Higher Waves

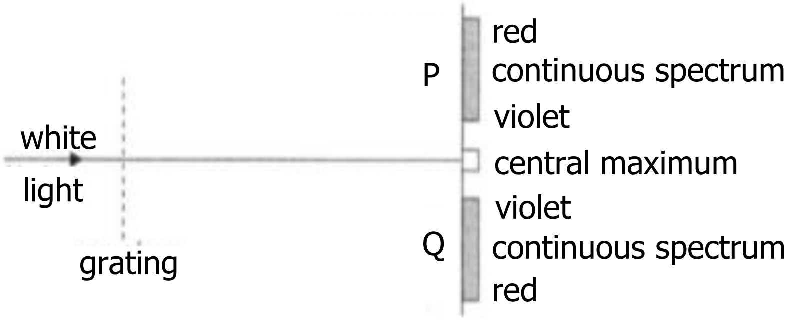
Past Paper Questions

Book 1

Contents

Interference and Diffraction Gratings

1. When white light passes through a grating, maxima of intensity are produced on a screen, as shown below. The central maximum is white. Continuous spectra are obtained at positions P and Q.



In the continuous spectra, violet is observed closest to the central maximum.

Which of the following statements is/are true?

I Violet light has the shortest wavelength of all the visible radiations.

II Violet light has the longest wavelength of all the visible radiations.

III Violet light travels faster through air than the other visible radiations.

A I only

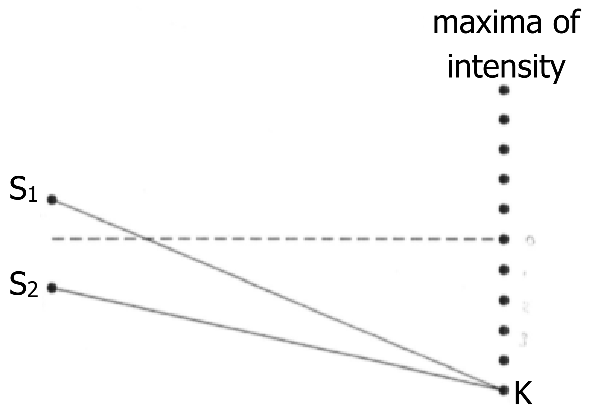
B II only

C III only

D I and III only

E II and III only

2. Waves from coherent sources, S_1 and S_2, produce an interference pattern. Maxima of intensity are detected at the positions shown below.



The path difference S_1K - S_2K is 154 mm. The wavelength of the waves is

A 15·4 mm

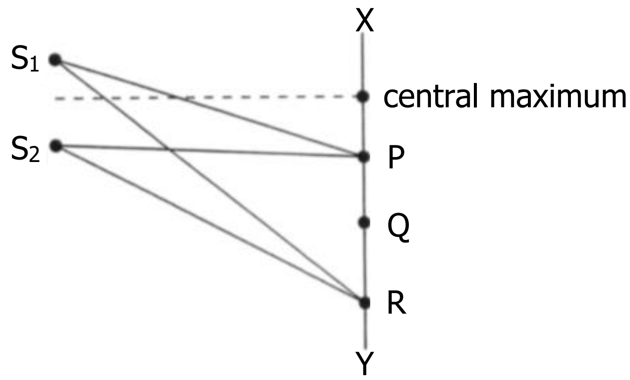
B 25·7 mm

C 28·0 mm

D 30·8 mm

E 34·2 mm.

3. S_1 and S_2 are sources of coherent waves which produce an interference pattern along the line XY.



The first maximum occurs at P, where S_1P = 20 cm and S_2P = 18cm.

For the third maximum, at R, the path difference (S_1R - S_2R) is

A 3 cm

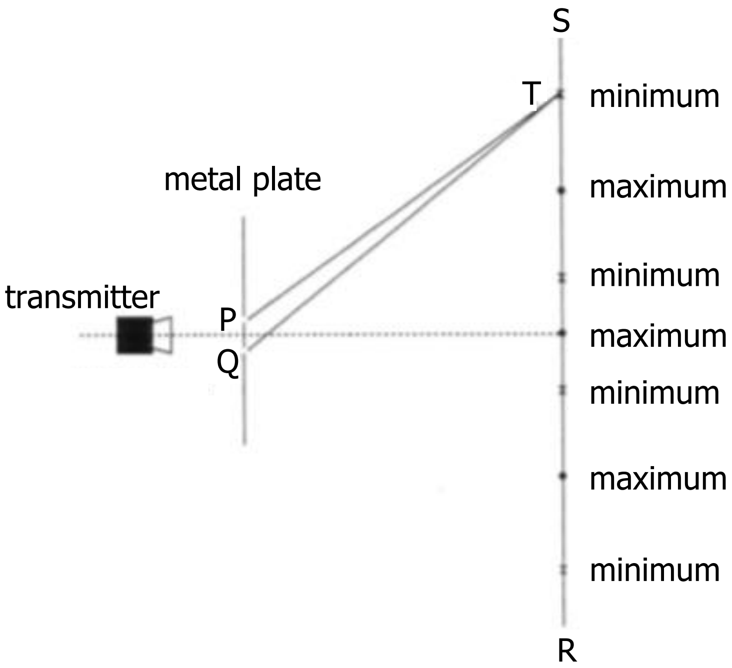
B 4 cm

C 5 cm

D 6 cm

E 8 cm.

4. Microwave radiation is incident on a metal plate which has 2 slits, P and Q. A microwave receiver is moved from R to S, and detects a series of maxima and minima of intensity at the positions shown.



The microwave radiation has a wavelength of 4 cm.

The path difference between PT and QT is

A 2 cm

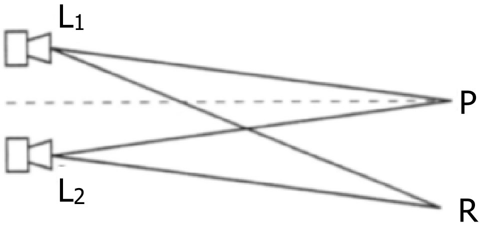
B 3 cm

C 4 cm

D 5 cm

E 6 cm

5. Two identical loudspeakers, L_1 and L_2, are operated at the same frequency and in phase with each other. An interference pattern is produced.



At position P, which is the same distance from both loudspeakers, there is a maximum intensity.

The next maximum intensity is at position R, where L_1R = 5·6 m and L_2R = 5·3 m.

The speed of the sound produced is 340 m s^{-1}.

The frequency of the sound emitted by the loudspeakers is given by

A $\frac{5{\cdot}6 - 5{\cdot}3}{340}$ Hz

B $\frac{340}{5{\cdot}6 + 5{\cdot}3}$ Hz

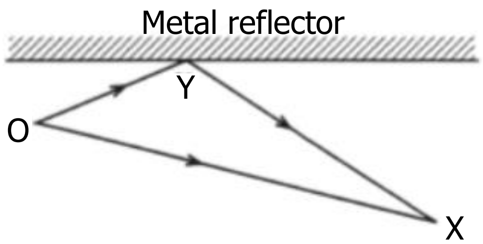
C $\frac{340}{5{\cdot}6 - 5{\cdot}3}$ Hz

D 340 x (5·6 - 5·3) Hz

E 340 x (5·6 + 5·3) Hz

6. A microwave source at point O produces waves of wavelength 28 mm.

A metal reflector is placed as shown.



An interference pattern is produced.
Constructive interference occurs at point X.
The distance OX is 400 mm.
The total path length OYX is

A 414 mm

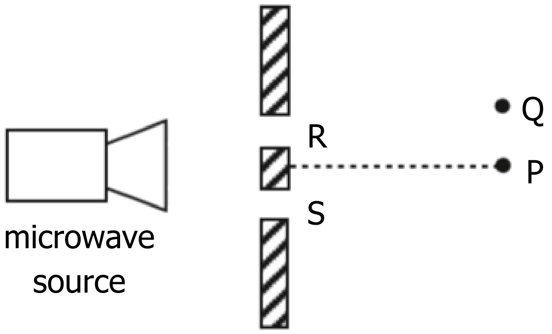
B 421 mm

C 442 mm

D 456 mm

E 463 mm.

7. A source of microwaves of wavelength λ is placed behind two slits, R and S.



The detector is moved and the **next** maximum is recorded at Q.

The path difference (SQ - RQ) is

A 0

B $\frac{\lambda}{2}$

C λ

D $\frac{3\lambda}{2}$

E 2λ

8. Which of the following proves that light is transmitted as waves?

A Light has a high velocity.

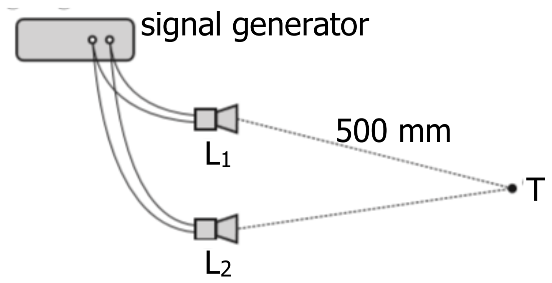
B Light can be reflected.

C Light irradiance reduces with distance.

D Light can be refracted.

E Light can produce interference patterns.

9. Two identical loudspeakers, L_1 and L_2, are connected to a signal generator as shown.



An interference pattern is produced.

A minimum is detected at point T.

The wavelength of the sound is 40 mm.

The distance from L_1 to T is 500 mm.

The distance from L_2 to T is

A 450 mm

B 460 mm

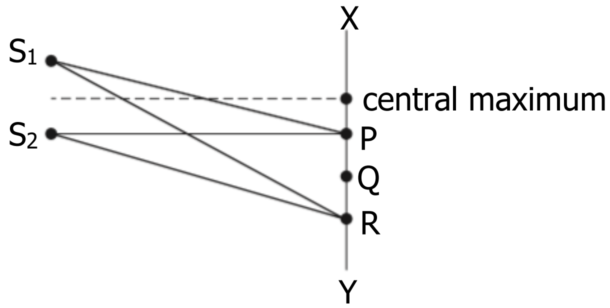
C 470 mm

D 480 mm

E 490 mm

10. S_1 and S_2 are sources of coherent waves.

An interference pattern is obtained between X an Y.



The first order maximum occurs at P, where S_1P = 200 mm and S_2P = 180 mm.

For the third order maximum, at R, the path difference (S_1R - S_2R) is

A 20 mm

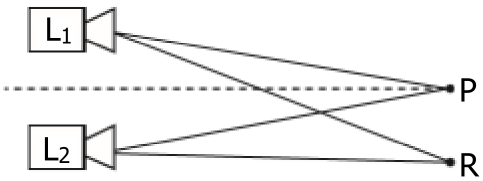
B 30 mm

C 40 mm

D 50 mm

E 60 mm.

11. Two identical loudspeakers, L_1 and L_2, operate at the same frequency and in phase with each other. An interference pattern is produced.



At position P, which is the same distance from both loudspeakers, there is a maximum.

The next maximum is at position R, where $L_1R = 5{\cdot}6$ m and $L_2R = 5{\cdot}3$ m.

The speed of sound in air is 340 m s^{-1}.

The frequency of the sound emitted by the loudspeakers is

A $8{\cdot}8 \times 10^{-4}$ Hz

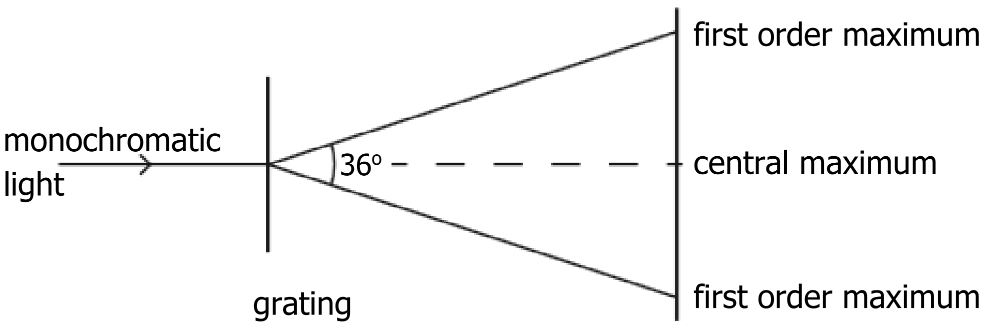
B $3{\cdot}1 \times 10^{1}$ Hz

C $1{\cdot}0 \times 10^{2}$ Hz

D $1{\cdot}1 \times 10^{3}$ Hz

E $3{\cdot}7 \times 10^{3}$ Hz

12. A ray of monochromatic light is incident on a grating as shown.



The wavelength of the light is 633 nm.

The separation of the slits on the grating is

A $1{\cdot}96 \times 10^{-7}$ m

B $1{\cdot}08 \times 10^{-6}$ m

C $2{\cdot}05 \times 10^{-6}$ m

D $2{\cdot}15 \times 10^{-6}$ m

E $4{\cdot}10 \times 10^{-6}$ m.

13. A student makes the following statements about waves from coherent sources.

I Waves from coherent sources have the same velocity.

II Waves from coherent sources have the same wavelength.

III Waves from coherent sources have a constant phase relationship.

Which of these statements is/are correct?

A I only

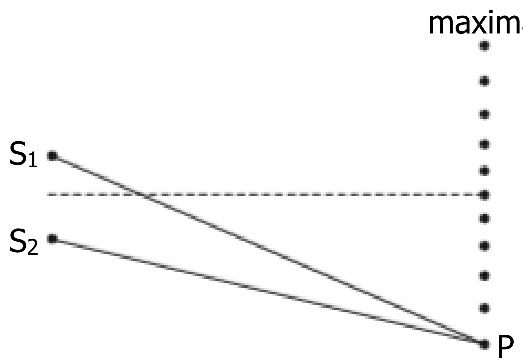
B II only

C I and II only

D I and III only

E I, II and III

14. Waves from two coherent sources, S_1 and S_2, produce an interference pattern. Maxima are detected at the positions shown below.



The path difference $S_1P - S_2P$ is 102 mm.

The wavelength of the waves is

A 10·2 mm

B 20·4 mm

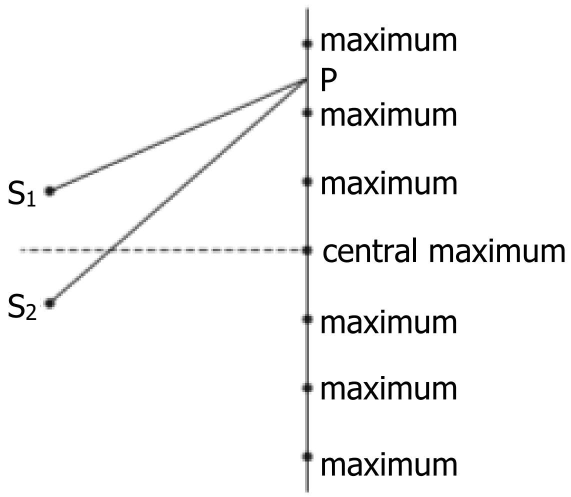
C 22·7 mm

D 459 mm

E 510 mm.

15. Waves from two coherent sources, S_1 and S_2, produce an interference pattern.

Maxima are detected at the positions shown.



The wavelength of the waves is 28 mm.

For the third minimum, at P, the path difference (S_2P - S_1P) is

A 42 mm

B 56 mm

C 70 mm

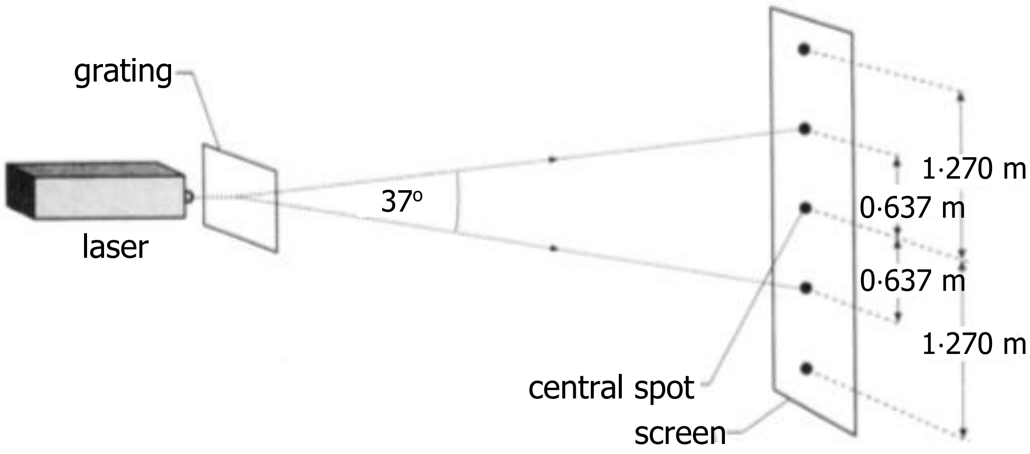
D 84 mm

E 98 mm.

Interference and Diffraction Gratings

16. (a) In an experiment, laser light of wavelength 633 nm is incident on a grating.

A series of bright spots are seen on a screen placed some distance from the grating. The distance between the spots and the central spot is shown.



Calculate the number of lines per metre on the grating. 4

(b) The laser is replaced with another laser and the experiment repeated. With this laser the bright spots are closer together.

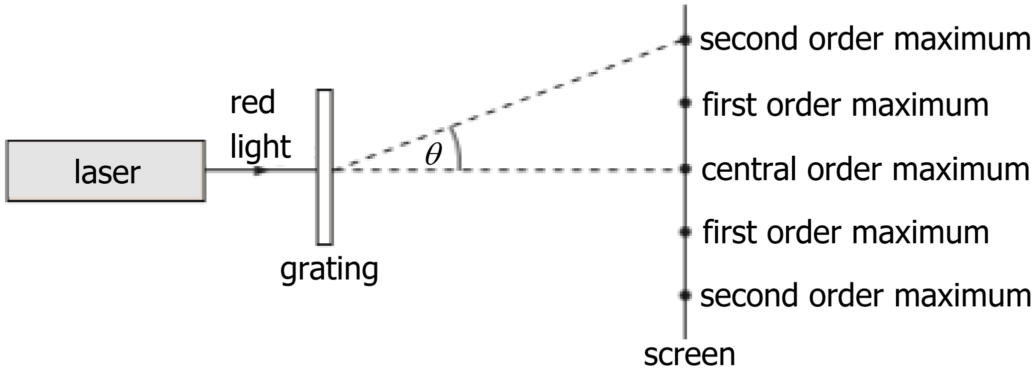
State how the wavelength of the light from this laser compares with that from the original laser.

You must justify your answer. 2

Interference and Diffraction Gratings

17. A laser produces a narrow beam of monochromatic light.

(a) Red light from a laser passes through a grating as shown.



A series of maxima and minima is observed on the screen.

Explain, in terms of waves, how a minimum is produced. 1

(b) The laser is now replaced by a second laser, which emits blue light.

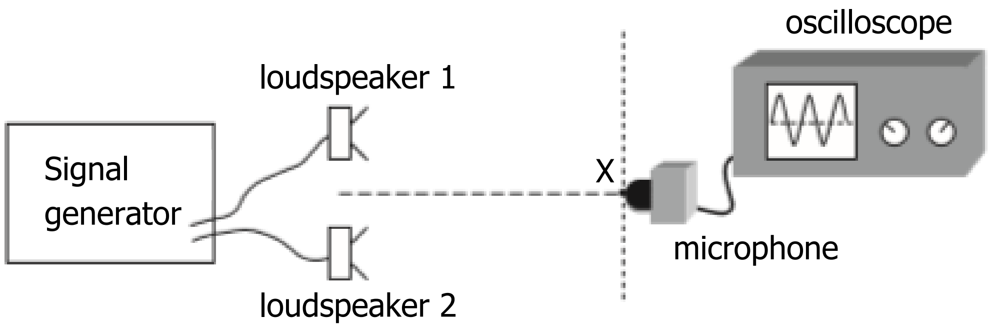
Explain why the observed maxima are now closer together. 2

(c) The wavelength of the blue light from the second laser is $4{\cdot}73 \times 10^{-7}$ m. The spacing between the lines on the grating is $2{\cdot}00 \times 10^{-6}$ m.

Calculate the angle between the central maximum and the second order maximum. 3

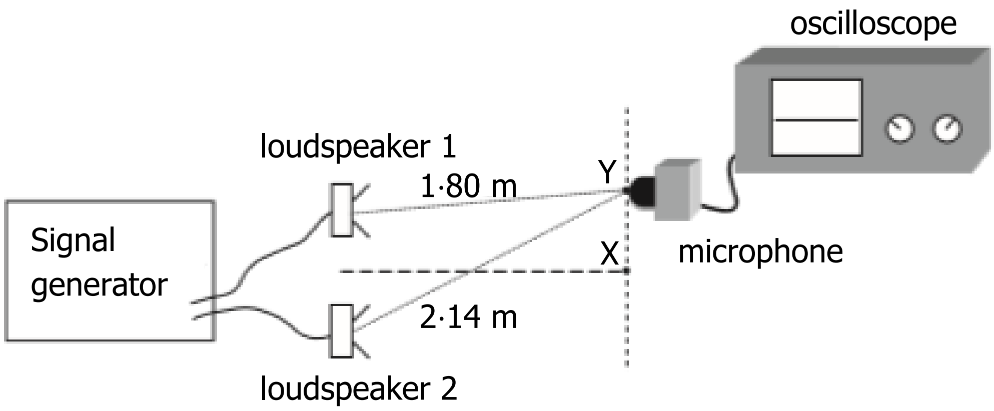
Interference and Diffraction Gratings

18. A student is carrying out an experiment to investigate the interference of sound waves. She sets up the following apparatus.



The microphone is initially placed at point X which is the same distance from each loudspeaker. A maximum is detected at X.

(a) The microphone is now moved to the first minimum at Y as shown.



Calculate the wavelength of the sound waves. 3

(b) Loudspeaker 1 is now disconnected.

State what happens to the amplitude of the sound detected by the microphone at Y.

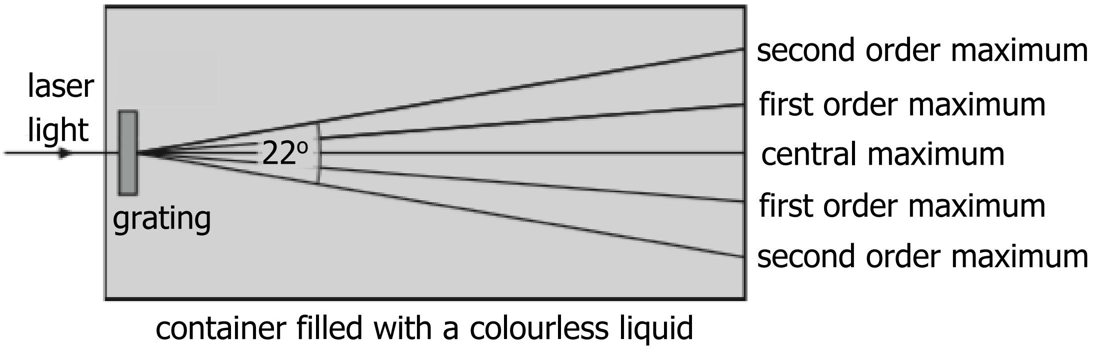
Explain your answer. 2

Interference and Diffraction Gratings; Refraction

19. (a) The first demonstration of the interference of light was performed by Thomas Young in 1801.

State what the demonstration of interference proves about the nature of light. 1

(b) A grating is placed in a colourless liquid in a container. Laser light is incident on the grating along the normal. The spacing between the lines on the grating is $5{\cdot}0 \times 10^{-6}$ m. Interference occurs and the maxima produced are shown in the diagram.



(i) Calculate the wavelength of the laser light in the liquid. 3

(ii) The refractive index of the colourless liquid decreases as the temperature of the liquid increases.

The liquid is now heated.

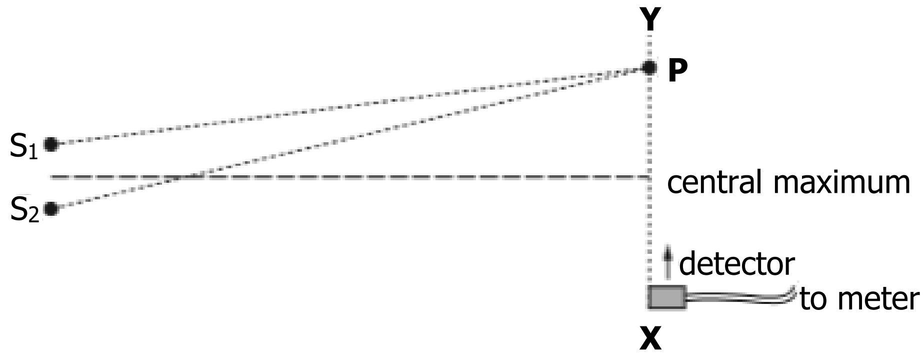
State the effect this has on the spacing between the maxima.

You must justify your answer. 2

Interference and Diffraction Gratings

20. A student is using different types of electromagnetic radiation to investigate interference.

(a) In the first experiment, two identical sources of microwaves, S_1 and S_2, are positioned a short distance apart as shown.



(i) The student moves a microwave detector from X towards Y. The reading on the meter increases and decreases regularly.

Explain, in terms of waves, what causes the minimum readings to occur. 1

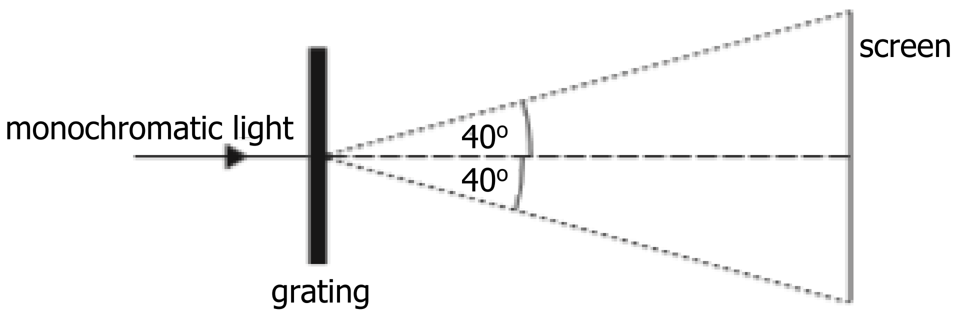
(ii) The **third** maximum from the central maximum is located at P.

The distance from S_1 to P is 620 mm.

The wavelength of the waves is 28 mm.

Calculate the distance from S_2 to P. 3

(b) In the second experiment, a beam of parallel, monochromatic light is incident on a grating. An interference pattern is produced on a screen. The edges of the screen are at an angle of 40° to the centre of the grating as shown.



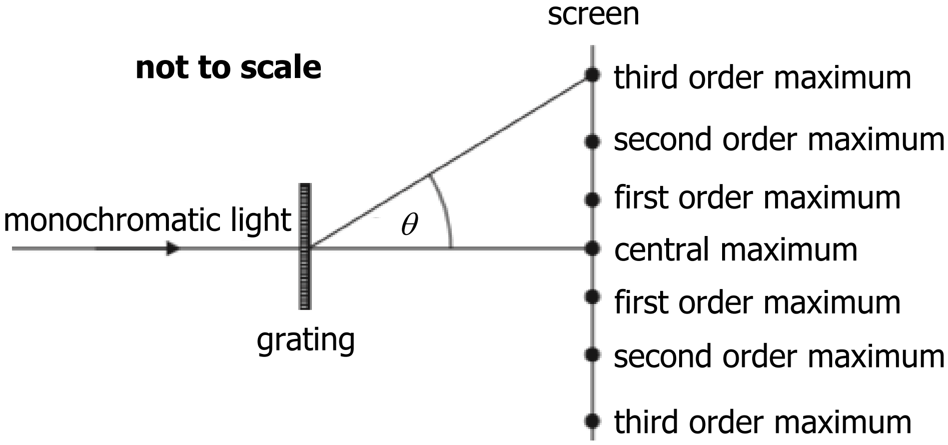
The wavelength of the light is 420 nm and the separation of the slits on the grating is $3{\cdot}27 \times 10^{-6}$ m.

Determine the total number of maxima visible on the screen. 4

Interference and Diffraction Gratings

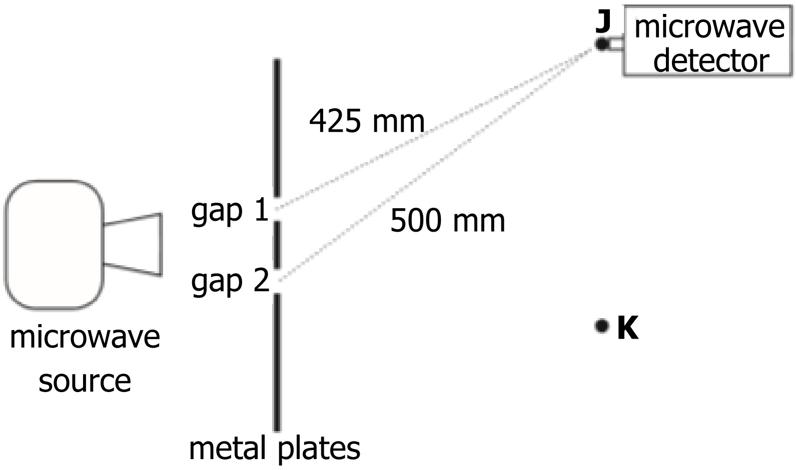
21. Two experiments are carried out to study the interference of waves.

(a) In the first experiment, monochromatic light of wavelength 589 nm passes through a grating. The distance between the slits on the grating is $5{\cdot}0 \times 10^{-6}$ m.



Calculate the angle θ between the central maximum and the third order maximum. 3

(b) In the second experiment, microwaves of wavelength 30 mm pass through two gaps between metal plates as shown.



(i) The distances from each of the gaps to point **J** are shown in the diagram.

Use this information to determine whether **J** is a point of constructive or destructive interference.

You must justify your answer by calculation. 2

(ii) The microwave detector is now moved to **K**, which is a point of destructive interference.

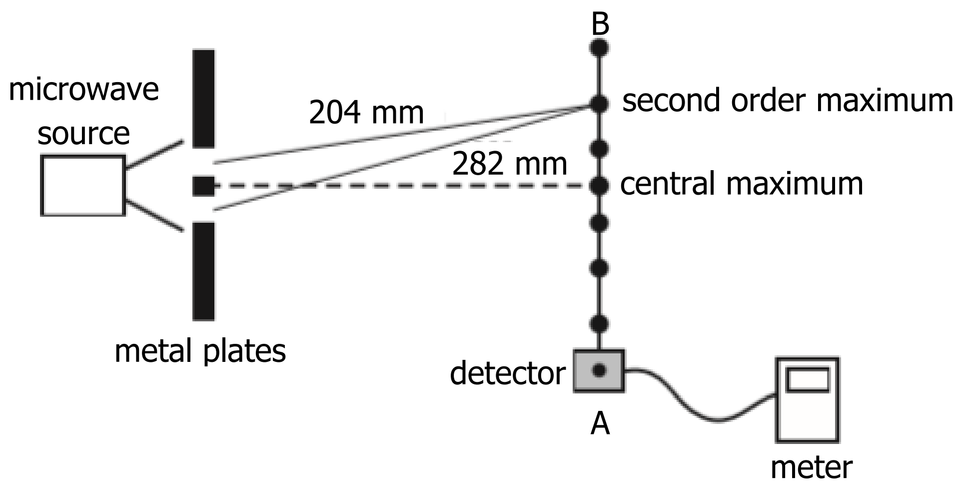
Gap 1 is then covered with a sheet of metal.

State whether the strength of the signal detected at **K** increases, decreases or stays the same.

You must explain your answer. 2

Interference and Diffraction Gratings

22. A student carries out an experiment to measure the wavelength of microwave radiation. Microwaves pass through two gaps between metal plates as shown.



As the detector is moved from A to B, a series of maxima and minima are detected.

(a) The microwaves passing through the gaps are coherent.

State what is meant by the term *coherent waves*. 1

(b) Explain, in terms of waves, how a maximum is produced. 1

(c) The measurements of the distance from each gap to the second order maximum are shown in the diagram above.

Calculate the wavelength of the microwaves. 3

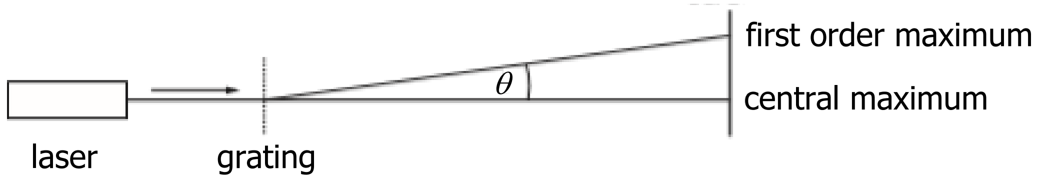
(d) The distance separating the two gaps is now increased.

State what happens to the path difference to the second order maximum.

Justify your answer. 2

Interference and Diffraction Gratings

23. An experiment is carried out to determine the wavelength of light from a laser.



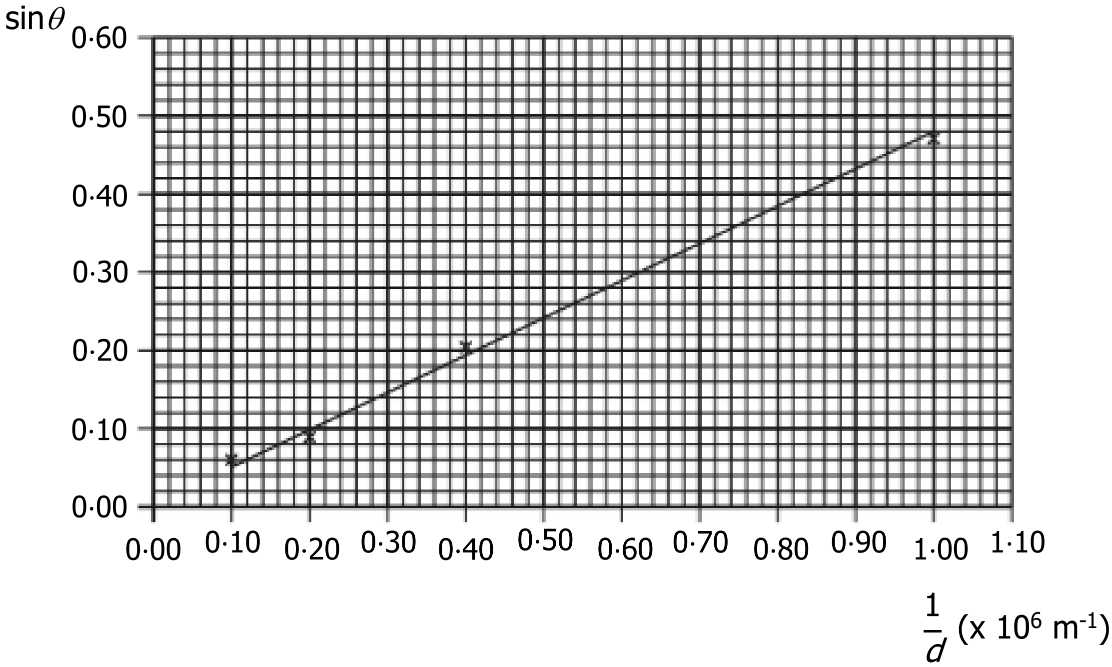
(a) Explain, in terms of waves, how a maximum is formed. 1

(b) The experiment is carried out with four gratings.

The separation of the slits d is different for each grating.

The angle between the central maximum and the first order maximum θ, produced by each grating, is measured.

The results are used to produce a graph of $\sin\theta$ against $\frac{1}{d}$.



(i) Determine the wavelength of the light from the laser used in this experiment. 3

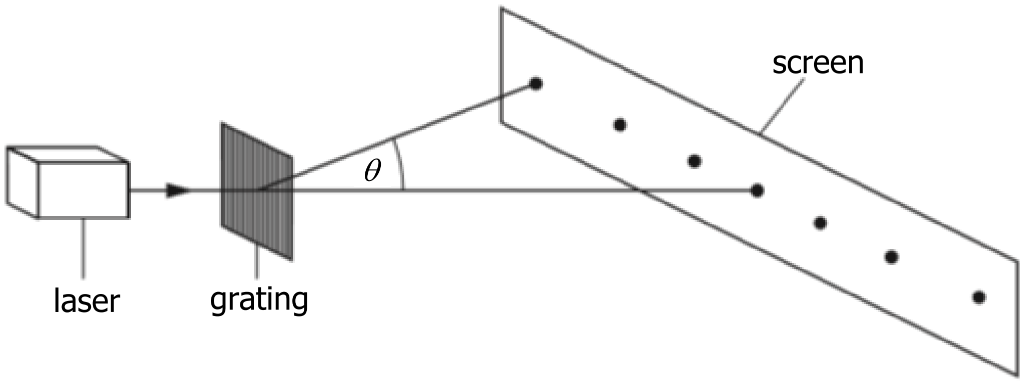
(ii) Determine the angle θ produced when a grating with a spacing d of $2 \cdot 0 \times 10^{-6}$ m is used with this laser. 3

(c) Suggest **two** improvements that could be made to the experiment to improve reliability. 2

Interference and Diffraction Gratings

24. A student investigates interference of light by directing laser light of wavelength 630 nm onto a grating as shown.

not to scale



(a) A pattern of bright spots is observed on a screen.

(i) Explain, in terms of waves, how bright spots are produced on the screen. 1

(ii) The grating has 250 lines per millimetre.

Calculate the angle θ between the central maximum and the third order maximum. 3

(iii) The grating is now replaced by one which has 600 lines per millimetre.

State the effect of this change on the pattern observed.

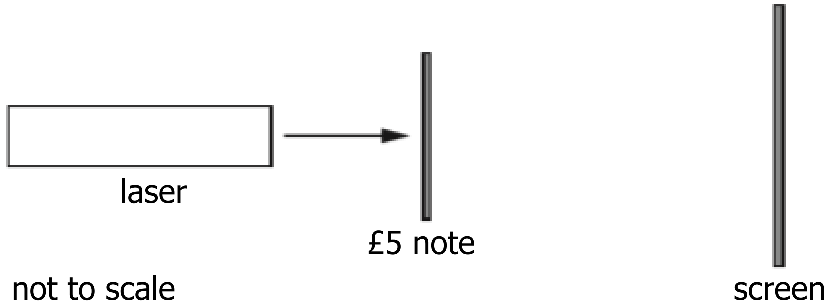
Justify your answer. 2

(iv) The interference pattern is produced by coherent light.

State what is meant by the term *coherent*. 1

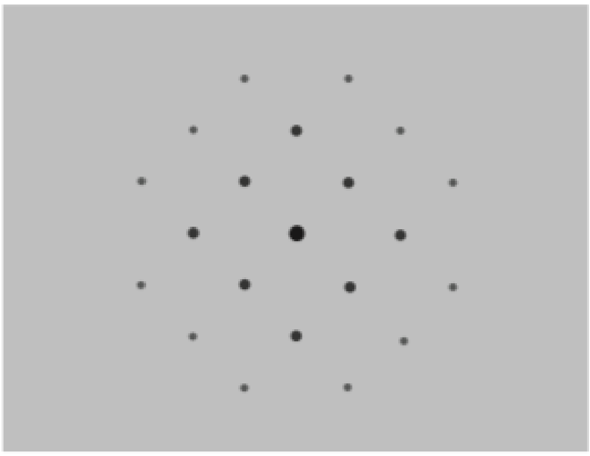
24. **(continued)**

(b) The student now shines light from the laser onto a £5 note.



When it is shone through the transparent section of the note the student observes a pattern of bright spots on the screen.

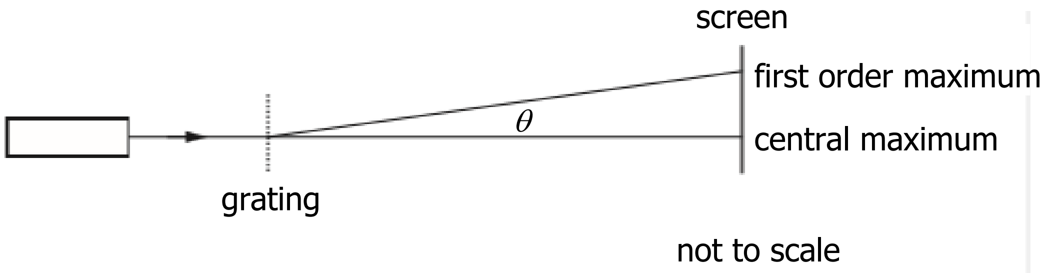
The diagram below shows the pattern that the student observes on the screen.



Suggest a reason for the difference in the pattern produced using the £5 note and the pattern produced using the grating. 1

Interference and Diffraction Gratings

25. A student carries out an experiment to investigate the effect of a grating on beams of light from three different lasers.



The three different lasers produce red, green and blue light respectively.

Each laser beam is directed in turn towards the grating.

The grating has a slit separation of $3{\cdot}3 \times 10^{-6}$ m.

(a) State which of these three colours of laser light would produce the smallest angle θ between the central maximum and the first order maximum.

Justify your answer. 3

(b) The angle θ between the central maximum and the first order maximum for light from one of the lasers is $8{\cdot}9^{o}$.

(i) Calculate the wavelength of this light. 3

(ii) Determine the colour of light from this laser. 1

(iii) Another student suggests that a more accurate value for the wavelength of this laser light can be found if a grating with a slit separation of $5{\cdot}0 \times 10^{-6}$ m is used.

Explain why this suggestion is incorrect. 2

Irradiance

1. The intensity of light from a point source is 20 W m^{-2} at a distance of 5·0 m from the source.

   The intensity of the light at a distance of 25 m from the source is

   A 0·032 W m^{-2}

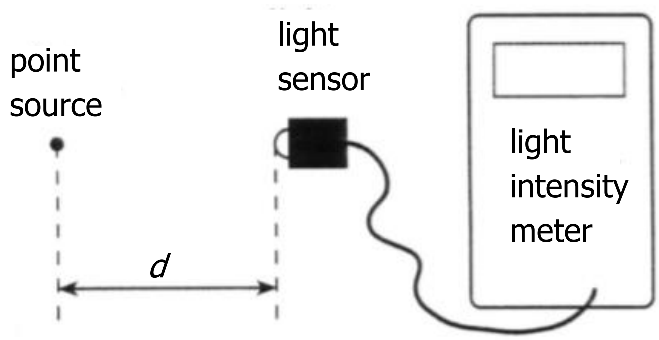
   B 0·80 W m^{-2}

   C 1·2 W m^{-2}

   D 4·0 W m^{-2}

   E 100 W m^{-2}.

2. The apparatus used to investigate the relationship between light intensity I and distance d from a point source is shown.



   The experiment is carried out in a darkened room.

   Which of the following expressions gives a constant value?

   A $I \times d$

   B $I \times d^2$

   C $\frac{I}{d}$

   D $\frac{I}{d^2}$

   E $I \times \sqrt{d}$

3. The intensity of light can be measured in

A W

B W m^{-1}

C W m

D W m^{-2}

E W m^2.

4. The irradiance of light from a point source is 160 units at a distance of 0·50 m from the source.

At a distance 2·0 m from this source, the irradiance is

A 160 units

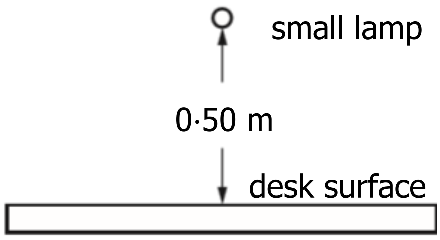
B 80 units

C 40 units

D 10 units

E 5 units.

5. A small lamp is placed 0·50 m above the surface of a desk.



There is no other source of light.

The lamp is now moved until the irradiance at the desk surface is halved.

The new distance of the lamp above the desk surface is approximately

A 0·7 m

B 1·0 m

C 1·4 m

D 1·5 m

E 2·0 m.

6. The irradiance of light from a point source is 32 W m^{-2} at a distance of 4·0 m from the source.

The irradiance of the light at a distance of 16 m from the source is

A 0·125 W m^{-2}

B 0·50 W m^{-2}

C 2·0 W m^{-2}

D 8·0 W m^{-2}

E 128 W m^{-2}.

7. A point source of light is 8·00 m away from a surface. The irradiance, due to the point source, at the surface is 50·0 mW m^{-2}. The point source is now moved to a distance of 12·0 m from the surface.

The irradiance, due to the point source, at the surface is now

A 22·2 mW m^{-2}

B 26·0 mW m^{-2}

C 33·3 mW m^{-2}

D 75·0 mW m^{-2}

E 267 mW m^{-2}.

8. The irradiance on a surface 0·50 m from a point source of light is I.

The irradiance on a surface 1·5 m from this source is

A 0·11I

B 0·33I

C 1·5I

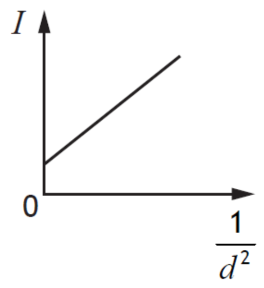
D 3·0I

E 9·0I

9. A student carries out an experiment to investigate how irradiance varies with distance.

A small lamp is placed at a distance d away from a light meter. The irradiance I at this distance is displayed on the meter. This measurement is repeated for a range of different distances.

The student uses these results to produce the graph shown.



The graph indicates that there is a systematic uncertainty in this experiment.

Which of the following would be most likely to reduce the systematic uncertainty in this experiment?

A Repeating the readings and calculating mean values.

B Replacing the small lamp with a larger lamp.

C Decreasing the brightness of the lamp.

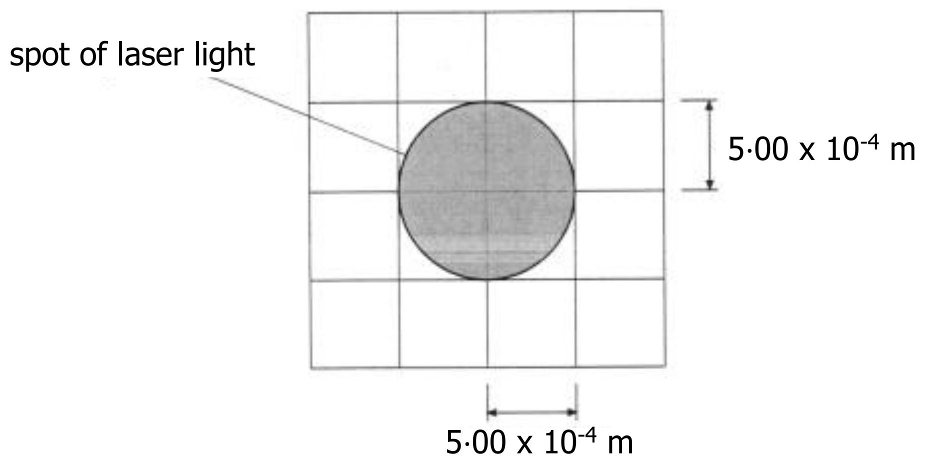
D Repeating the experiment in a darkened room.

E Increasing the range of distances.

Irradiance

10. A laser beam is shone on to a screen which is marked with a grid.

The beam produces a uniformly lit spot of radius 5·00 x 10^{-4} m as shown.



(a) The intensity of the spot of light on the screen is 1020 W m^{-2}.

Calculate the power of the laser beam. 4

(b) The distance between the screen and the laser is now doubled.

State how the radius of the spot now compares with the one shown in the diagram.

You must justify your answer. 2

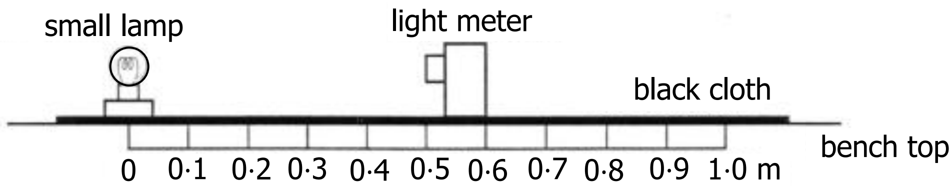
Irradiance

11. A student carries out an experiment to investigate how irradiance on a surface varies with distance from a small lamp.

Irradiance is measured with a light meter.

The distance between the small lamp and the light meter is measured with a metre stick.

The apparatus is set up as shown in a darkened laboratory.



The following results are obtained.

Distance from source / m	0·20	0·30	0·40	0·50
Irradiance / units	675	302	170	108

(a) State what is meant by the term *irradiance*. 1

(b) Use **all** the data to find the relationship between irradiance I and distance d from the source. 3

(c) Explain the purpose of the black cloth on top of the bench. 1

(d) The small lamp is replaced by a laser.

Light from the laser is shone on to the light meter.

A reading is taken from the light meter when the distance between the laser is 0·50 m.

The distance is now increased to 1·00 m.

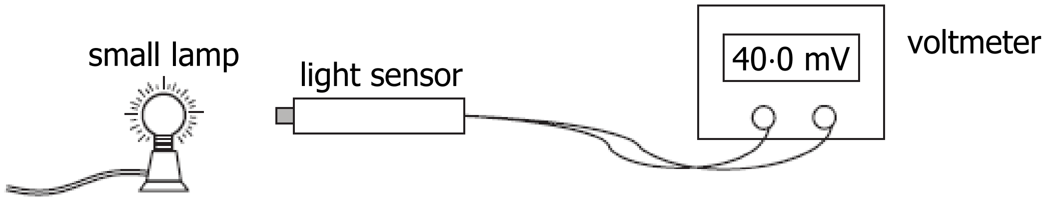
State how the new reading on the light meter compares with the one at 0·50 m.

Justify your answer. 2

Irradiance

12. The diagram shows a light sensor connected to a voltmeter.

A small lamp is placed in front of the sensor.



The reading on the voltmeter is 20 mV for each 1·0 mW of power incident on the sensor.

(a) The reading on the voltmeter is 40·0 mV.

The area of the light sensor is 8·0 x 10^{-5} m^2.

Calculate the irradiance of light on the sensor. 4

(b) The small lamp is replaced by a different source of light.

Using this new source, a student investigates how irradiance varies with distance.

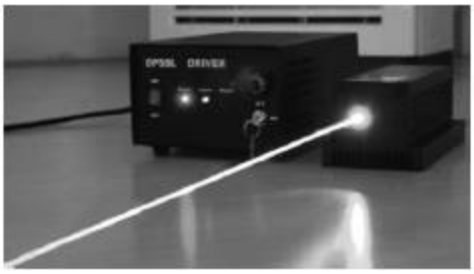
The results are shown.

Distance / m	0·20	0·30	0·40
Irradiance / W m^{-2}	675	302	170

Using **all** the data, prove whether or not this new source can be considered a point source of light. 3

Irradiance; Interference and Diffraction Gratings

13. A laser produces a beam of light with a frequency of $4{\cdot}74 \times 10^{14}$ Hz.

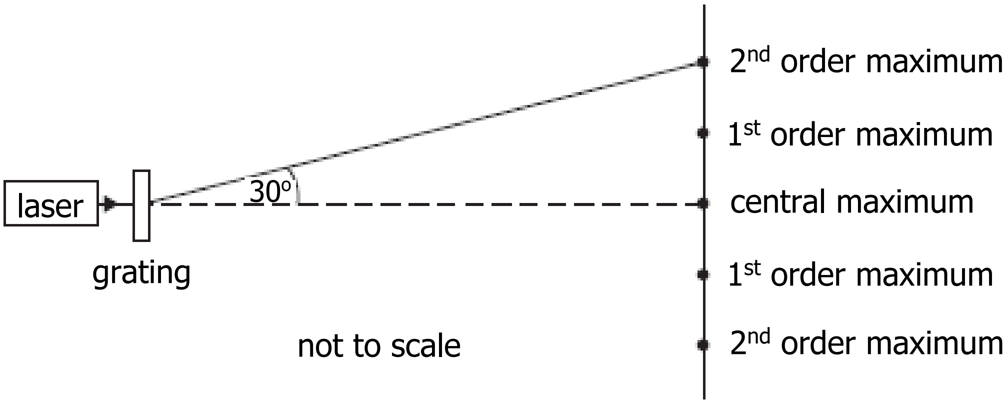


(a) The laser has a power of 0·10 mW.

Explain why light from this laser can cause eye damage. 1

(b) Calculate the energy of each photon in the laser beam. 3

(c) This laser beam is now incident on a grating as shown below.



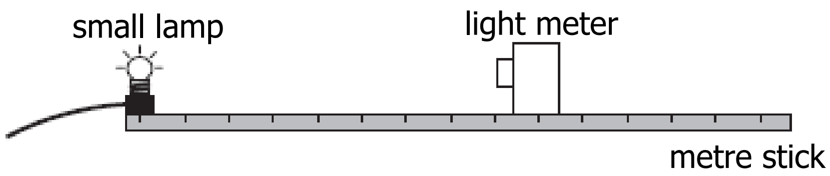
The second order maximum is detected at an angle of 30° from the central maximum.

Calculate the separation of the slits on the grating. 4

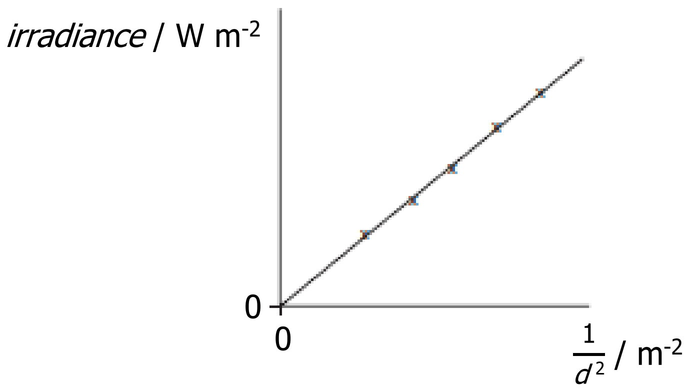
Irradiance

14. A student investigates how irradiance I varies with distance d from a small lamp.

The following apparatus is set up in a darkened laboratory.



The results are used to produce the following graph.



(a) Explain why this graph confirms the relationship $I = \frac{k}{d^2}$ 1

(b) The irradiance of light from the lamp at a distance of 1·6 m is 4·0 W m^{-2}.

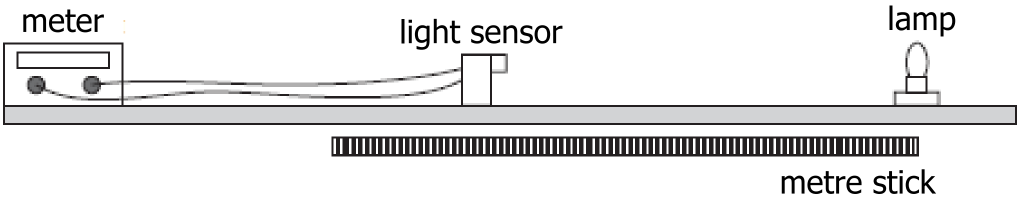
Calculate the irradiance of the light at a distance of 0·40 m from the lamp. 3

(c) The experiment is repeated with the laboratory lights switched on.

Copy the graph shown and, on the same axes, draw another line to show the results of the second, repeated experiment. 2

Irradiance

15. (a) A technician uses the following apparatus to investigate the relationship between the irradiance of the light from a lamp and the distance from it.

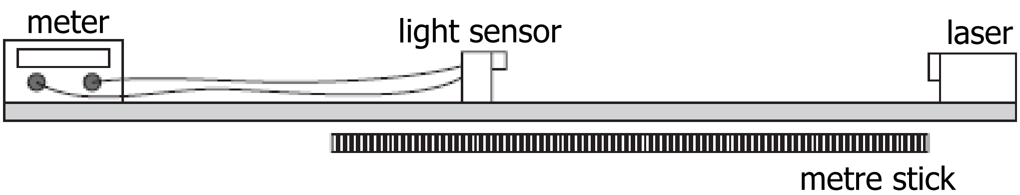


The results of the experiment are shown.

Distance between light sensor and lamp / m	*Irradiance* / units
0·10	242
0·15	106
0·20	60
0·25	39

Use **all** the results to determine whether or not the lamp behaves like a point source of light in this experiment. 3

(b) The experiment is now repeated using a $1{\cdot}00 \times 10^{-4}$ W laser which produces light of wavelength 633 nm.



(i) Explain why the results obtained with the laser differ from those obtained using the lamp. 1

(ii) Calculate the energy of each photon being emitted. 4

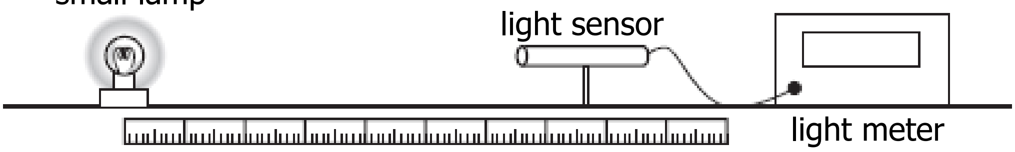
(iii) Calculate the number of photons being emitted in a time of 5 seconds. 4

(iv) Light from the laser is described as *coherent*.

State what is meant by the term *coherent.* 1

Irradiance

16. A student investigates how irradiance I varies with distance d from a point source of light.



The distance between a small lamp and a light sensor is measured with a metre stick. The irradiance is measured with a light meter.

The apparatus is set up as shown in a darkened laboratory.

The following results are obtained.

d (m)	0·20	0·30	0·40	0·50
I (W m^{-2})	134·0	60·5	33·6	21·8

(a) State what is meant by the term *irradiance*. 1

(b) Use all the data to establish the relationship between irradiance I and distance d. 3

(c) The lamp is now moved to a distance of 0·60 m from the light sensor.

Calculate the irradiance of light from the lamp at this distance. 3

(d) Suggest one way in which the experiment could be improved.

You must justify your answer. 2