is independent of the distance between the source and slits, thus same s

✓ (3) $\Delta = 3000 \text{ nm} = \dfrac{3000}{500}\lambda = 6\lambda$ $\therefore$ constructive interference occurs, it is a bright fringe

44. D

The wavelength of light is very small (about 10^{-7} m).

In order to have observable interference, slit separation a should be much decreased to give observable interference.

45. D

By $d\sin\theta = 1\lambda$ $\therefore$ To have greater θ, d should be smaller and λ should be greater

① grating in lines per mm should be greater so that grating spacing d is smaller $\therefore$ 400 is better

② red light has longer wavelength than green light $\therefore$ red light is better

46. C

✓ (1) Grating spacing $d = \dfrac{1\times10^{-2}}{5000} = 2\times10^{-6}$ m $= 2000$ nm

✓ (2) By $d\sin\theta = n\lambda$ $\therefore\ (2\times10^{-6})\sin\theta_2 = (2)(500\times10^{-9})$ $\therefore\ \theta_2 = 30°$

× (3) $\sin\theta_3 = 3\sin\theta_1 = 1.5\sin\theta_2 = 1.5\sin 30°$ $\therefore\ \theta_3 = 48.6°$ $\therefore$ Third order spectrum exists.

47. A

By using fringe separation : $\Delta y = \dfrac{\lambda D}{a}$

✓ (1) $\lambda\uparrow \Rightarrow \Delta y\uparrow$

× (2) $a\uparrow \Rightarrow \Delta y\downarrow$

× (3) Larger slit width gives the same fringe separation Δy

48. B

By $d\sin\theta = n\lambda$

① $d\sin 45° = 3\lambda$

② $d\sin 90° = n\lambda$

$\therefore\ n = 4.24$

Thus the highest order is the 4th order.

49. C

Fringe separation : $\Delta y = 5.0\text{ mm} \times \frac{1}{4} = 1.25\text{ mm}$

By $\Delta y = \dfrac{\lambda D}{a}$

$\therefore\ (1.25\times10^{-3}) = \dfrac{(550\times10^{-9})\cdot(1)}{a}$

$\therefore\ a = 4.4\times10^{-4}\text{ m}$

50. B

✓ (1) The diffraction pattern is symmetrical on both sides of the central line.

× (2) For the same order, it should be the sin of the angle proportional to the wavelength, i.e. $\sin\theta \propto \lambda$.

✓ (3) For smaller d, the angle θ is greater, thus the first maxima are separated at greater angles.

51. D

For grating or interference pattern, the second order and the third order must be overlapped.

The overlapping cannot be changed by any methods.

52. A

✓ (1) For the first-order spectrum : $d\sin\theta = 1\lambda$.
$\therefore\ \lambda_{violet} < \lambda_{yellow} \Rightarrow \theta_{violet} < \theta_{yellow}$ $\therefore$ violet is closer.

✓ (2) By $d\sin\theta = n\lambda$
For 2nd order image of yellow light : $d\sin\theta = (2)(600) = 1200$ nm
For 3rd order image of violet light : $d\sin\theta = (3)(400) = 1200$ nm
Same value of $d\sin\theta \Rightarrow$ the 2 lights coincide at the same diffracted angle θ

× (3) Consider the 4th order image for violet light.
By $d\sin\theta = n\lambda$ $\therefore\ (\dfrac{10^{-3}}{500})\sin\theta = (4)(400\times10^{-9})$ $\therefore\ \theta = 53.1^\circ$
$\therefore$ 4th order violet maximum exists.

53. B

Typical order of wavelength of infra-red radiation in air is 10^{-5} m.

Typical order of wavelength of ultra-violet radiation in air is 10^{-8} m.

54. B

× (1) Since the two light sources are identical, they should have same amplitudes.

× (2) Since the two light sources are identical, they should have the same wavelength and frequency.

✓ (3) Two independent light source cannot have constant phase relationship.
Thus, they are not coherent sources, and therefore, no interference pattern can be observed.

55. B

From the figure, the wavelength : $\lambda = 10\times10^{-7}\times\dfrac{2}{5} = 4\times10^{-7}$ m

The colour is violet since violet has the shortest wavelength among the visible light that has range of 400 nm to 700 nm.

By $c = f\lambda$

$\therefore\ (3\times10^{8}) = f\times(4\times10^{-7})$ $\therefore\ f = 7.5\times10^{14}$ Hz

56. B

① $\tan\theta_2 = \dfrac{x}{d} = \dfrac{0.686/2}{0.75}$ $\therefore\ \theta_2 = 24.58^\circ$

② $d\sin\theta = n\lambda$ $\therefore\ (\dfrac{1\times10^{-2}}{4000})\sin 24.58^\circ = (2)\lambda$ $\therefore\ \lambda = 520$ nm

57. A

Fringe width in double-slit interference : $\Delta y = \dfrac{\lambda D}{a}$

✓ (1) $\lambda\uparrow \Rightarrow \Delta y\uparrow$

× (2) $a\uparrow \Rightarrow \Delta y\downarrow$

× (3) Larger slit width gives the same fringe separation Δy, as Δy is not affected by the slit width.

58. D

By $d\sin\theta = 1\lambda$ $\therefore$ To have greater θ, d should be smaller and λ should be greater

① grating in lines per mm should be greater so that grating spacing d is smaller $\therefore$ 400 is better

② red light has longer wavelength than blue light $\therefore$ red light is better

59. B

By $d\sin\theta = n\lambda$

① $(\dfrac{1\times10^{-3}}{400})\sin\theta_4 = (4)(590\times10^{-9})$ $\therefore\ \theta_4 = 70.73^\circ$

② $(\dfrac{1\times10^{-3}}{400})\sin\theta_3 = (3)(590\times10^{-9})$ $\therefore\ \theta_3 = 45.07^\circ$

$\therefore\ \Delta\theta = 70.73 - 45.07 = 25.7^\circ$

60. C

By $\Delta y = \dfrac{\lambda D}{a}$

① $(5\times10^{-3}) = \dfrac{(600\times10^{-9})D}{a}$ ② $\Delta y = \dfrac{(450\times10^{-9})D}{(a/2)}$

Combine ① and ② : $\Delta y = 7.5\times10^{-3}\text{ m} = 7.5\text{ mm}$

61. D

× A. All waves carry energy. Carry energy cannot prove that light is an electromagnetic wave.
× B. All waves reflect. Reflection cannot prove that light is an electromagnetic wave.
× C. All waves bend to give refraction. Refraction cannot prove that light is an electromagnetic wave.
✓ D. Light can travel in space (vacuum) is a proof for electromagnetic wave.

62. A

× A. The wavelength of the infra-red radiation is longer than that of ultra-violet radiation.
✓ B. Visible light travels at the greatest speed in air or vacuum. In glass, the speed is smaller.
✓ C. Microwaves are electromagnetic waves, which must be travel at the speed of light in a vacuum.
✓ D. Since light and sound are waves, they exhibit diffraction.

63. A

By $d\sin\theta = n\lambda$

Red light : $(\frac{1\times10^{-3}}{600})\sin 52^\circ = n(657\times10^{-9})$ $\therefore n = 2$

Violet light : $(\frac{1\times10^{-3}}{600})\sin 52^\circ = n(438\times10^{-9})$ $\therefore n = 3$

64. A

By $d\sin\theta = n\lambda$

For the first order bright fringe, $n = 1$ $\therefore \sin\theta = \frac{\lambda}{d}$

To give greatest angle θ,

d should be smaller, thus the grating should have more line per mm, that is, 400

λ should be greater, thus the colour of light should be green, since wavelength of green light is longer than blue light

65. A

① When white light passes through a prism, it is dispersed into its component colours.
Red (R) light is least deviated from the original direction.

② When white light passes through a diffraction grating, the first order consists of continuous spectrum.
Red (R) light with longest wavelength has the largest diffracted angle from the central line.

66. A

Order of magnitude of wavelength of ultra-violet radiation $= 10^{-8}$ m

Order of magnitude of wavelength of microwaves $= 10^{-2}$ m

67. D

✓ (1) When light passes through a pinhole, light spreads out from the hole to give diffraction.
✓ (2) When light passes by a sharp edge, light bends round the corner to give diffraction.
✓ (3) When light passes through a slit, light spreads out from the slit to give diffraction.

68. B

× (1) The bright fringes produced by a diffraction grating is not evenly distributed,
thus θ_2 must not equal θ_1, actually, $\theta_2 > \theta_1$.

× (2) By $d\sin\theta = n\lambda$
① $d\sin 20^\circ = (1)\lambda$ ② $d\sin 90^\circ = n\lambda$
$\therefore n = 2.92$
The maximum order of bright fringe should be 2.

✓ (3) If the experiment is performed in water, λ will decrease.
By $d\sin\theta = n\lambda$, θ will decrease.

Use the following data wherever necessary :

Speed of light in vacuum $c = 3 \times 10^8 \text{ m s}^{-1}$

The following list of formulae may be found useful :

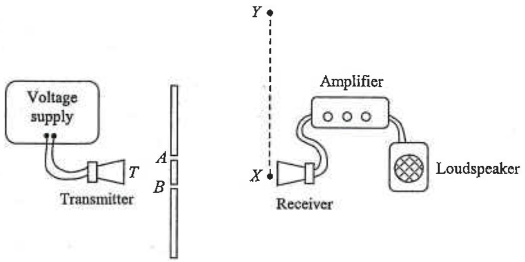
Fringe width in double-slit interference $\Delta y = \dfrac{\lambda D}{a}$

Diffraction grating equation $d \sin\theta = n\lambda$

Part A : HKCE examination questions

1. **< HKCE 1986 Paper I - 6 >**

(a) The below figure shows an experimental set-up to study the interference of 3 cm microwave. Microwaves emitted from a transmitter at T pass through two narrow slits A and B where $TA = TB$. The microwaves are picked up by a receiver at X where $XA = XB$. The receiver is connected to a loudspeaker through an amplifier. The loudness of sound from the loudspeaker indicates the intensity of the microwaves received.



(i) What is the frequency of the microwaves ? (3 marks)

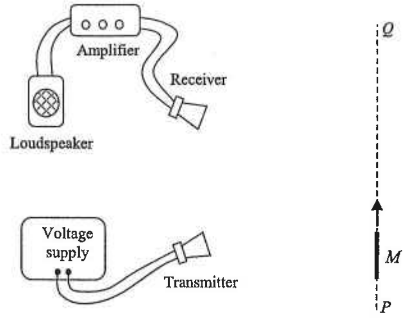
(ii) What is the path difference of the microwaves from A and B at X ? (1 mark)

(iii) Are the waves at constructive or destructive interference at X ? (1 mark)

(iv) Would the sound from the loudspeaker be loud or soft ? (1 mark)

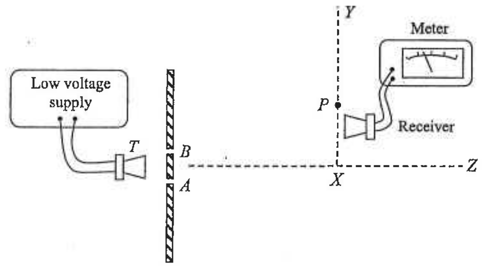
(v) Describe briefly the variation of the loudness of the sound from the loudspeaker when the receiver is being moved along XY. (2 marks)

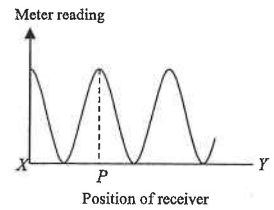
1. (b) The following figure shows another experimental set-up using the same microwave transmitter and receiver. 3 cm-microwaves are emitted from the transmitter. A metal plate M is then moved from P to Q. Describe the variation of the loudness of the sound from the loudspeaker. Explain briefly with the aid of a diagram. (5 marks)



(c) Give two examples of applications of microwaves. (2 marks)

2. **< HKCE 1995 Paper I - 4 >**





The figure above shows a set-up to investigate the interference of microwaves. Microwaves emitted from a transmitter T pass through two narrow slits A and B, which are equidistant from T. The receiver is then connected to a meter, which indicates the intensity of microwaves received.

The graph above then shows the variation of the meter reading as the receiver is moved from X to Y. X is equidistant from A and B.

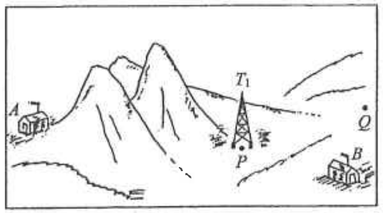
(a) Explain briefly why the meter shows maximum and minimum readings. (3 marks)

2. (b) What type of interference is observed at P ? (1 mark)

(c) If AP = 36 cm, BP = 33 cm, find the wavelength and frequency of the microwaves. (4 marks)

(d) Sketch a graph to show the variation of the meter reading as the receiver is moved from X to Z (XZ is perpendicular to XY). Explain briefly why the reading varies in this way. (4 marks)

3. **< HKCE 1999 Paper I - 10 >**



Peter lives in a house A on one side of a hill. A transmitting station T_1 is located at site P on the other side of the hill. (See the above figure.) The station transmits radio waves of frequency 600 kHz and TV waves of frequency 500 MHz.

(a) Find the wavelengths of the radio waves and TV waves. (3 marks)

(b) (i) Name the wave phenomenon which enables the waves transmitted by T_1 to reach Peter's house. (1 mark)

3. (b) (ii) Peter finds that the radio reception is better than the TV reception. Explain this phenomenon. (2 marks)

(c) Peter is watching TV in his house. He finds that the reception is affected when an aeroplane flies overhead. Explain this phenomenon. (2 marks)

(d) Another transmitting station will be built at site Q. (See the above figure.) Mary lives in a house B such that BP = 3.95 km and BQ = 3.20 km.

(i) Find the path difference at B from P and Q. (1 mark)

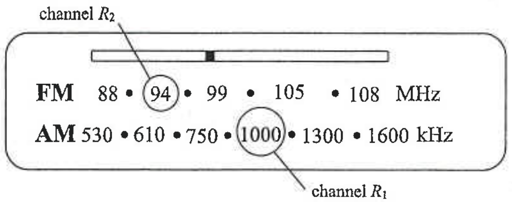
(ii) Mary listens to the radio in her house. How will the reception be affected if both stations transmit identical radio waves at 600 kHz ? Explain your answer. (Neglect the reflection of waves from the hill.) (3 marks)

(e) The table below shows the broadcasting frequencies of RTHK Radio 1 (FM) in different districts :

District	Frequency / MHz
Hong Kong north	92.6
Hong Kong south	93.6
Kowloon east	94.4
Kowloon west	92.9
Shatin, Ma On Shan	93.5
Tai Po, Fanling	93.2
Tuen Mun, Yuen Long	93.4

State one advantage of broadcasting at different frequencies in different districts. (2 marks)

4. < HKCE 2004 Paper I - 4 >



The Figure above shows the display panel of a radio and the broadcasting frequencies of two radio channels R_1 and R_2.

(a) Find the wavelength of the radio waves used by channel R_1. (2 marks)

____

____

(b) Anita's house is surrounded by hills and at her house, the reception of one of the two radio channels is better. For which radio channel is the reception better ? Explain your answer. (3 marks)

____

____

5. < HKCE 2006 Paper I - 1 >

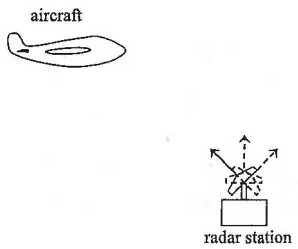


Figure 1

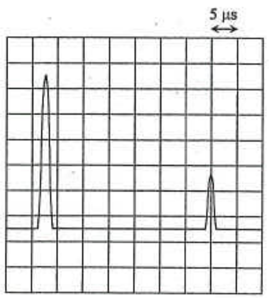


Figure 2

RADAR (RAdio Detecting And Ranging) is a useful device in air traffic control. In Figure 1, an aircraft is flying near a radar station. A pulse of electromagnetic wave with a speed of 3×10^8 m s^{-1} and a frequency of 1.2×10^9 Hz is emitted from the radar station towards the aircraft.

(a) Find the wavelength of the electromagnetic wave. (2 marks)

____

____

(b) The electromagnetic wave pulse emitted is reflected by the aircraft back to the radar station. The emitted and reflected pulses are displayed on the screen of a CRO as shown in Figure 2. The time-base setting of the CRO is 5 μs per division. Estimate the distance between the radar station and the aircraft. (3 marks)

____

____

____

6. < HKCE 2006 Paper I - 2 >

RADAR is a useful device to detect aircraft. However, the air-forces of many countries try to build aircraft that can hide away from their enemies. Read the following passage about a stealth bomber (see Figure 1).

Stealth Bomber

There are some special features in the design of the stealth bomber to make it invisible to enemy sensors. The aircraft needs to blend in with the background visually and its engine needs to be very quiet. Furthermore, it needs to hide from enemy radar and infrared sensors. Defending against radar detection, the surface of the stealth bomber is particularly good at absorbing radio waves. More importantly, the large flat areas on the top and bottom of the aircraft reflect most incoming radio waves away from the radar station in the same manner as plane mirrors usually reflect light rays away from light sources. In regard to infrared sensors typically picking up on hot engine exhaust, all of the exhausts in a stealth bomber pass through cooling vents before flowing out of the plane. With the designs mentioned above, a stealth bomber has the ability to fly almost undetected through enemy airspace.

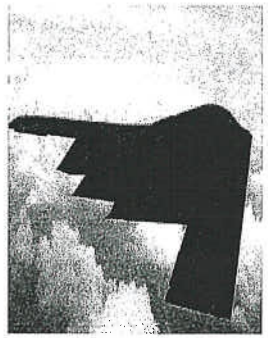


Figure 1

Source: http://science.howstuffworks.com/stealth-bomber3.htm

(a) (i) In Figure 2 below, draw a ray to show how a wave from the radar is reflected at the bottom of the stealth bomber. (1 mark)

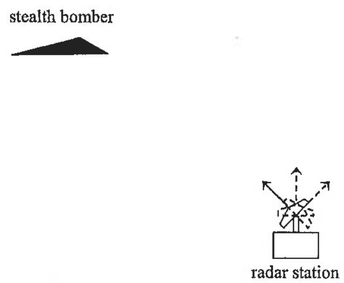


Figure 2

(ii) If the stealth bomber flies horizontally to a particular position around the radar, it can be detected by the radar. Mark this position with a symbol X in Figure 2. (1 mark)

(b) All of the exhausts in a stealth bomber pass through cooling vents before flowing out of the plane. Explain how this can help the stealth bomber to hide away from enemy detection. (2 marks)

____

____

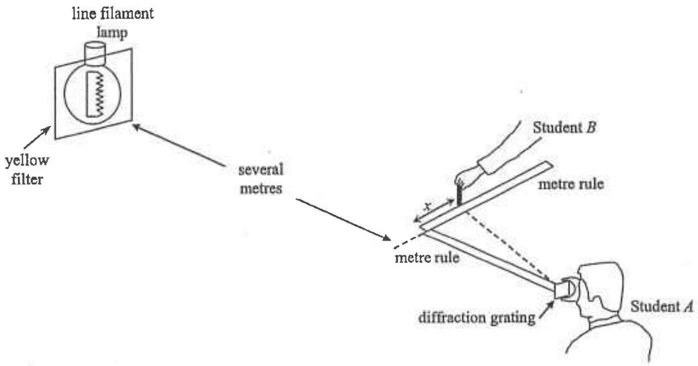
(c) Apart from the above designs which help prevent the stealth bomber being detected by radar and infrared sensors, state two other essential features which are important in building the stealth bomber so that it can hide away from enemy detection. (2 marks)

____

____

Part B : HKAL examination questions

7. < HKAL 1981 Paper IIB - 3 >

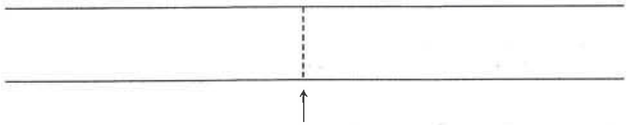


Student A views a line filament lamp with a yellow filter through a diffraction grating with its lines parallel to the filament as shown. The grating is held at one end of a metre rule which is directed towards the lamp. At the other end of the metre rule, a second rule is placed at right angles to the first rule. The diffraction grating has 6.0×10^5 lines per metre.

(a) Student B was told to move a pencil held vertically along the second rule until it coincides with the yellow band in the first image of the lamp as seen through the grating. If the distance between the first rule and the pencil is $x = 0.37$ m as shown in the figure, calculate the wavelength of the yellow light. (2 marks)

(b) If student B keeps moving the pencil along the second metre rule in the same direction, how many more yellow bands will be encountered ? Explain. (You may extend the length of the second metre rule by using more metre rules.) (2 marks)

(c) If the filter is removed, sketch the pattern seen by student A on both sides of the filament, up to the second order, on the figure below. Label the significant features. (4 marks)

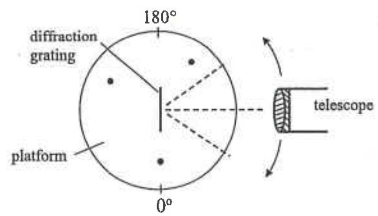


8. < HKAL 1994 Paper I - 6 >

(a) A student views a green light source through a double slit. The pattern observed is shown in the Figure below.

How would the pattern be affected if red light is used instead ? (1 mark)

(b)



To observe the light spectrum of the sodium lamp, a student places a diffraction grating on a platform such that the incident light falls normally on the grating. There is a protractor scale on the platform from 0° to 180°. The sodium lamp produces a yellow light of a certain wavelength. The student uses the second-order images and records the angular position readings of the yellow line on each side of the central line as follows :

	Left-hand side (second order)	Right-hand side (second order)
scale reading on protractor	45.67°	134.37°

(i) Give the grating spacing to be 1684 nm, calculate the wavelength of the yellow light produced by the sodium lamp. Give your answer to 4 significant figures. (2 marks)

(ii) Suggest ONE reason for making measurements by using the second-order images instead of the first-order ones. (1 mark)

9. **< HKAL 2010 Paper I - 2 >**

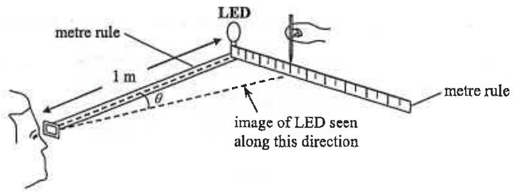


Figure 1

An LED (Light Emitting Diode) emitting monochromatic light of wavelength λ is viewed through a diffraction grating of 160 lines per mm as shown in Figure 1. With the aid of a pencil and two mutually perpendicular metre rules, several positions of images corresponding to the maxima are located in the way shown. Figure 2 shows the observation through the diffraction grating.

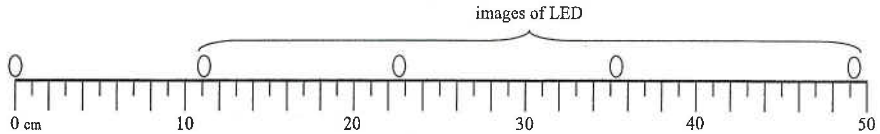
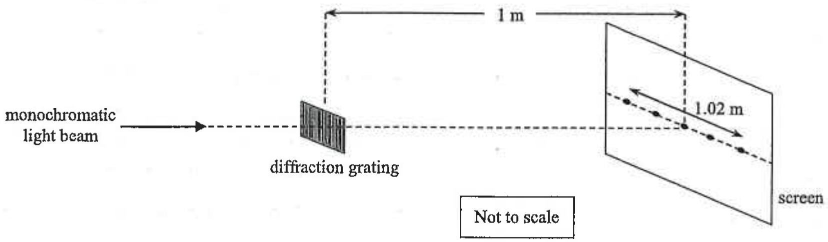


Figure 2

(a) Find the angular position θ of the image of the fourth maximum according to the above observation. Hence determine the wavelength λ of the light emitted by the LED. (3 marks)

(b) Calculate the maximum order of the LED image that may be observed for the above grating. (2 marks)

10. **< HKAL 2011 Paper I - 3 >**



Monochromatic light of wavelength 570 nm from a laser is directed normally onto a diffraction grating as shown. A screen is placed at a distance 1 m behind the grating. The central part of the resulting diffraction pattern is shown in the figure. The separation between the second-order bright spots on both sides of the pattern is 1.02 m.

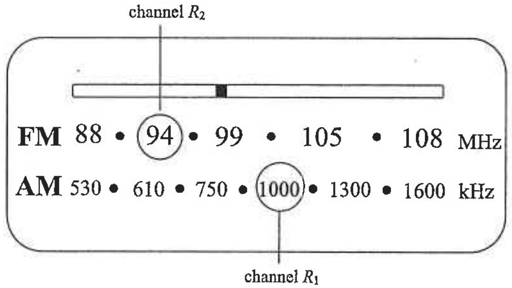
(a) Calculate the grating spacing d of the diffraction grating. (3 marks)

10. (b) State one safety precaution in using the laser light. (1 mark)

(c) State one precaution in performing the above experiment. (1 mark)

Part C : HKDSE examination questions

11. **< HKDSE Sample Paper IB - 5 >**



The Figure above shows the display panel of a radio and the broadcasting frequencies of two radio channels R_1 and R_2.

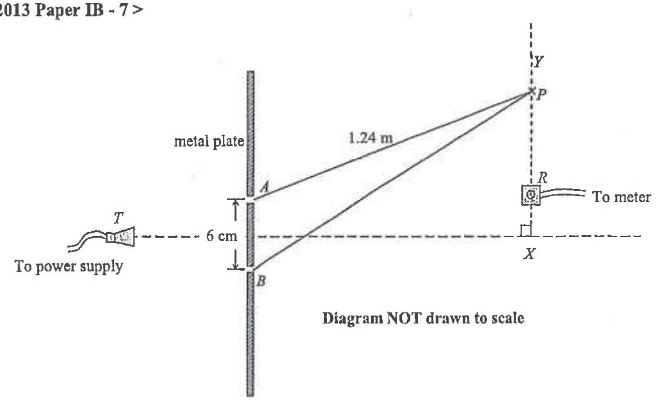
(a) Find the wavelength of the radio waves used by channel R_1. (1 mark)

(b) Anita's house is surrounded by hills and at her house, the reception of one of the two radio channels is better. For which radio channel is the reception better ? Explain your answer. (2 marks)

12. **< HKDSE 2012 Paper IB - 6 >**

A double-slit set-up is used for the demonstration of the interference of light in which the separation between slits S_1 and S_2 is 0.5 mm and the screen is at 2.5 m from the slits. Calculate the average separation between adjacent bright fringes on the screen for a monochromatic light of wavelength 550 nm. (2 marks)

13. **< HKDSE 2013 Paper IB - 7 >**



The Figure above shows a set-up for the study of interference of microwaves. Microwaves of wavelength 2 cm emitted from a transmitter T pass through two slits A and B formed by metal plates. The slits are separated by 6 cm as shown. A probe R connecting to a meter is moved from X to Y to detect the intensity of microwaves received. Transmitter T and point X are equidistant from A and B.

(a) Calculate the frequency of the microwaves. (2 marks)

(b) (i) The meter shows alternate maxima and minima when R moves along XY. Explain. (2 marks)

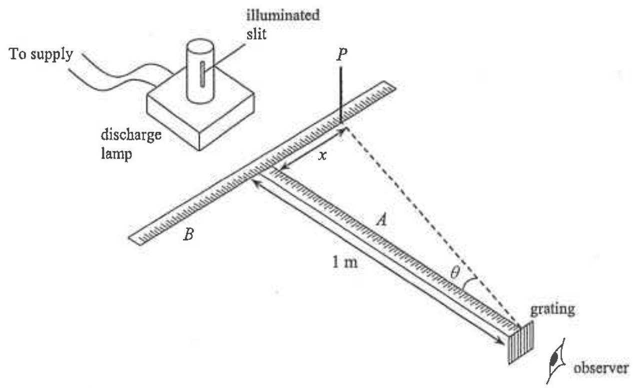
(ii) The second minimum is found at position P where AP = 1.24 m. Find BP. (2 marks)

(iii) When R is moved along XY from X towards Y and beyond, explain whether or not it is possible to detect more than three maxima. (2 marks)

(c) Microwaves can be used in radar. Why are radio waves of lower frequencies not suitable for use in radar ? (2 marks)

14. **< HKDSE 2014 Paper IB - 7 >**

The Figure below 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 metre 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 pin is in line with the diffracted image of the second-order to the observer. The corresponding distance x is measured for finding the diffraction angle θ.



The grating has 300 lines per mm and x is found to be 0.38 m for the **second-order** image.

(a) (i) Calculate the diffraction angle θ. (1 mark)

(ii) Hence find the wavelength of the light from the lamp. (3 marks)

(iii) Give ONE advantage of measuring the position of the second-order image instead of the first-order one. (1 mark)

(b) In the experiment, the illuminated slit may not be well aligned along metre rule A. Suggest one way to reduce this error. (2 marks)

15. < **HKDSE 2015 Paper IB - 7** >

(a) A laser light beam of wavelength 650 nm is incident normally on a pair of slits separated by $a = 0.325$ mm. Interference pattern is observed on a screen at a distance $D = 3.0$ m from the slits as shown in Figure 1. What is the separation between adjacent first- and second-order bright fringes ? (2 marks)

Figure 1

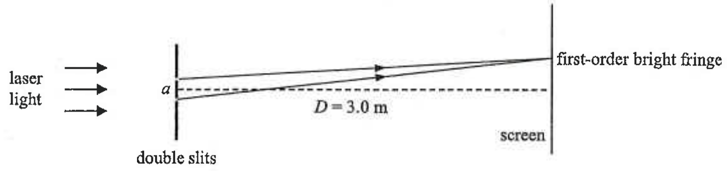


Diagram NOT drawn to scale

(b) Figure 2 shows a set-up with two small LEDs separated by 6 mm and both LEDs emit light of wavelength 650 nm. State and explain what you would expect to see on the screen. (2 marks)

Figure 2

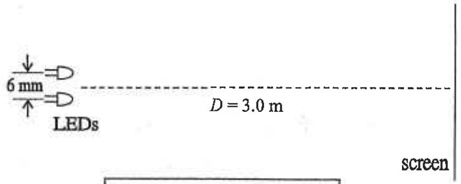
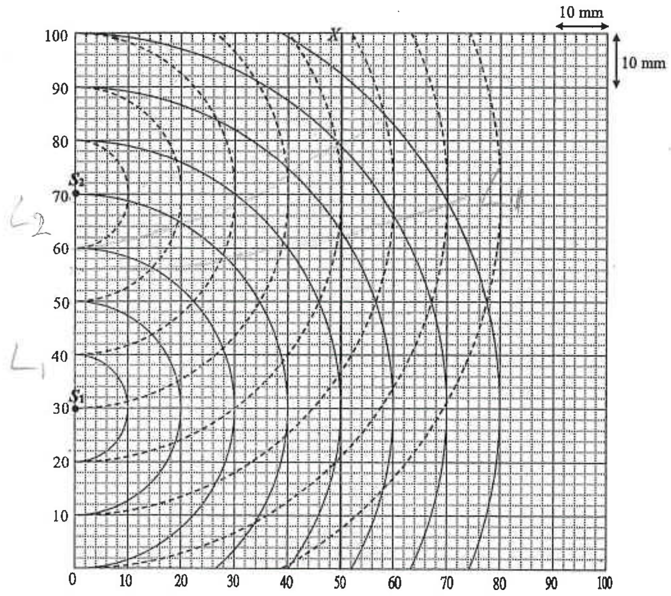


Diagram NOT drawn to scale

15. Figure 3 shows circular water waves in a ripple tank. The two point sources S_1 and S_2, separated by 40 mm, are driven by the same vibrator. The solid lines represent the wave crests from S_1 and the dotted lines represent the wave crests from S_2. The wavelength of the waves is 10 mm.

Figure 3



(c) Sketch on Figure 3 two lines to indicate all points P with path difference $PS_1 - PS_2$ equals to 10 mm (L_1) and 20 mm (L_2). State the kind of interference that occurs at these points P. (3 marks)

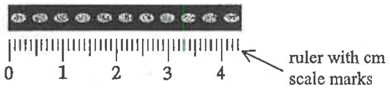
(d) (i) If the interference pattern is observed along line XY at 50 mm from the source as shown, measure the separation between adjacent first- and second-order maxima Δy. (1 mark)

separation Δy = ____________

(ii) However, using the calculation method in (a) would obtain 12.5 mm for this separation. Why does this calculated value differ with the measurement in (d) (i) ? (2 marks)

16. < HKDSE 2016 Paper IB - 6 >

(a) 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 in the Figure below.



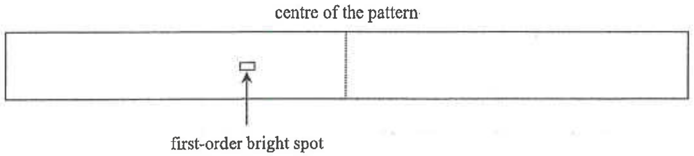
(i) Find the wavelength of the laser beam. (3 marks)

(ii) Explain why the slit width has to be very narrow in order for the above pattern to be observed. (2 marks)

(b) The double slit is now 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. (3 marks)

(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. (2 marks)



17. < HKDSE 2018 Paper IB - 7 >

(a)

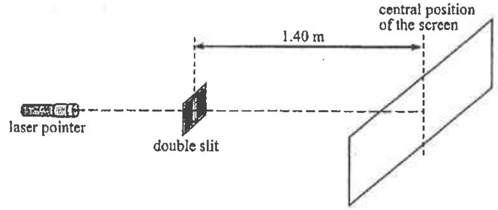


Figure 1

Figure 1 above shows a set-up for measuring the wavelength λ of light emitted by a laser pointer. Several bright dots of average separation about 2 mm can be seen on the screen.

(i) For the same set of apparatus, suggest a way to increase the average separation between the bright dots on the screen. (1 mark)

The double slit is now replaced by a diffraction grating with 400 lines per mm.

(ii) Briefly explain why the accuracy of the experiment can be improved. (1 mark)

(iii) Only five bright dots are observed on the screen such that the separation between the 1st and 5th dots is 1.56 m. Find λ. (3 marks)

(b) To measure the speed of sound in air, a student connects two loudspeakers, A and B, to a signal generator as shown in Figure 2.

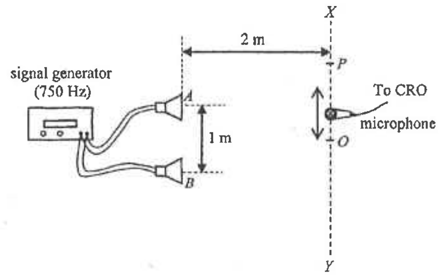
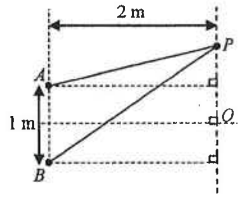


Figure 2

The separation of A and B is 1 m. A microphone is used to pick up the sound along the line XY at a distance of 2 m from the loudspeakers. The central maximum is at point O while the next maximum is at point P.

(i) With reference to the above settings, use the fringe separation equation $\Delta y = \frac{\lambda D}{a}$ in double-slit interference to find the wavelength λ of sound is not accurate. Explain briefly. (1 mark)

17. (b) (ii) The distance between O and P is found to be 1 m when the signal generator is set at 750 Hz. By considering the path difference $PB - PA$, use the results of the experiment to find the speed of sound in air.



HKEAA's Marking Scheme is prepared for the markers' reference. It should not be regarded as a set of model answers. Students and teachers who are not involved in the marking process are advised to interpret the Marking Scheme with care.

Question Solution

1. (a) (i) $v = f\lambda$ [1]

$(3 \times 10^8) = f(0.03)$ [1]

$f = 10^{10}$ Hz [1]

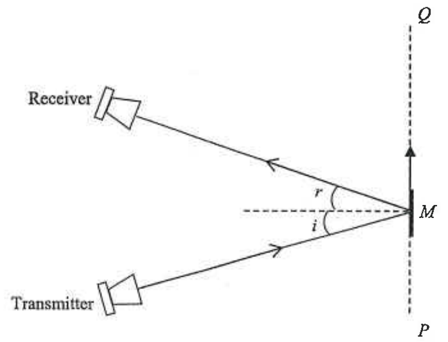
(ii) path difference = 0 [1]

(iii) constructive interference [1]

(iv) loud [1]

(v) Along XY, loud and soft sounds are heard [1]
alternately [1]

(b)



[1]

As M moves, the intensity of sound increases to a maximum [1]
and then decreases again as it approaches Q. [1]
When M is mid-way between P and Q, (**OR** indication in the figure that $i = r$), [1]
microwaves emitted from the transmitter is reflected by M and collected by the receiver. [1]

(c) Any **TWO** of the following : [2]
- Radar
- Microwave oven
- Satellite communication
- Mobile phone

2. (a) Interference of microwaves from A and B occurs due to different path difference. [1]
The reading reaches a maximum at positions of constructive interference [1]
and a minimum at positions of destructive interference. [1]

2. (b) Constructive interference occurs at P. [1]

(c) Path difference at $P = 1\lambda$ [1]

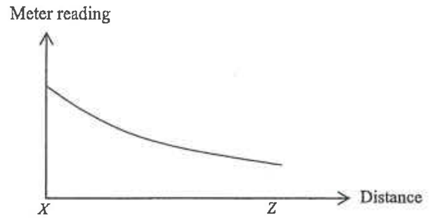
$\therefore \lambda = 36 - 33 = 3$ cm [1]

By $v = f\lambda$

$\therefore (3 \times 10^8) = f(0.03)$ [1]

$\therefore f = 10^{10}$ Hz [1]

(d) [2]



The interference is always constructive along XZ, so the reading is always at a maximum. [1]

However the intensity of the waves decreases with distance,

so the reading decreases as the probe moves away from X. [1]

3. (a) By $v = f\lambda$ [1]

For Radio waves :

$(3 \times 10^8) = (600 \times 10^3)\lambda$

$\therefore \lambda = 500$ m [1]

For TV waves :

$(3 \times 10^8) = (500 \times 10^6)\lambda$

$\therefore \lambda = 0.6$ m [1]

(b) (i) The phenomenon is diffraction. [1]

(ii) As the wavelength of the radio waves is longer than that of the TV waves, [1]

the radio waves are diffracted more by the hills, so the radio reception is better. [1]

(c) The aeroplane reflects the TV waves. [1]

The waves travelling directly to the aerial has interference with the waves reflected by the aeroplane. [1]

(d) (i) Path difference $= BP - BQ$

$= 3.95 - 3.20 = 0.75$ km

$= 750$ m [1]

3. (d) (ii) A path difference of 750 m is equal to $1\frac{1}{2}\lambda$. [1]

So the two signals give destructive interference. [1]

As a result, the radio reception will become poorer. [1]

(e) Destructive interference of signals from 2 neighbouring transmitters [1]

can be avoided. [1]

4. (a) By $v = f\lambda$

$\therefore (3 \times 10^8) = (1000 \times 10^3)\lambda$ [1]

$\therefore \lambda = 300$ m [1]

(b) The reception of channel R_1 is better. [1]

Since the wavelength of R_1 is longer than that of R_2, [1]

the radio waves of R_1 diffract more than that of R_2. [1]

5. (a) $v = f\lambda$

$\therefore (3 \times 10^8) = (1.2 \times 10^9)\lambda$ [1]

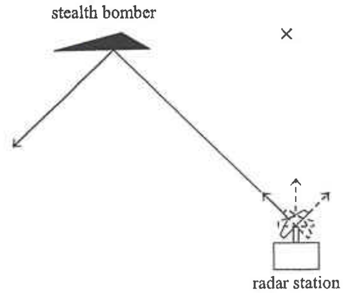
$\therefore \lambda = 0.25$ m [1]

(b) $\Delta t = 6.5 \times 5 \times 10^{-6} = 3.25 \times 10^{-5}$ s [1]

$d = \frac{1}{2} \times v \times \Delta t = \frac{1}{2} \times (3 \times 10^8) \times (3.25 \times 10^{-5})$ [1]

$= 4880$ m < accept 4875 m > [1]

6. (a)



(i) < The incident ray and the reflected ray drawn with reflected angle equals the incident angle > [1]

(ii) < The cross X marked vertically above the radar station > [1]

6. (b) To lower the temperature of the exhausts [1]

and reduce the emission of infra-red radiation. [1]

(c) ① The engine is very quiet. [1]

② The aircraft blends in with the background visually. [1]

7. (a) $\tan\theta = \frac{0.37}{1} = 0.37$

$\therefore\ \theta = 20.3°$ [1]

By $d\sin\theta = n\lambda$

$\therefore\ \left(\frac{1}{6.0\times10^5}\right)\times\sin 20.3° = 1\times\lambda$

$\therefore\ \lambda = 5.78\times10^{-7}$ m [1]

(b) The maximum diffracted angle is 90°

By $d\sin\theta = n\lambda$

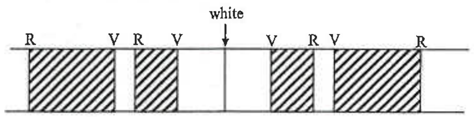
$\therefore\ \left(\frac{1}{6.0\times10^5}\right)\times\sin 90° = n\times(5.78\times10^{-7})$

$\therefore\ n = 2.9$ [1]

∴ No 3rd or higher order maximum can be observed.

∴ One more yellow band will be observed. [1]

(c)



Any **FOUR** of the following features in the diagram : [4]

* zero order image - white
* continuous spectra in each order
* violet / red ends marked correctly
* two orders shown on each side
* distance between 2nd and 1st order > distance between 1st and zeroth order
* spreading of colours greater in second order than the first order

8. (a) The fringe separation increases. [1]

8. (b) (i) By $d\sin\theta = n\lambda$

$\therefore\ (1684)\times\sin\left[\frac{134.37° - 45.67°}{2}\right] = (2)\lambda$ [1]

$\therefore\ \lambda = 588.6$ nm [1]

(ii) Larger diffraction angle gives smaller percentage error. [1]

9. (a) For the 4th order image : $x = 49.2$ cm

$\therefore\ \tan\theta = \frac{49.2\times10^{-2}}{1}$

$\therefore\ \theta = 26.2°$ < accept 26.0° to 26.4° > [1]

By $d\sin\theta = n\lambda$

$\therefore\ (\frac{1\times10^{-3}}{160})\sin 26.2° = (4)\lambda$ [1]

$\therefore\ \lambda = 6.90\times10^{-7}$ m < accept 6.8×10^{-7} m to 7.0×10^{-7} m > [1]

(b) By $d\sin\theta = n\lambda$

$\therefore\ (\frac{1\times10^{-3}}{160})\sin 90° = n(6.90\times10^{-7})$ [1]

$\therefore\ n = 9.06$ ∴ maximum order is 9 [1]

OR

By $\frac{n}{4} = \frac{\sin 90°}{\sin 26.2°}$ [1]

$\therefore\ n = 9.06$ ∴ maximum order is 9 [1]

10. (a) Second order : $\tan\theta = \frac{1.02/2}{1.00}$ $\therefore\ \theta = 27.02°$ [1]

By $d\sin\theta = n\lambda$

$\therefore\ d\sin 27.02° = (2)(570\times10^{-9})$ [1]

$\therefore\ d = 2.51\times10^{-6}$ m < accept 2.5×10^{-6} m > [1]

< Do not accept answer by using $\Delta y = \lambda D / a$ >

(b) Any **ONE** of the following [1]

* Do not view the laser light directly with eyes.
* Do not point laser light towards human bodies.

(c) Any **ONE** of the following [1]

* Grating should be perpendicular to the incident light.
* Screen should be parallel to the grating.

11. (a) $v = f\lambda$

$\therefore\ (3 \times 10^8) = (1000 \times 10^3)\,\lambda$

$\therefore\ \lambda = 300$ m [1]

(b) The reception of channel R_1 is better. [1]

Since the wavelength of R_1 is longer than that of R_2,

the radio waves of R_1 diffract more than that of R_2. [1]

12. $\Delta y = \dfrac{\lambda D}{a} = \dfrac{(550\times10^{-9})(2.5)}{(0.5\times10^{-3})}$ [1]

$= 2.75 \times 10^{-3}$ m [1]

13. (a) $c = f\lambda$

$\therefore\ (3 \times 10^8) = f(0.02)$ [1]

$\therefore\ f = 1.5 \times 10^{10}$ Hz [1]

(b) (i) Path difference of the diffracted waves from slits A and B varies along XY. [1]

Constructive and destructive interference occur alternately to give maximum and minimum. [1]

(ii) $BP - AP = 1.5\,\lambda$ [1]

$BP - 1.24 = 0.03$

$BP = 1.27$ m [1]

(iii) Path difference along XY must be less than slit separation AB.

$AB = 6$ cm $= 3\,\lambda$

Thus the path difference can never reach 3λ along XY. [1]

Therefore, it is not possible to detect more than 3 maxima along XY. [1]

(Only $\Delta = 0\lambda, 1\lambda, 2\lambda$ can be detected.)

(c) Radio waves with lower frequencies and longer wavelength have greater diffraction effect. [1]

Radio waves by-pass small obstacles (**OR** Radio waves cannot be reflected by small obstacles). [1]

14. (a) (i) $\tan\theta = \dfrac{0.38}{1}$ $\therefore\ \theta = 20.8°$ [1]

(ii) Grating spacing : $d = (\dfrac{1\times10^{-3}}{300})$ [1]

By $d\sin\theta = n\lambda$ $\therefore\ (\dfrac{1\times10^{-3}}{300})\sin 20.8° = (2)\lambda$ [1]

$\therefore\ \lambda = 5.92 \times 10^{-7}$ m < accept 5.90×10^{-7} m to 5.97×10^{-7} m > [1]

14. (a) (iii) The diffracted angle θ is greater and thus the percentage error is reduced. [1]

OR

The value x is greater and thus the percentage error is reduced. [1]

(b) Locate the second order images at the other side of the central line. [1]

Take the average value of x obtained from both sides to find λ. [1]

OR

Measure the distance between the two images and divide it by 2 to give x. [1]

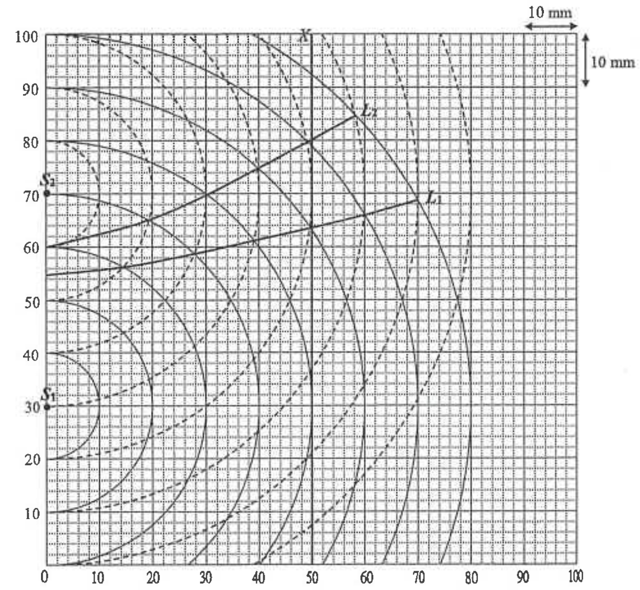
15. (a) $\Delta y = \dfrac{\lambda D}{a} = \dfrac{(650\times10^{-9})(3.0)}{(0.325\times10^{-3})}$ [1]

$= 6 \times 10^{-3}$ m (6 mm) [1]

(b) The screen is uniformly illuminated. < **OR** No alternate bright and dark fringes can be observed > [1]

The lights from the LEDs are not coherent. < **OR** No constant phase relationship > [1]

(c)



< $\Delta = PS_1 - PS_2 = 10$ mm $= 1\,\lambda$: drawn correctly > [1]

< $\Delta = PS_1 - PS_2 = 20$ mm $= 2\,\lambda$: drawn correctly > [1]

Constructive interference occurs at P. [1]

15. (d) (i) Δy = 17 mm <accept 15 mm to 19 mm> [1]

(ii) The calculation is true only for small angle close to the central line. [1]

Moreover, the screen is too close to the sources, $D >> a$ cannot be satisfied. [1]

16. (a) (i) $\Delta y = \frac{(4.0 - 0)}{10} = 0.4$ cm <accept 0.39 to 0.41 cm> [1]

By $\Delta y = \frac{\lambda D}{a}$

$\therefore (0.4\times10^{-2}) = \frac{\lambda(1.8)}{(0.3\times10^{-3})}$ [1]

$\therefore \lambda = 6.67\times10^{-7}$ m <accept 6.5 – 6.7 × 10^{-7} m> [1]

(ii) To ensure that light through the two slits have large diffraction [1]

so that the two diffracted light can interfere (**OR** overlap). [1]

(b) (i) By $d\sin\theta = n\lambda$

$\therefore (\frac{10^{-3}}{500})\sin\theta = (1)(6.67\times10^{-7})$ [1]

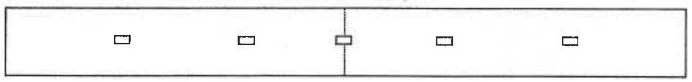
$\therefore \theta = 19.5°$

By $\tan 19.5° = \frac{x}{(1.8)}$ [1]

$\therefore x = 0.637$ m <accept 0.633 m to 0.640 m> [1]

(ii)

centre of the pattern



<5 spots shown with symmetry about the centre> [1]

<separation between 1st and 2nd order spots is larger> [1]

17. (a) (i) Increase the separation D between the double slit and the screen. [1]

(ii) The separation of the bright dots on the screen becomes larger, thus the percentage error is smaller. [1]

(iii) Second order bright fringe : $\tan\theta_2 = \frac{(1.56/2)}{(1.40)}$ $\therefore \theta_2 = 29.1°$ [1]

Grating spacing : $d = \frac{(10^{-3})}{(400)} = 2.5\times10^{-6}$ m [1]

By $d\sin\theta = n\lambda$

$\therefore (2.5\times10^{-6})\sin 29.1° = (2)\lambda$ $\therefore \lambda = 6.08\times10^{-7}$ m <accept 6.06 to 6.10 × 10^{-7} m> [1]

17. (b) (i) The equation can only be applied for $a << D$. [1]

(ii) Path difference at $P = 1\lambda$ [1]

$\Delta = \sqrt{(1+0.5)^2+2^2} - \sqrt{(1-0.5)^2+2^2} = 1\lambda$ [1]

$\therefore \lambda = 0.438$ m

By $v = f\lambda$

$\therefore v = (750)(0.438) = 329$ m s^{-1} <accept 328 to 330 m s^{-1}> [1]