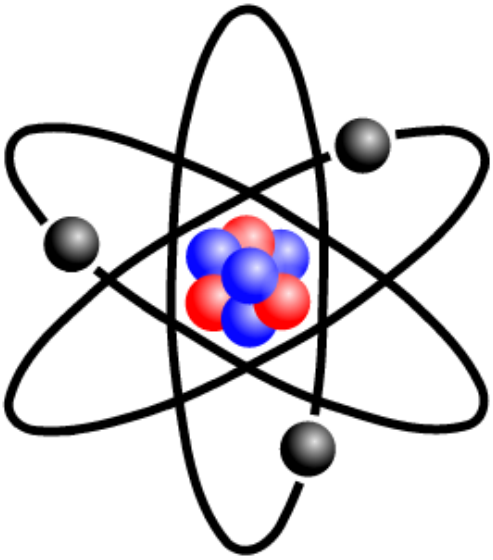
Wallace Hall Academy

Physics Department

Higher

Particles and Waves

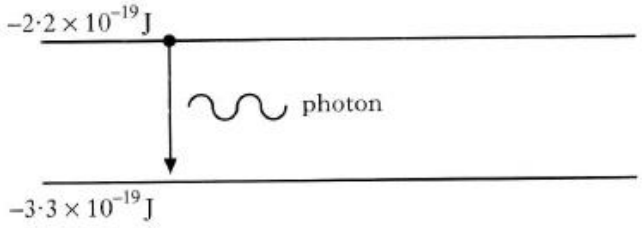


Homework

Exercise 7 - Wave- Particle Duality

Past Paper Homework Questions

1. In a laser, a photon of radiation is emitted when an electron makes a transition from a higher energy level to a lower level, as shown below.



The energy in each pulse of radiation from the laser is 10 J. How many photons are there in each pulse?

A $1{\cdot}8 \times 10^{19}$

B $3{\cdot}0 \times 10^{19}$

C $3{\cdot}7 \times 10^{19}$

D $4{\cdot}5 \times 10^{19}$

E $9{\cdot}1 \times 10^{19}$

2. Ultraviolet radiation is incident on a clean zinc plate. Photoelectrons are ejected.

The clean zinc plate is replaced by a different metal which has a lower work function. The same intensity of ultraviolet radiation is incident on this metal.

Compared to the zinc plate, which of the following statements is/are true for the new metal?

I The maximum speed of the photoelectrons is greater.

II The maximum kinetic energy of the photoelectrons is greater.

III There are more photoelectrons ejected per second.

A I only

B II only

C III only

D I and II only

E I, II and III

3. When light of frequency f is shone on to a certain metal, photoelectrons are ejected with a maximum velocity v and kinetic energy E_k.

When light of the same frequency and twice the intensity is shone on the same surface then

I twice as many electrons are ejected per second

II the speed of the fastest electrons is now $2v$

III the kinetic energy of the fastest electrons is now $2E_k$.

Which of the statements above is/are correct?

A I only

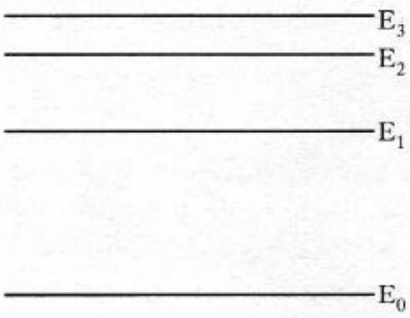
B II only

C III only

D I and II only

E II and III only

4. An atom has the energy levels shown.



Electron transitions occur between all of these levels to produce emission lines in the spectrum of this atom.

How many emission lines are produced by transitions between these energy levels?

A 3

B 4

C 5

D 6

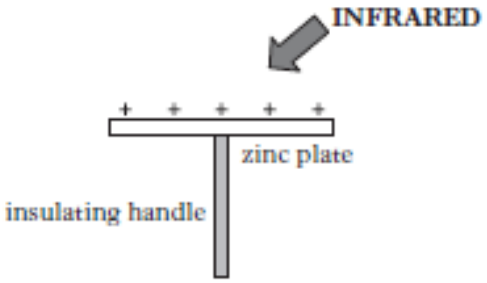
E 7

5. Clean zinc plates are mounted on insulating handles and then charged.

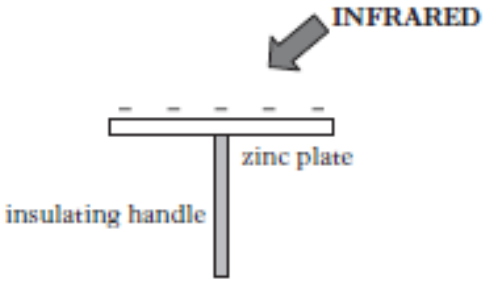
Different types of electromagnetic radiation are now incident on the plates as shown.

Which of the zinc plates is most likely to discharge due to photoelectric emission?

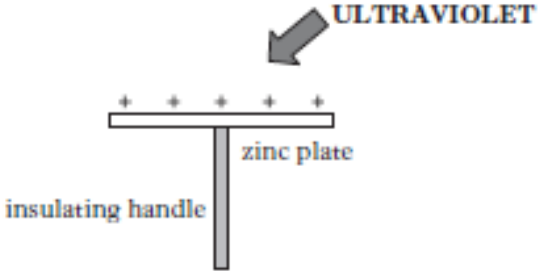
A



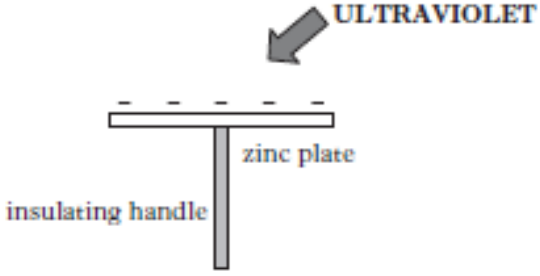
B



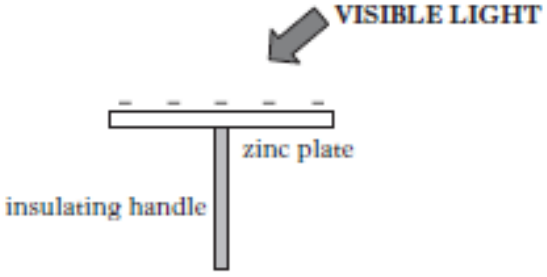
C



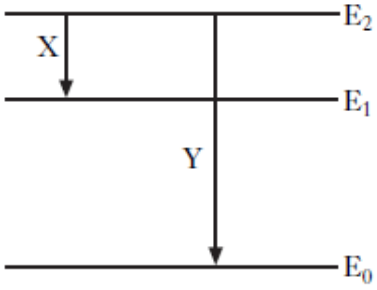
D



E



6. Part of the energy level diagram for an atom is shown.



X and Y represent two possible electron transitions.
Which of the following statements is/are correct?

I Transition Y produces photons of higher frequency than transition X.

II Transition X produces photons of longer wavelength than transition Y.

III When an electron is in the energy level E_0, the atom is ionised.

A I only

B I and II only

C I and III only

D II and III only

E I, II and III

7. Photons of energy $7{\cdot}0 \times 10^{-19}$ J are incident on a clean metal surface. The work function of the metal is $9{\cdot}0 \times 10^{-19}$ J.

Which of the following is correct?

A No electrons are emitted from the metal.

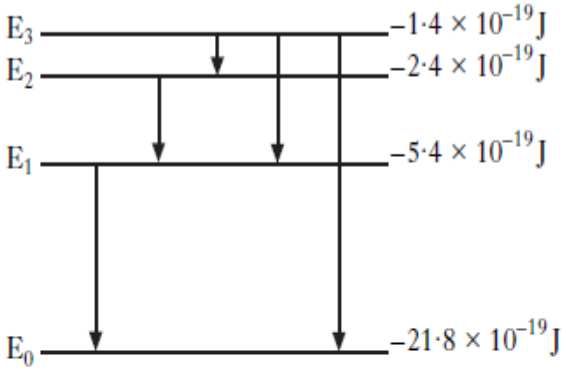
B Electrons with a maximum kinetic energy of $2{\cdot}0 \times 10^{-19}$ J are emitted from the metal.

C Electrons with a maximum kinetic energy of $7{\cdot}0 \times 10^{-19}$ J are emitted from the metal.

D Electrons with a maximum kinetic energy of $9{\cdot}0 \times 10^{-19}$ J are emitted from the metal.

E Electrons with a maximum kinetic energy of 16×10^{-19} J are emitted from the metal.

8. The diagram represents some electron transitions between energy levels in an atom.



The radiation emitted with the shortest wavelength is produced by an electron making transition

A E_1 to E_0

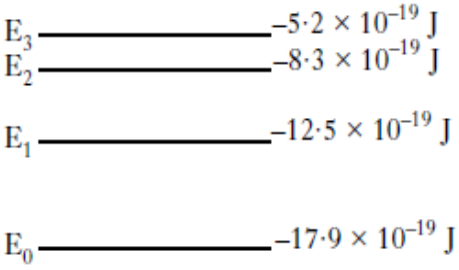
B E_2 to E_1

C E_3 to E_2

D E_3 to E_1

E E_3 to E_0.

9. The diagram represents some of the energy levels for an atom of a gas.



White light passes through the gas and absorption lines are observed in the spectrum.

Which electron transition produces the absorption line corresponding to the lowest frequency?

A E_3 to E_2

B E_2 to E_3

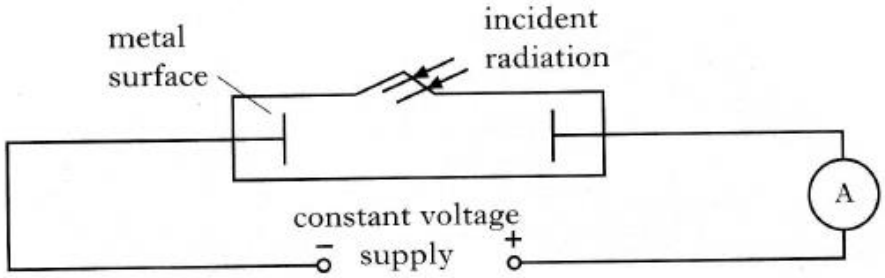
C E_1 to E_0

D E_0 to E_1

E E_0 to E_3

10. (*a*) The apparatus shown below is used to investigate photoelectric emission from a metal surface when electromagnetic radiation is shone on the surface.

The intensity and frequency of the incident radiation can be varied as required.



(i) Explain what is meant by *photoelectric emission* from a metal.

(ii) What is the name given to the minimum frequency of the radiation that produces a current in the circuit?

(iii) A particular source of radiation produces a current in the circuit.

Explain why the current in the circuit increases as the intensity of the incident radiation increases.

4

(*b*) A semiconductor chip is used to store information. The information can only be erased by exposing the chip to ultraviolet radiation for a period of time.

The following data is provided.

Frequency of ultraviolet radiation used	= $9{\cdot}0 \times 10^{14}$ Hz
Minimum intensity of ultraviolet radiation required at the chip	= 25 W m^{-2}
Area of the chip exposed to radiation	= $1{\cdot}8 \times 10^{-9}$ m^2
Time taken to erase the information	= 15 minutes
Energy of radiation needed to erase the information	= 40·5 μJ

(i) Calculate the energy of a photon of the ultraviolet radiation used.

(ii) Calculate the number of photons of the ultraviolet radiation required to erase the information.

(iii) Sunlight of intensity 25 W m^{-2}, at the chip, can also be used to erase the information.

State whether the time taken to erase the information is greater than, equal to or less than 15 minutes.

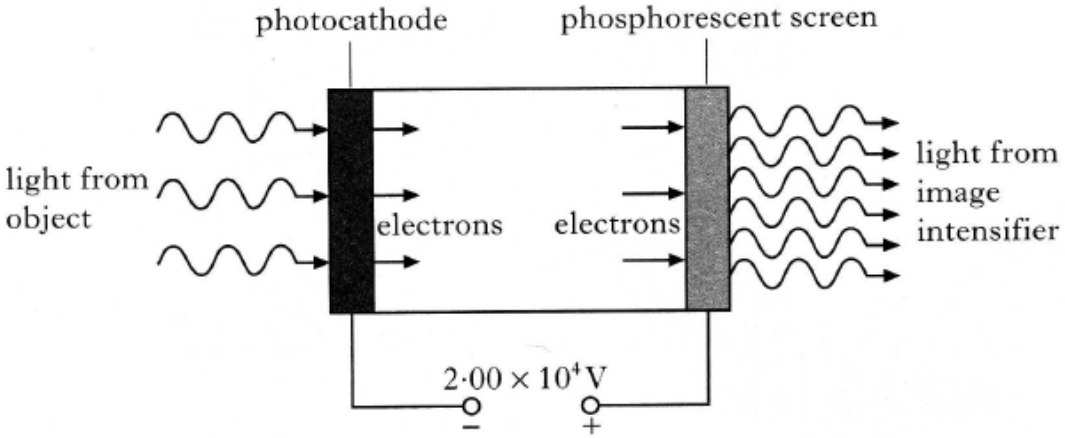
You must justify your answer.

5

(9)

11. An image intensifier is used to improve night vision. It does this by amplifying the light from an object.

Light incident on a photocathode causes the emission of photoelectrons. These electrons are accelerated by an electric field and strike a phosphorescent screen causing it to emit light. This emitted light is of a greater intensity than the light that was incident on the photocathode.



The voltage between the photocathode and the phosphorescent screen is $2{\cdot}00 \times 10^4$ V.

The minimum frequency of the incident light that allows photoemission to take place is $3{\cdot}33 \times 10^{14}$ Hz.

(*a*) What name is given to the minimum frequency of the light required for photoemission to take place? **1**

(*b*) (i) Show that the work function of the photocathode material is $2{\cdot}21 \times 10^{-19}$ J.

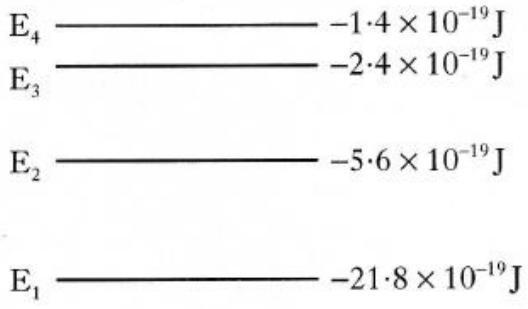
(ii) Light of frequency $5{\cdot}66 \times 10^{14}$ Hz is incident on the photocathode. Calculate the maximum kinetic energy of an electron emitted from the photocathode.

(iii) Calculate the kinetic energy gained by an electron as it is accelerated from the photocathode to the phosphorescent screen. **6**

(7)

12. (*a*) Electrons which orbit the nucleus of an atom can be considered as occupying discrete energy levels.

The following diagram shows some of the energy levels for a particular atom.



(i) The transition between which two of these energy levels produces radiation with the longest wavelength? You must justify your answer.

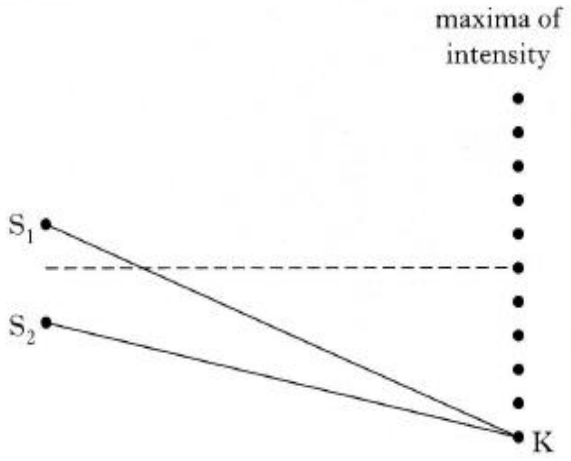
(ii) Calculate the frequency of the photon produced when an electron falls from E_3 to E_2. **5**

30 marks

Exercise 8 – Interference and Diffraction

Past Paper Homework Questions

1. 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

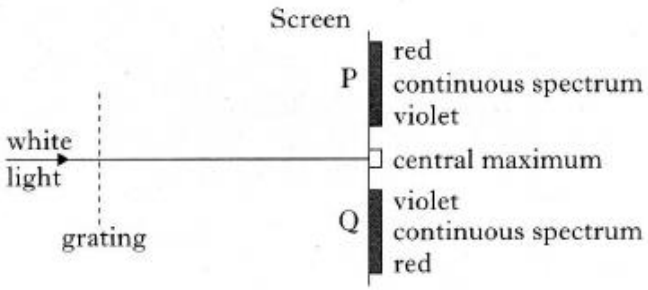
B 25·7 mm

C 28·0 mm

D 30·8 mm

E 34·2 mm.

2. 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

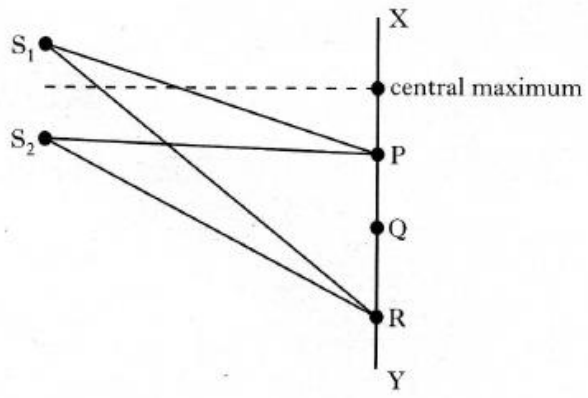
B II only

C III only

D I and III only

E II and III only

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 $S_2P = 18$ cm.

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. The spectrum of white light from a filament lamp may be viewed using a prism or a grating.

A student, asked to compare the spectra formed by the two methods, made the following statements.

I The prism produces a spectrum by refraction. The grating produces a spectrum by interference.

II The spectrum formed by the prism shows all the wavelengths present in the white light. The spectrum formed by the grating shows only a few specific wavelengths.

III The prism produces a single spectrum. The grating produces more than one spectrum.

Which of the above statements is/are true?

A I only

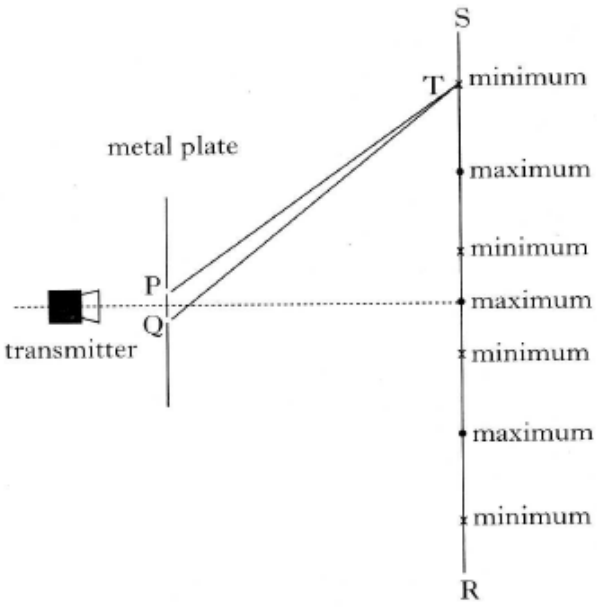
B II only

C I and II only

D I and III only

E I, II and III

5. 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.

6. In the following passage three words have been replaced by the letters **X**, **Y** and **Z**.

"*Monochromatic light is incident on a grating and the resulting interference pattern is viewed on a screen. The distance between neighbouring areas of constructive interference on the screen:*

is ..... **X** ..... *when the screen is moved further away from the grating;*

is ..... **Y** ..... *when light of a greater wavelength is used;*

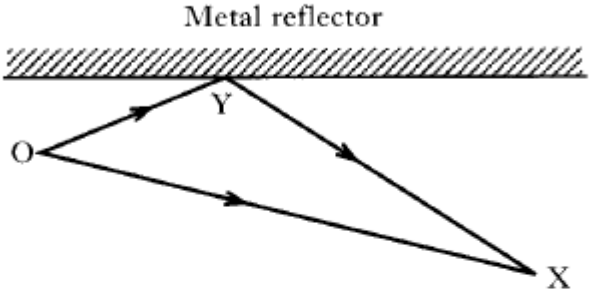
is ..... **Z** ..... *when the distance between the slits is increased.*"

Which row of the table shows the missing words?

	X	*Y*	*Z*
A	increased	increased	increased
B	increased	increased	decreased
C	decreased	decreased	increased
D	decreased	decreased	decreased
E	increased	decreased	decreased

7. 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

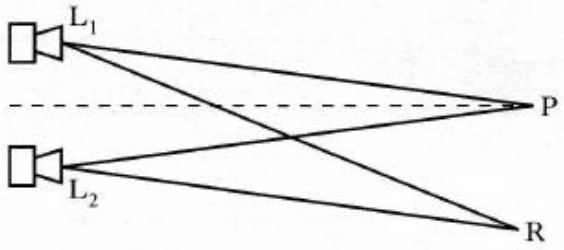
B 421 mm

C 442 mm

D 456 mm

E 463 mm.

8. 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 $L_1R = 5{\cdot}6$ m and $L_2R = 5{\cdot}3$ m.

The speed of sound 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 $340\times(5{\cdot}6-5{\cdot}3)$ Hz

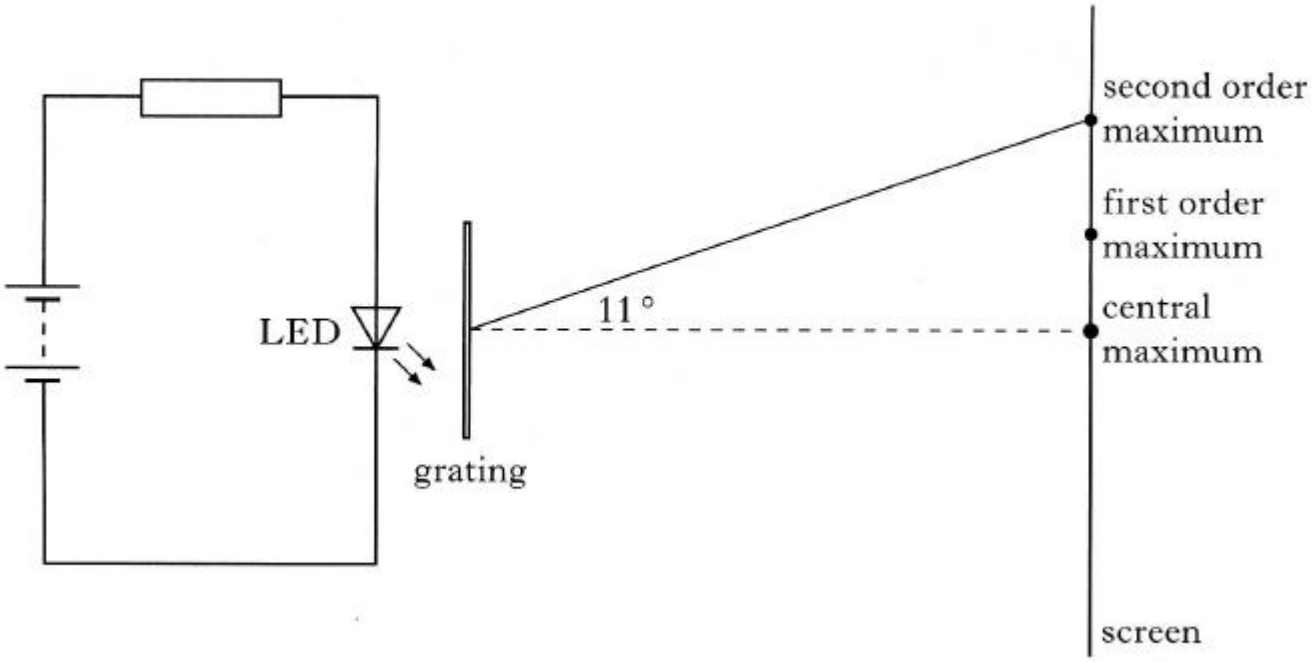
E $340\times(5{\cdot}6+5{\cdot}3)$ Hz.

9. (*a*) Light of wavelength 486×10^{-9}m is viewed using a grating with a slit spacing of $2{\cdot}16 \times 10^{-6}$m.

Calculate the angle between the central maximum and the second order maximum. **2**

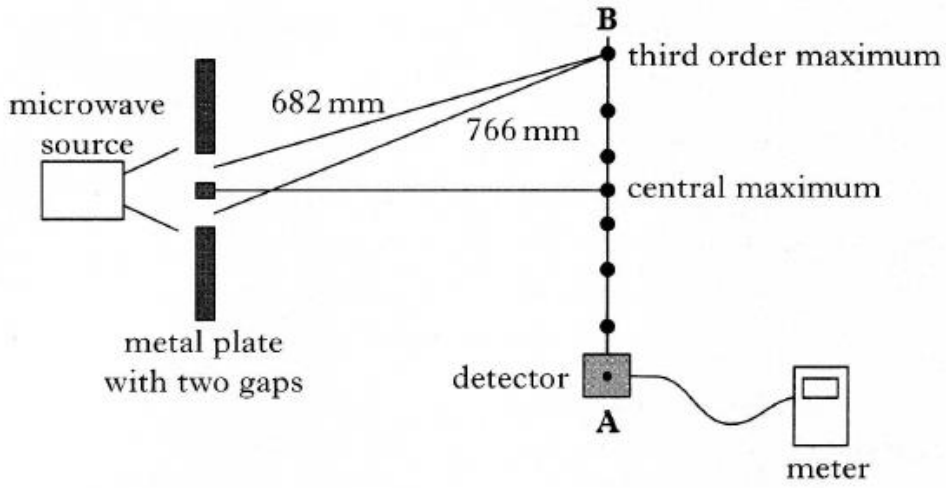
10. Monochromatic light from the LED is incident on a grating as shown.

The spacing between lines in the grating is $5{\cdot}0 \times 10^{-6}$m.



What is the wavelength of the light emitted by the LED? **4**

11. (*a*) An experiment with microwaves is set up as shown below.



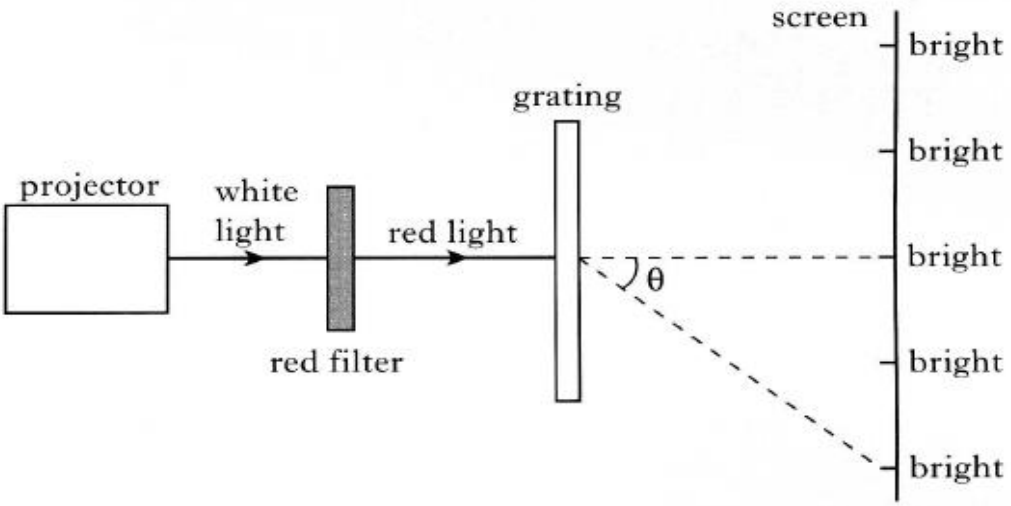
(i) As the detector is moved from **A** to **B**, the reading on the meter increases and decreases several times.

Explain, in terms of waves, how the pattern of maxima and minima is produced.

(ii) The measurements of the distance from each gap to a third order maximum are shown. Calculate the wavelength of the microwaves. **3**

12. A physics student investigates what happens when monochromatic light passes through a glass prism or a grating.

The apparatus for the second experiment is shown below.



A pattern of bright and dark fringes is observed on the screen.

The grating has 300 lines per millimetre and the wavelength of the red light is 650 nm.

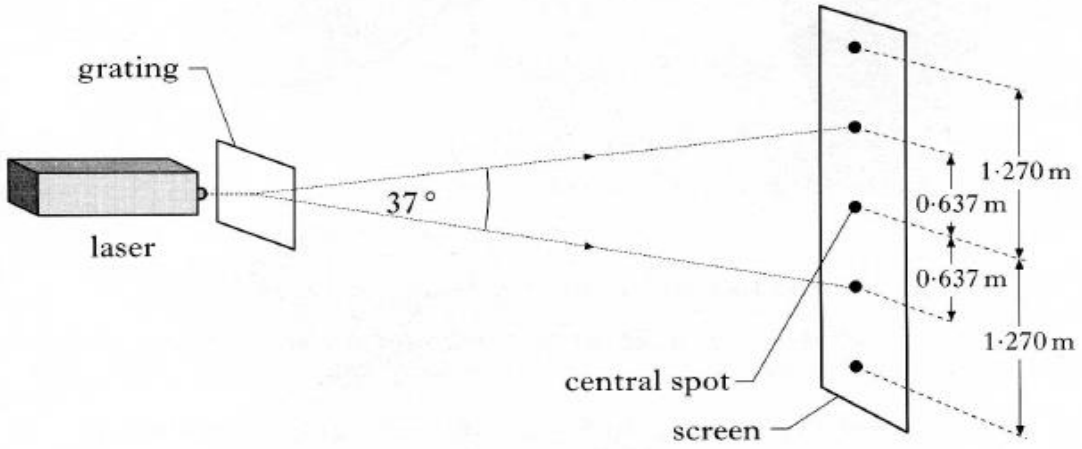
(i) Explain how the bright fringes are produced. **1**

(ii) Calculate the angle θ of the second order maximum. **2**

(iii) The red filter is replaced by a blue filter. Describe the effect of this change on the pattern observed.
Justify your answer. **1**

13. 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 these spots and the central spot is shown.



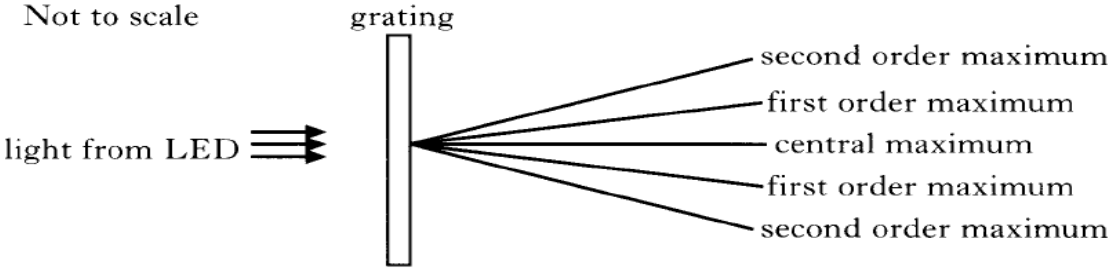
Calculate the number of lines per metre on the grating. **3**

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

How does the wavelength of the light from this laser compare with that from the original laser?

You must justify your answer. **2**

14. Light from an LED is passed through a grating as shown below.

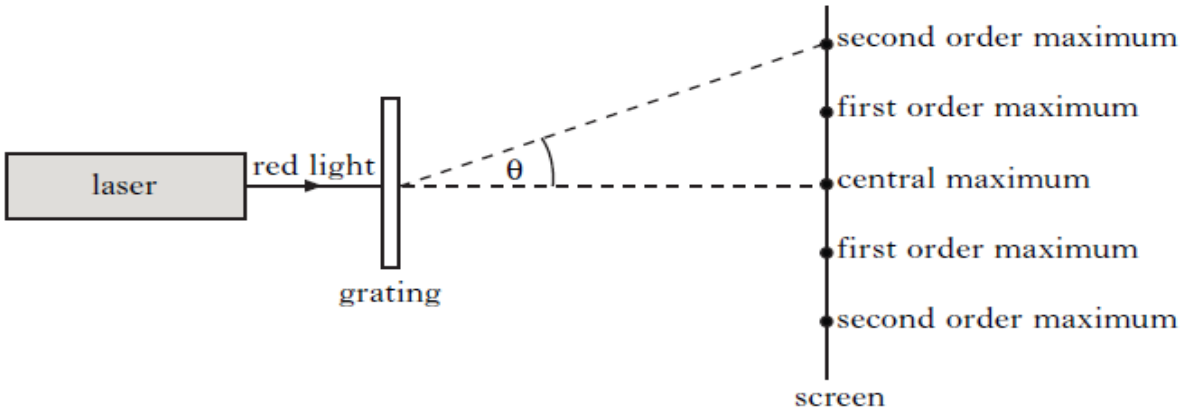


Light from this LED has a wavelength of $6{\cdot}35 \times 10^{-7}$ m. The spacing between lines in the grating is $5{\cdot}0 \times 10^{-6}$ m.

Calculate the angle between the central maximum and the **second** order maximum. **2**

15. 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.

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. **1**

30 marks

Exercise 9 – Refraction of Light

Past Paper Homework Questions

1. A ray of light passes from air into a substance that has a refractive index of 2·0. In air, the light has a wavelength λ and frequency f.

Which row in the following table gives the wavelength and frequency of the light in the substance?

	Wavelength	*Frequency*
A	λ	f
B	$\lambda/2$	$f/2$
C	$\lambda/2$	f
D	2λ	$2f$
E	2λ	f

2. The spectrum of white light from a filament lamp may be viewed using a prism or a grating.

A student, asked to compare the spectra formed by the two methods, made the following statements.

I The prism produces a spectrum by refraction. The grating produces a spectrum by interference.

II The spectrum formed by the prism shows all the wavelengths present in the white light. The spectrum formed by the grating shows only a few specific wavelengths.

III The prism produces a single spectrum. The grating produces more than one spectrum.

Which of the above statements is/are true?

A I only

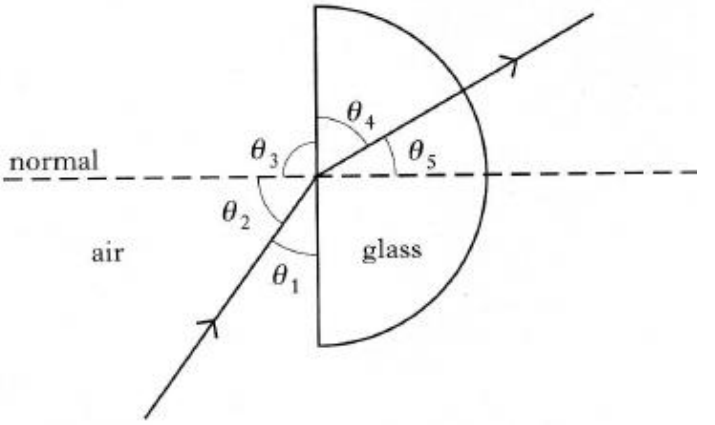
B II only

C I and II only

D I and III only

E I, II and III

3. The diagram below shows a ray of red light passing through a semicircular block of glass.



The refractive index of the glass for this light can be calculated from

A $\dfrac{\sin\theta_3}{\sin\theta_4}$

B $\dfrac{\sin\theta_1}{\sin\theta_4}$

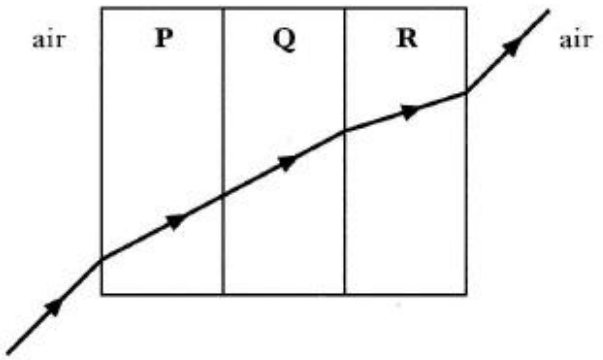
C $\dfrac{\sin\theta_2}{\sin\theta_5}$

D $\dfrac{\sin\theta_2}{\sin\theta_4}$

E $\dfrac{\sin\theta_1}{\sin\theta_5}$.

4. An engineer creates an experimental window using sheets of transparent plastics **P**, **Q** and **R**.

A ray of light directed at the window follows the path shown.



Which row in the table gives possible values for the refractive indices of the three plastics?

	P	*Q*	*R*
A	1·5	1·9	2·3
B	1·5	1·5	2·3
C	2·3	2·3	1·5
D	2·3	1·9	1·5
E	1·5	1·5	1·2

5. Microwaves of frequency $2{\cdot}0 \times 10^{10}$ Hz travel through air with a speed of $3{\cdot}0 \times 10^{8}\,m\,s^{-1}$. On entering a bath of oil, the speed reduces to $1{\cdot}5 \times 10^{8}\,m\,s^{-1}$.

The frequency of the microwaves in the oil is

A $1{\cdot}0 \times 10^{10}$ Hz

B $2{\cdot}0 \times 10^{10}$ Hz

C $4{\cdot}0 \times 10^{10}$ Hz

D $3{\cdot}0 \times 10^{18}$ Hz

E $6{\cdot}0 \times 10^{18}$ Hz.

6. A liquid and a solid have the same refractive index.

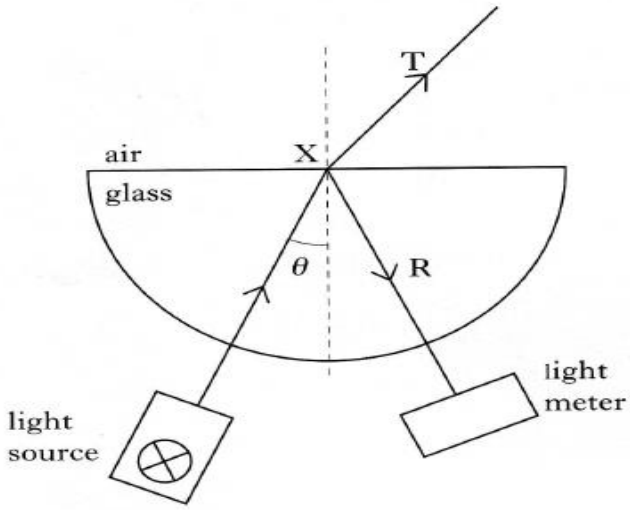
What happens to the speed and the wavelength of light passing from the liquid into the solid?

	Speed	*Wavelength*
A	stays the same	stays the same
B	decreases	decreases
C	decreases	increases
D	increases	increases
E	increases	decreases

7. A student is investigating the effect that a semicircular glass block has on a ray of monochromatic light.

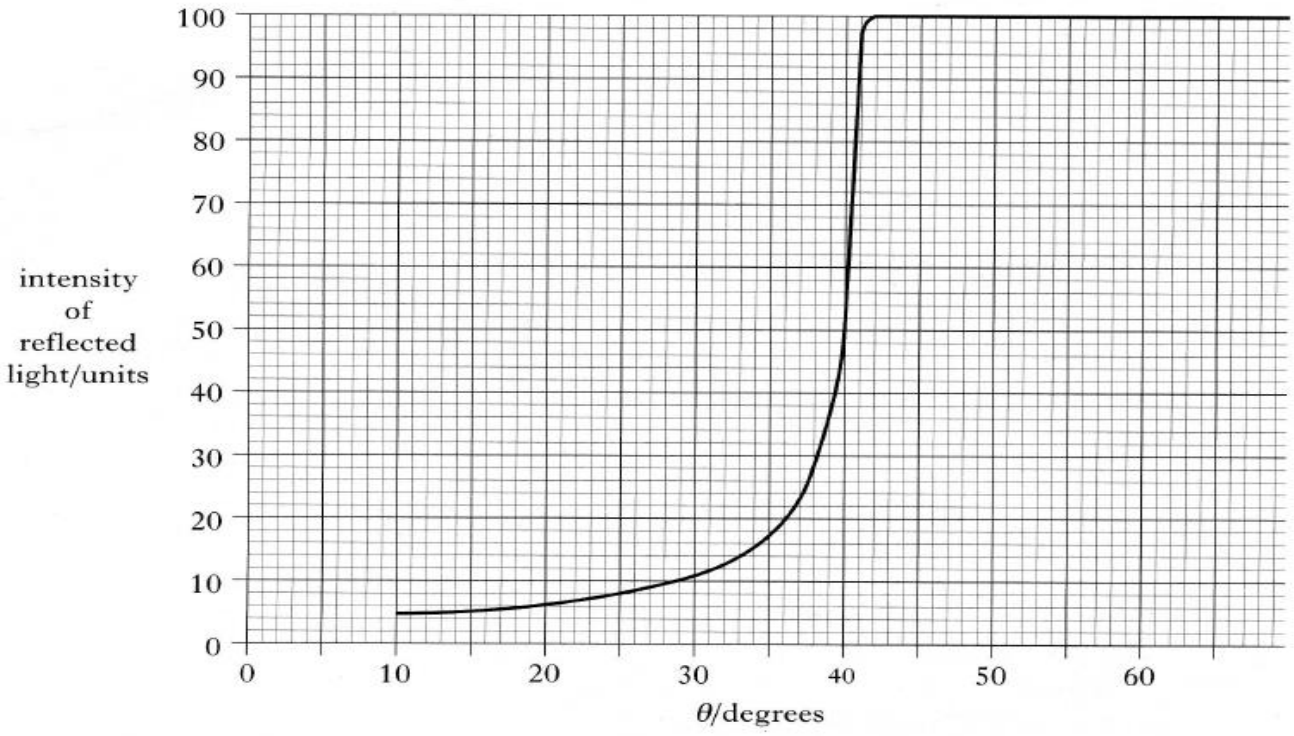
She observes that at point X the incident ray splits into two rays:

T — a transmitted ray
R — a reflected ray.



The student uses a light meter to measure the intensity of ray R as angle θ is changed.

(*c*) The graph below is obtained from the student's results.



(i) What is the value of the critical angle in the glass for this light?

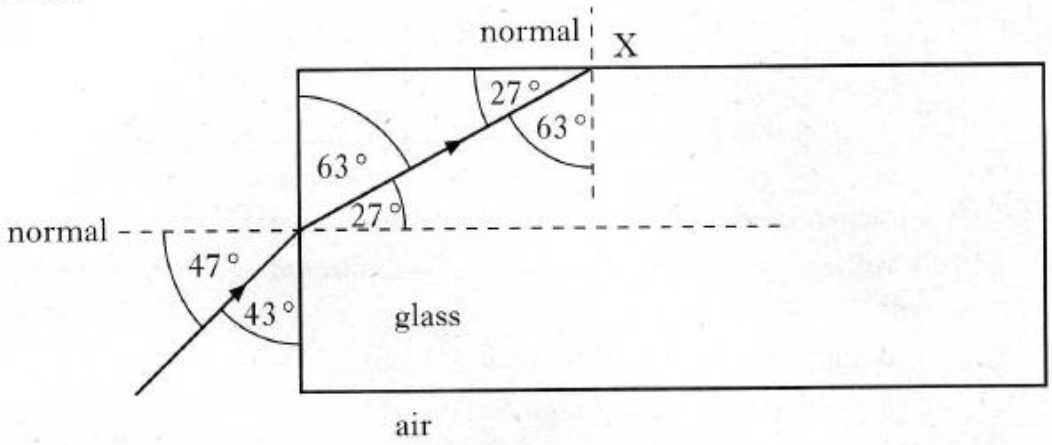
(ii) Calculate the refractive index of the glass for this light.

(iii) As the angle θ is increased, what happens to the intensity of ray T? **4**

8. (*a*) Light of wavelength 486×10^{-9} m is viewed using a grating with a slit spacing of $2{\cdot}16 \times 10^{-6}$ m.

Calculate the angle between the central maximum and the second order maximum. **2**

(*b*) A ray of monochromatic light passes from air into a block of glass as shown.

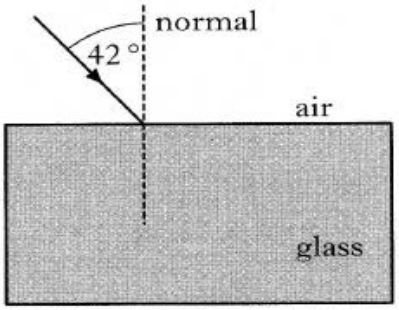


(i) Using information from the diagram, show that the refractive index of the glass for this light is 1·61.

(ii) Show by calculation whether the ray is totally internally reflected at point X. **4**

9. A laser produces light of frequency $4{\cdot}74 \times 10^{14}$ Hz in air.

A ray of light from this laser is directed into a block of glass as shown below.

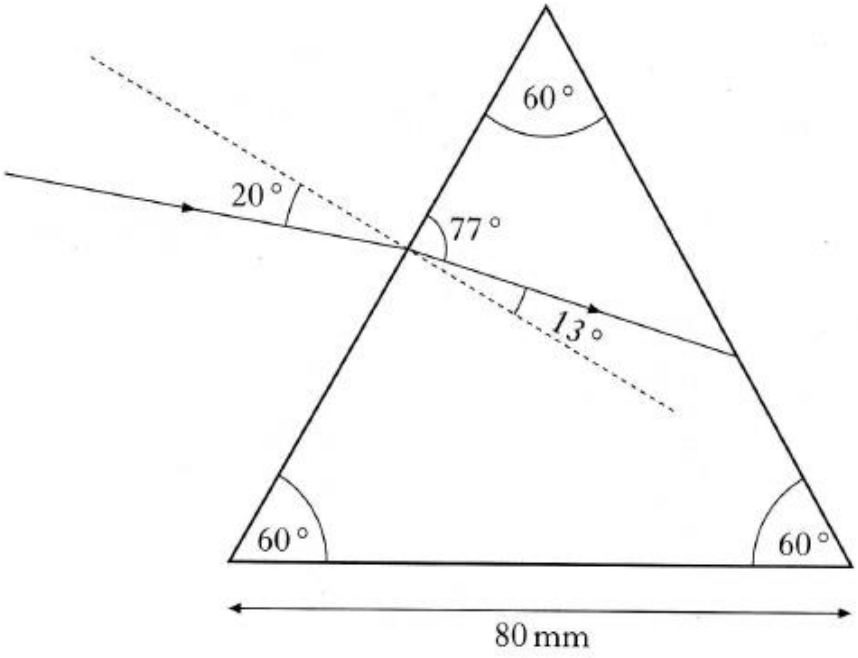


The refractive index of the glass for this light is 1·60.

(i) What is the value of the frequency of the light in the block of glass?

(ii) Calculate the wavelength of the light in the glass. **4**

10. A ray of red light is directed at a glass prism of side 80 mm as shown in the diagram below.



(*a*) Using information from this diagram, show that the refractive index of the glass for this red light is 1·52. **1**

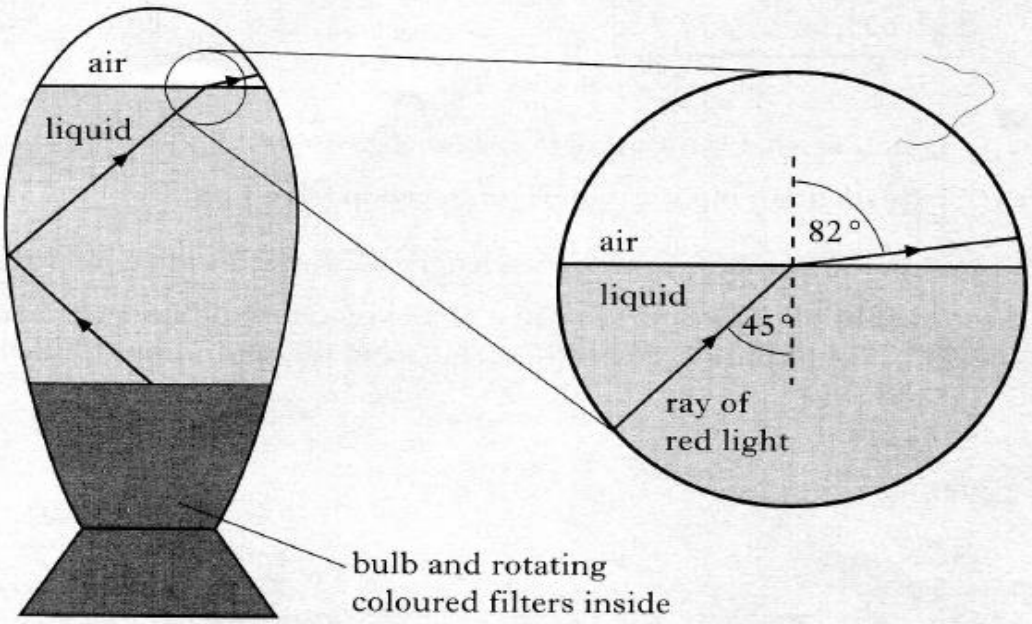
(*b*) What is meant by the term *critical angle*? **1**

(*c*) Calculate the critical angle for the red light in the prism. **2**

(*d*) Sketch a diagram showing the path of the ray of red light until after it leaves the prism. Mark on your diagram the values of all relevant angles. **3**

11. A decorative lamp has a transparent liquid in the space above a bulb. Light from the bulb passes through rotating coloured filters giving red or blue light in the liquid.

(*a*) A ray of red light is incident on the liquid surface as shown.



(i) Calculate the refractive index of the liquid for the red light.

(ii) A ray of blue light is incident on the liquid surface at the same angle as the ray of red light.

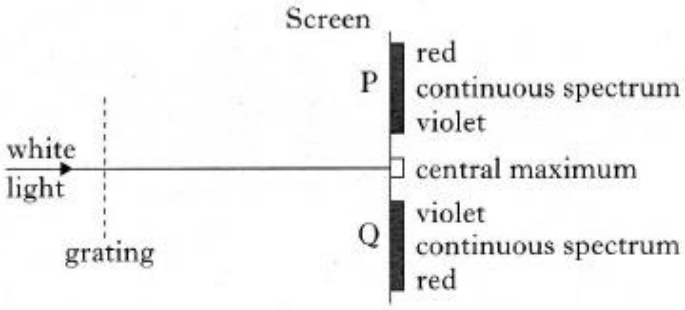
The refractive index of the liquid for blue light is greater than that for red light. Is the angle of refraction greater than, equal to or less than 82° for the blue light?

You must explain your answer. **3**

Exercise 10 – Spectra

Past Paper Homework Questions

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. The spectrum of white light from a filament lamp may be viewed using a prism or a grating.

A student, asked to compare the spectra formed by the two methods, made the following statements.

I The prism produces a spectrum by refraction. The grating produces a spectrum by interference.

II The spectrum formed by the prism shows all the wavelengths present in the white light. The spectrum formed by the grating shows only a few specific wavelengths.

III The prism produces a single spectrum. The grating produces more than one spectrum.

Which of the above statements is/are true?

A I only

B II only

C I and II only

D I and III only

E I, II and III

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

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

A $0{\cdot}032\,W\,m^{-2}$

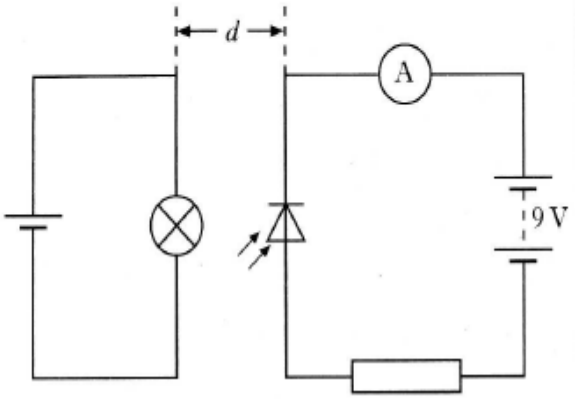
B $0{\cdot}80\,W\,m^{-2}$

C $1{\cdot}2\,W\,m^{-2}$

D $4{\cdot}0\,W\,m^{-2}$

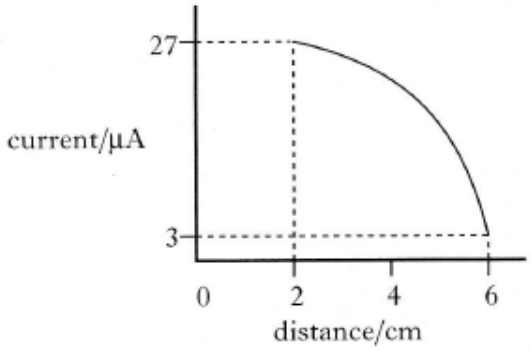
E $100\,W\,m^{-2}$

4. In a darkened room, a small lamp is placed 2 cm from a photodiode which is connected in the circuit as shown. The lamp may be regarded as a point source. The reading on the ammeter is 27 μA.

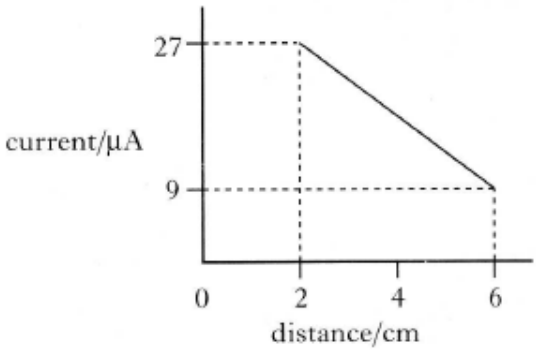


Which graph shows correctly how the ammeter reading changes as the distance d between the lamp and the photodiode is increased to 6 cm?

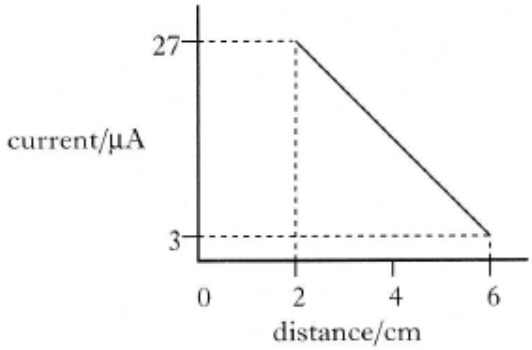
A



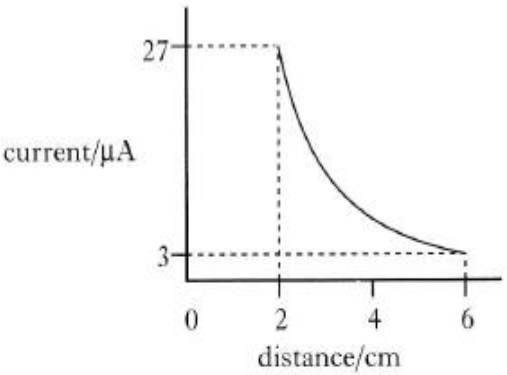
B



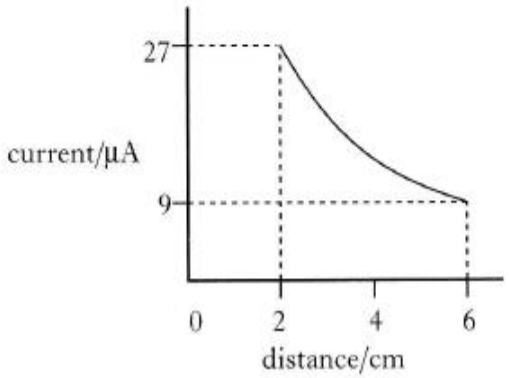
C



D



E



5. A unit for the intensity of light is

A $J\,m^{-1}$

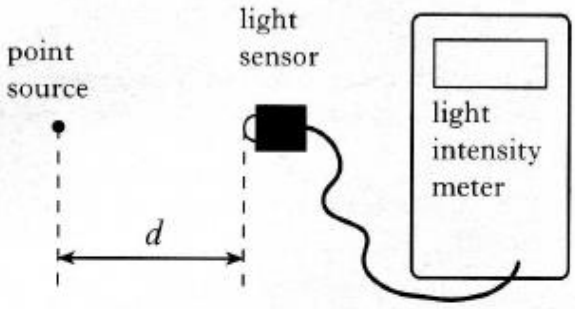
B $J\,m^{-2}$

C $J\,s^{-1}\,m^{-1}$

D $J\,s^{-1}\,m^{-2}$

E $J\,s^{-2}\,m^{-2}$.

6. 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 $I \times d$

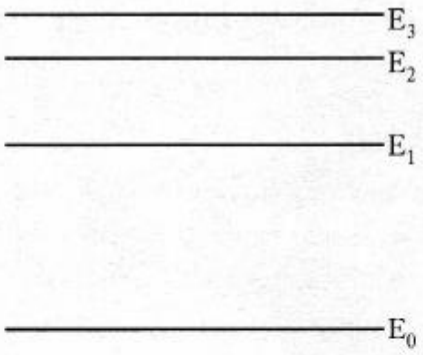
B $I \times d^2$

C $\frac{I}{d}$

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

E $I \times \sqrt{d}$

7. An atom has the energy levels shown.



Electron transitions occur between all of these levels to produce emission lines in the spectrum of this atom.

How many emission lines are produced by transitions between these energy levels?

A 3

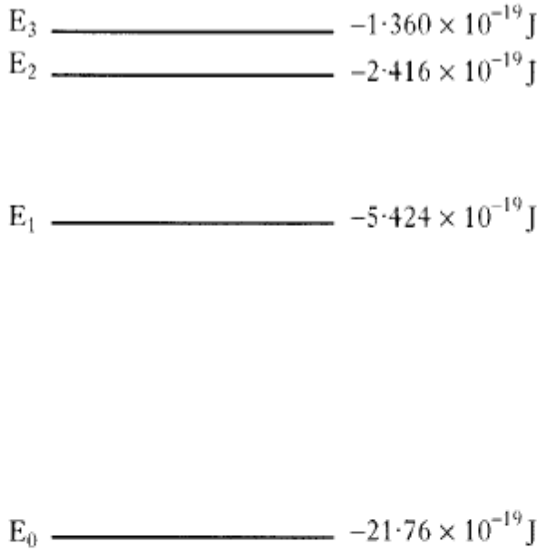
B 4

C 5

D 6

E 7

8. The diagram shows some of the energy levels for the hydrogen atom.



The highest frequency of radiation emitted due to a transition between two of these energy levels is

A $1{\cdot}59 \times 10^{14}$ Hz

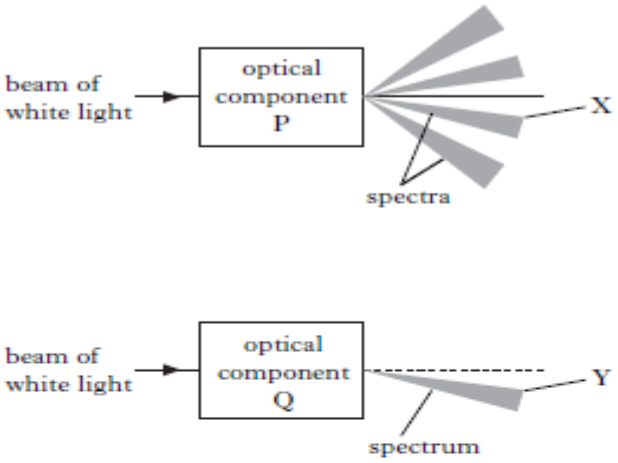
B $2{\cdot}46 \times 10^{15}$ Hz

C $3{\cdot}08 \times 10^{15}$ Hz

D $1{\cdot}63 \times 10^{20}$ Hz

E $2{\cdot}04 \times 10^{20}$ Hz.

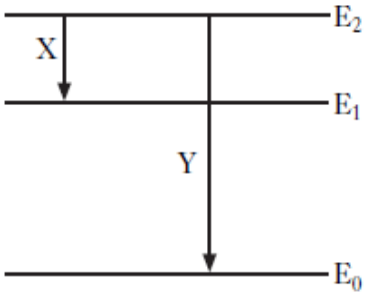
9. A beam of white light is passed through two optical components P and Q. Component P produces a number of spectra and component Q produces a spectrum as shown.



Which row in the table identifies the optical components and the colour of light seen at position X and position Y?

	Optical component P	*Colour seen at X*	*Optical component Q*	*Colour seen at Y*
A	grating	red	triangular prism	red
B	grating	red	triangular prism	violet
C	grating	violet	triangular prism	red
D	triangular prism	red	grating	violet
E	triangular prism	violet	grating	red

10. Part of the energy level diagram for an atom is shown.



X and Y represent two possible electron transitions.
Which of the following statements is/are correct?

I Transition Y produces photons of higher frequency than transition X.

II Transition X produces photons of longer wavelength than transition Y.

III When an electron is in the energy level E_0, the atom is ionised.

A I only

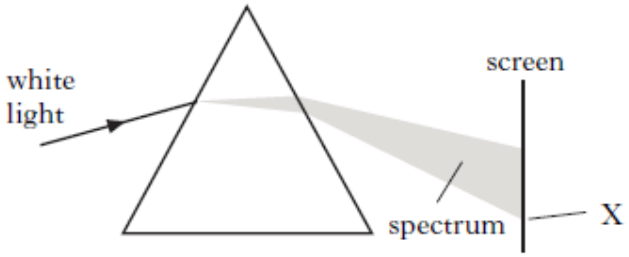
B I and II only

C I and III only

D II and III only

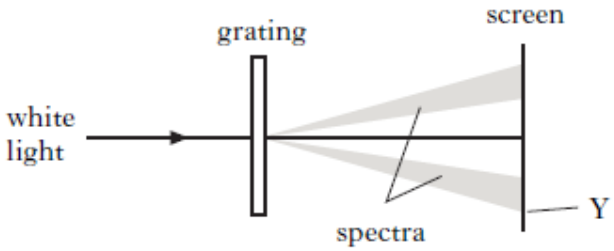
E I, II and III

11. A prism is used to produce a spectrum from a source of white light as shown.



The colour observed at X is noted.

The prism is then replaced by a grating to produce spectra as shown.



The colour observed at Y is noted.

Which row in the table gives the colour and wavelength of the light observed at X and the light observed at Y?

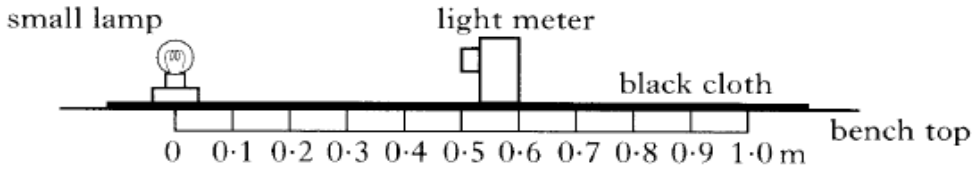
	Colour of light at X	Wavelength of light at X/nm	Colour of light at Y	Wavelength of light at Y/nm
A	Red	450	Red	450
B	Blue	450	Blue	450
C	Blue	650	Red	450
D	Blue	450	Red	650
E	Red	650	Blue	450

12. 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*) 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. **2**

(*c*) What is 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 it and the laser is 0·50 m.

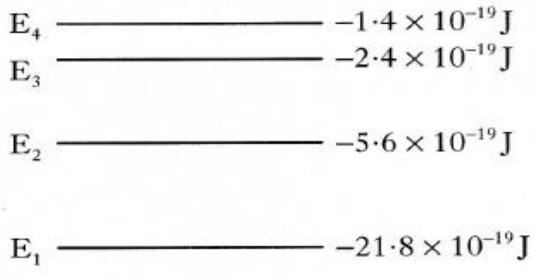
The distance is now increased to 1·00 m.

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

Justify your answer. **2**

13. (*a*) Electrons which orbit the nucleus of an atom can be considered as occupying discrete energy levels.

The following diagram shows some of the energy levels for a particular atom.

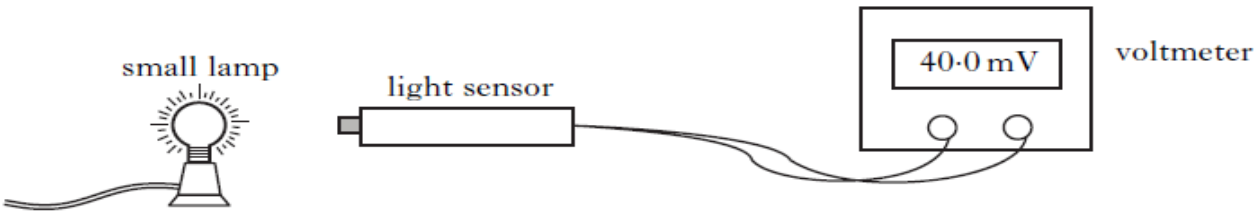


(i) The transition between which two of these energy levels produces radiation with the longest wavelength? You must justify your answer.

(ii) Calculate the frequency of the photon produced when an electron falls from E_3 to E_2. **5**

14. 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 $8{\cdot}0 \times 10^{-5}\,m^2$.

Calculate the irradiance of light on the sensor. **3**

(*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	0·5	0·7	0·9
Irradiance/W m^{-2}	1·1	0·8	0·6

Can this new source be considered to be a point source of light?

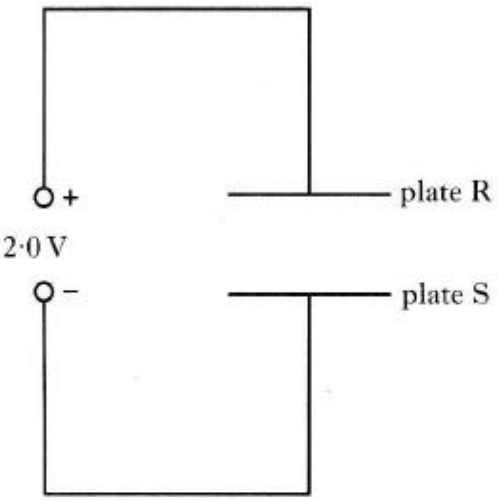
Use **all** the data to justify your answer. **2**

(5)

Exercise 11- Standard Model and Forces on Charged Particles

Past Paper Homework Questions

1. Two parallel metal plates, R and S, are connected to a 2·0 V d.c. supply as shown.



An electron is moved from plate R to plate S.

The gain in electrical potential energy of the electron is

A $8{\cdot}0 \times 10^{-20}$ J

B $1{\cdot}6 \times 10^{-19}$ J

C $3{\cdot}2 \times 10^{-19}$ J

D $6{\cdot}4 \times 10^{-19}$ J

E $1{\cdot}3 \times 10^{-19}$ J.

2. An electron is accelerated from rest through a potential difference of 2·0 kV.

The kinetic energy gained by the electron is

A $8{\cdot}0 \times 10^{-23}$ J

B $8{\cdot}0 \times 10^{-20}$ J

C $3{\cdot}2 \times 10^{-19}$ J

D $1{\cdot}6 \times 10^{-16}$ J

E $3{\cdot}2 \times 10^{-16}$ J.

3. A student writes the following statements about electric fields.

I There is a force on a charge in an electric field.

II When an electric field is applied to a conductor, the free electric charges in the conductor move.

III Work is done when a charge is moved in an electric field.

Which of the above statements is/are correct?

A I only

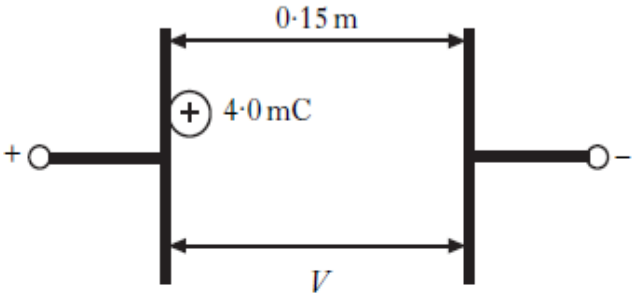
B II only

C I and II only

D I and III only

E I, II and III

4. A potential difference, V, is applied between two metal plates. The plates are 0·15 m apart. A charge of +4·0 mC is released from rest at the positively charged plate as shown.



The kinetic energy of the charge just before it hits the negative plate is 8·0 J.

The potential difference between the plates is

A $3{\cdot}2 \times 10^{-2}$ V

B 1·2 V

C 2·0 V

D $2{\cdot}0 \times 10^{3}$ V

E $4{\cdot}0 \times 10^{3}$ V.

5. The potential difference between two points is

A the work done in moving one electron between the two points

B the voltage between the two points when there is a current of one ampere

C the work done in moving one coulomb of charge between the two points

D the kinetic energy gained by an electron as it moves between the two points

E the work done in moving any charge between the two points.

6. A student writes the following statements about electric fields.

I There is a force on a charge in an electric field.

II When an electric field is applied to a conductor, the free electric charges in the conductor move.

III Work is done when a charge is moved in an electric field.

Which of the 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

7. One volt is equivalent to one

A farad per coulomb

B ampere per ohm

C joule per ampere

D joule per ohm

E joule per coulomb.

8. The letters **X**, **Y** and **Z** represent the missing words from the following passage.

There are four fundamental forces.

*Gravity and the electromagnetic force act over a …***X**… *range.*

*The strong and weak force act over a …***Y**… range.

*The …***Z**… *force is responsible for beta decay.*

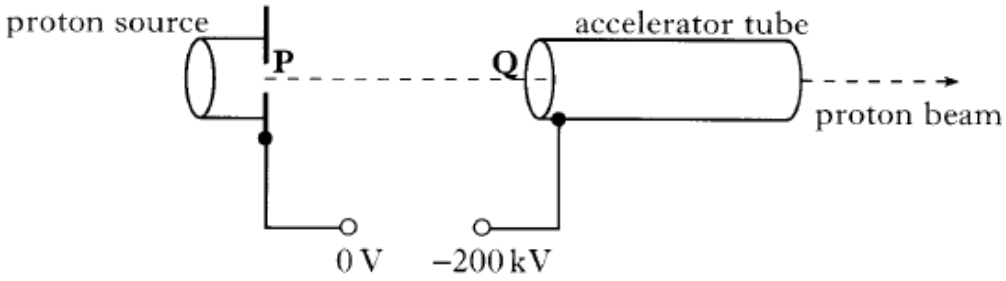
Which row in the table identifies the missing words represented by the letters **X**, **Y** and **Z**?

	X	**Y**	**Z**
A	short	long	strong
B	long	short	strong
C	long	short	weak
D	long	long	electromagnetic
E	short	long	weak

9. Which row in the table shows an example of a hadron, lepton and boson?

	Hadron	*Lepton*	*Boson*
A	neutron	photon	electron
B	electron	neutron	photon
C	photon	electron	neutron
D	neutron	electron	photon
E	electron	photon	neutron

10. The diagram below shows the basic features of a proton accelerator. It is enclosed in an evacuated container.



Protons released from the proton source start from rest at **P**.
A potential difference of 200 kV is maintained between **P** and **Q**.

(*a*) What is meant by the term *potential difference of 200 kV*? **1**

(*b*) Explain why protons released at **P** are accelerated towards **Q**. **1**

(*c*) Calculate:

(i) the work done on a proton as it accelerates from **P** to **Q**; **2**

(ii) the speed of a proton as it reaches **Q**. **2**

(*d*) The distance between **P** and **Q** is now halved.

What effect, if any, does this change have on the speed of a proton as it reaches **Q**? Justify your answer. **2**

(8)

11. (*a*) A conversation is overheard between two young pupils who are discussing their science lessons.

Pupil A *"We learned in science today that the nucleus of an atom is made of protons which are positively charged and neutrons which have no charge."*

Pupil B *"That's interesting because we learned in science that like charges repel. How come the protons in the nucleus don't fly apart?"*

Pupil A *"I don't know."*

Write a paragraph that would explain to the pupils why the protons in a nucleus do not fly apart. **3**

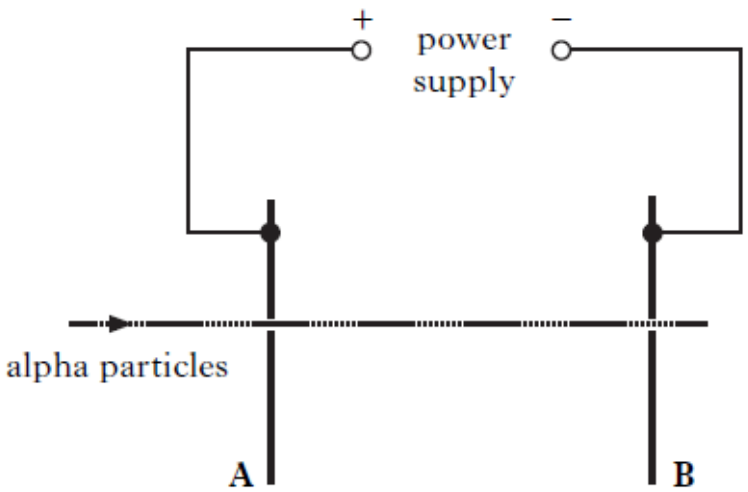
(*b*) Protons and neutrons each contain two different types of quark: the up quark which has an electric charge of $+\frac{2}{3}$ and the down quark which has an electric charge of $-\frac{1}{3}$.

Use this information to show:

(i) the overall charge on the proton is +1;

(ii) the overall charge on the neutron is zero. **2**

12. The apparatus shown in the diagram is designed to accelerate alpha particles.



An alpha particle travelling at a speed of $2{\cdot}60 \times 10^{6}\,\text{m s}^{-1}$ passes through a hole in plate A. The mass of an alpha particle is $6{\cdot}64 \times 10^{-27}\,\text{kg}$ and its charge is $3{\cdot}2 \times 10^{-19}\,\text{C}$.

(*a*) When the alpha particle reaches plate B, its kinetic energy has increased to $3{\cdot}05 \times 10^{-14}\,\text{J}$.

Show that the work done on the alpha particle as it moves from plate A to plate B is $8{\cdot}1 \times 10^{-15}\,\text{J}$. **2**

(*b*) Calculate the potential difference between plates A and B. **2**

(*c*) The apparatus is now adapted to accelerate **electrons** from A to B through the same potential difference.

How does the increase in the kinetic energy of an electron compare with the increase in kinetic energy of the alpha particle in part (*a*)?

Justify your answer. **2**

(6)

13. (*a*) A conversation is overheard between two young pupils who are discussing their science lessons.

Pupil A *"We learned in science today that the nucleus of an atom is made of protons which are positively charged and neutrons which have no charge."*

Pupil B *"That's interesting because we learned in science that like charges repel. How come the protons in the nucleus don't fly apart?"*

Pupil A *"I don't know."*

Write a paragraph that would explain to the pupils why the protons in a nucleus do not fly apart. **3**

(*b*) Protons and neutrons each contain two different types of quark: the up quark which has an electric charge of $+\frac{2}{3}$ and the down quark which has an electric charge of $-\frac{1}{3}$.

Use this information to show:

(i) the overall charge on the proton is +1;

(ii) the overall charge on the neutron is zero. **2**

Exercise 12- Nuclear Reactions

Past Paper Homework Questions

1. The statement below represents a nuclear reaction.

$$^{235}_{92}\text{U} + ^{1}_{0}\text{n} \rightarrow ^{92}_{36}\text{Kr} + ^{141}_{56}\text{Ba} + ^{1}_{0}\text{n} + ^{1}_{0}\text{n} + ^{1}_{0}\text{n}$$

This is an example of

A nuclear fusion

B alpha particle emission

C beta particle emission

D spontaneous nuclear fission

E induced nuclear fission.

2. Which row of the table shows the correct values of x, y and z for the nuclear reaction described below?

$$^{214}_{x}\text{Pb} \rightarrow ^{y}_{83}\text{Bi} + ^{0}_{z}\text{e}$$

	x	y	z
A	84	214	1
B	83	210	4
C	85	214	2
D	82	214	−1
E	82	210	−1

3. Under certain conditions, a nucleus of nitrogen absorbs an alpha particle to form the nucleus of another element and releases a single particle.

Which one of the following statements correctly describes this process?

A $^{14}_{7}\text{N} + ^{3}_{2}\text{He} \rightarrow ^{16}_{9}\text{F} + ^{1}_{0}\text{n}$

B $^{14}_{7}\text{N} + ^{4}_{2}\text{He} \rightarrow ^{17}_{10}\text{Ne} + ^{0}_{-1}\text{e}$

C $^{14}_{7}\text{N} + ^{3}_{2}\text{He} \rightarrow ^{16}_{8}\text{O} + ^{1}_{1}\text{p}$

D $^{14}_{7}\text{N} + ^{4}_{2}\text{He} \rightarrow ^{18}_{9}\text{F} + 2\,^{0}_{-1}\text{e}$

E $^{14}_{7}\text{N} + ^{4}_{2}\text{He} \rightarrow ^{17}_{8}\text{O} + ^{1}_{1}\text{p}$

4. Which of the following statements describes nuclear fission?

A A nucleus of large mass number splits into two nuclei, releasing several neutrons.

B A nucleus of large mass number splits into two nuclei, releasing several electrons.

C A nucleus of large mass number splits into two nuclei, releasing several protons.

D Two nuclei combine to form one nucleus, releasing several electrons.

E Two nuclei combine to form one nucleus, releasing several neutrons.

5. A series of radioactive decays starts from the isotope Uranium 238.

Two alpha particles and two beta particles are emitted during the decays.

Which row in the table gives the mass number and the atomic number of the resulting nucleus?

	Mass number	*Atomic number*
A	232	88
B	230	86
C	230	90
D	246	94
E	246	98

6. The following statement describes a fusion reaction.

$$^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \longrightarrow {}^{3}_{2}\mathrm{He} + {}^{1}_{0}\mathrm{n} + \text{energy}$$

The total mass of the particles before the reaction is $6{\cdot}684 \times 10^{-27}$ kg.

The total mass of the particles after the reaction is $6{\cdot}680 \times 10^{-27}$ kg.

The energy released in this reaction is

A $6{\cdot}012 \times 10^{-10}$ J

B $6{\cdot}016 \times 10^{-10}$ J

C $1{\cdot}800 \times 10^{-13}$ J

D $3{\cdot}600 \times 10^{-13}$ J

E $1{\cdot}200 \times 10^{-21}$ J.

7. Compared with a proton, an alpha particle has

A twice the mass and twice the charge

B twice the mass and the same charge

C four times the mass and twice the charge

D four times the mass and the same charge

E twice the mass and four times the charge.

8. For the nuclear decay shown, which row of the table gives the correct values of x, y and z?

$$^{214}_{x}\mathrm{Pb} \longrightarrow {}^{y}_{83}\mathrm{Bi} + {}^{0}_{z}\mathrm{e}$$

	x	y	z
A	85	214	2
B	84	214	1
C	83	210	4
D	82	214	–1
E	82	210	–1

9. Radium (Ra) decays to radon (Rn) by the emission of an alpha particle.
Some energy is also released by this decay.
The decay is represented by the statement shown below.

$$^{226}_{88}\text{Ra} \longrightarrow {}^{x}_{y}\text{Rn} + {}^{4}_{2}\text{He}$$

The masses of the nuclides involved are as follows.

Mass of $^{226}_{88}\text{Ra} = 3{\cdot}75428 \times 10^{-25}\,\text{kg}$

Mass of $^{x}_{y}\text{Rn} = 3{\cdot}68771 \times 10^{-25}\,\text{kg}$

Mass of $^{4}_{2}\text{He} = 6{\cdot}64832 \times 10^{-27}\,\text{kg}$

(*a*) (i) What are the values of x and y for the nuclide $^{x}_{y}\text{Rn}$?

(ii) Why is energy released by this decay?

(iii) Calculate the energy released by one decay of this type. **5**

(*b*) The alpha particle leaves the radium nucleus with a speed of $1{\cdot}5 \times 10^{7}\,\text{m s}^{-1}$.

The alpha particle is now accelerated through a potential difference of 25 kV.

Calculate the **final** kinetic energy, in joules, of the alpha particle. **3**

10. (*a*) The following statement represents a nuclear reaction.

$$^{239}_{94}\text{Pu} + {}^{1}_{0}\text{n} \longrightarrow {}^{137}_{52}\text{Te} + {}^{100}_{42}\text{Mo} + 3\,{}^{1}_{0}\text{n} + \text{energy}$$

The total mass of the particles before the reaction is $3{\cdot}9842 \times 10^{-27}\,\text{kg}$ and the total mass of the particles after the reaction is $3{\cdot}9825 \times 10^{-27}\,\text{kg}$.

(i) State and explain whether this reaction is spontaneous or induced.

(ii) Calculate the energy, in joules, released by this reaction. **3**

11. (*a*) Torbernite is a mineral which contains uranium.

The activity of 1·0 kg of pure torbernite is $5{\cdot}9 \times 10^6$ decays per second.

A sample of material of mass 0·6 kg contains 40% torbernite. The remaining 60% of the material is not radioactive.

What is the activity of the sample in becquerels? **2**

12. A technician is studying samples of radioactive substances.

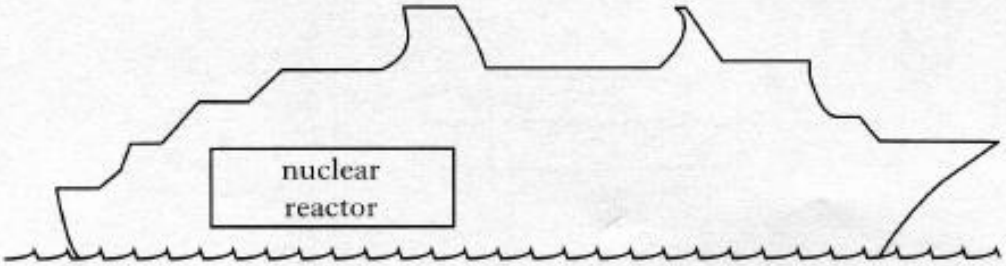
(*a*) The following statement describes a nuclear decay in one of the samples used by the technician.

$$^{238}_{92}\mathrm{U} \rightarrow {}^{234}_{90}\mathrm{Th} + {}^{4}_{2}\mathrm{He}$$

(i) What type of particle is emitted during this decay?

(ii) In this sample $7{\cdot}2 \times 10^5$ nuclei decay in two minutes.
Calculate the average activity of the sample during this time. **3**

13. A ship is powered by a nuclear reactor.



One reaction that takes place in the core of the nuclear reactor is represented by the statement below.

$$^{235}_{92}\mathrm{U} + {}^{1}_{0}\mathrm{n} \rightarrow {}^{140}_{58}\mathrm{Ce} + {}^{94}_{40}\mathrm{Zr} + 2\,{}^{1}_{0}\mathrm{n} + 6\,{}^{0}_{-1}\mathrm{e}$$

(*a*) The symbol for the Uranium nucleus is $^{235}_{92}\mathrm{U}$.

What information about the nucleus is provided by the following numbers?

(i) 92

(ii) 235 **2**

(*b*) Describe how neutrons produced during the reaction can cause further nuclear reactions. **1**

(*c*) The masses of particles involved in the reaction are shown in the table.

Particles	*Mass*/kg
$^{235}_{92}\mathrm{U}$	$390{\cdot}173 \times 10^{-27}$
$^{140}_{58}\mathrm{Ce}$	$232{\cdot}242 \times 10^{-27}$
$^{94}_{40}\mathrm{Zr}$	$155{\cdot}884 \times 10^{-27}$
$^{1}_{0}\mathrm{n}$	$1{\cdot}675 \times 10^{-27}$
$^{0}_{-1}\mathrm{e}$	negligible

Calculate the energy released in the reaction. **3**

(6)