Higher
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Past Paper questions
2000 - 2010
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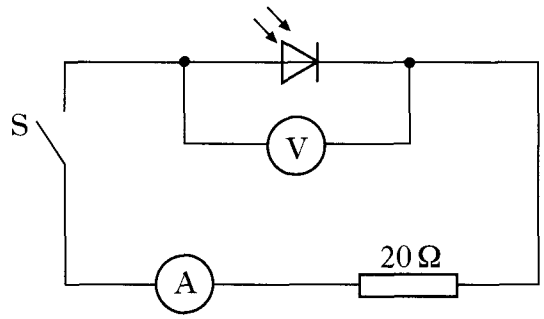
3.5 Optoelectronics

2000 Q25

A photodiode is connected in a circuit as shown below.



Switch S is open.
Light is shone on to the photodiode.
A reading is obtained on the voltmeter.

(a) (i) State the mode in which the photodiode is operating.

(ii) Describe the effect of light on the material of which the photodiode is made.

(iii) The irradiance of the light on the photodiode is increased.
What happens to the reading on the voltmeter?

(b) Light of a constant irradiance is shone on to the photodiode in the circuit shown above.
The following measurements are obtained with S open and then with S closed.

	S open	S closed
reading on voltmeter/V	0·508	0·040
reading on ammeter/mA	0·00	2.00

(i) What is the value of the e.m.f. produced by the photodiode for this light irradiance?

(ii) Calculate the internal resistance of the photodiode for this light irradiance.

(c) In the circuit above, the 20 Ω resistor is now replaced with a 10 Ω resistor.
The irradiance of the light is unchanged.
The following measurements are obtained.

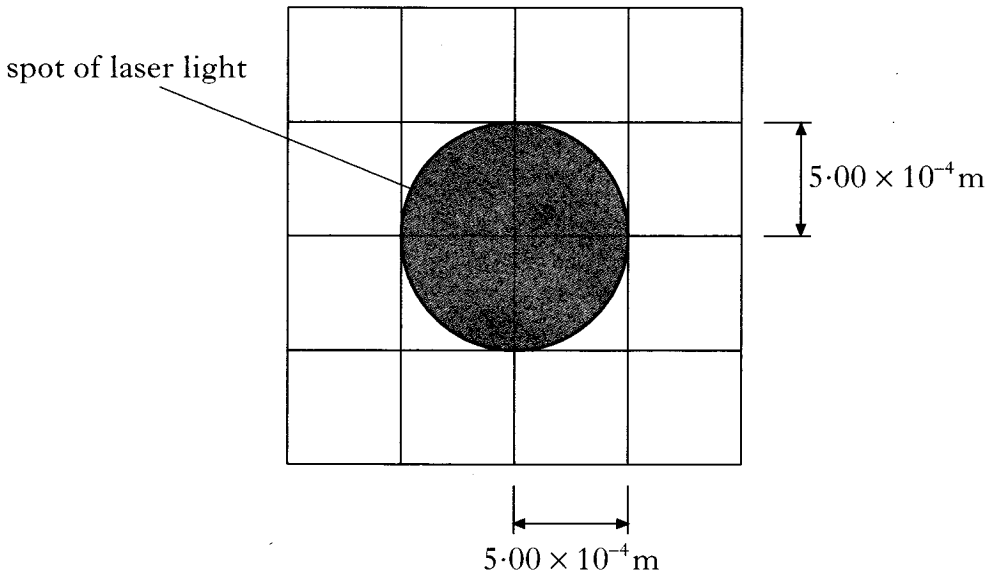
	S open	S closed
reading on voltmeter/V	0·508	0.021

Explain why the reading on the voltmeter, when S is closed, is smaller than the corresponding reading in part (b).

2001 Q28.

(a) In a laser, the light is produced by stimulated emission of radiation.
Explain the term "stimulated emission" by making reference to the energy levels in atoms.

(b) A laser beam is shone on to a screen which is marked with a grid.
The beam produces a uniformly lit spot of radius 5.00×10^{-4}m as shown.

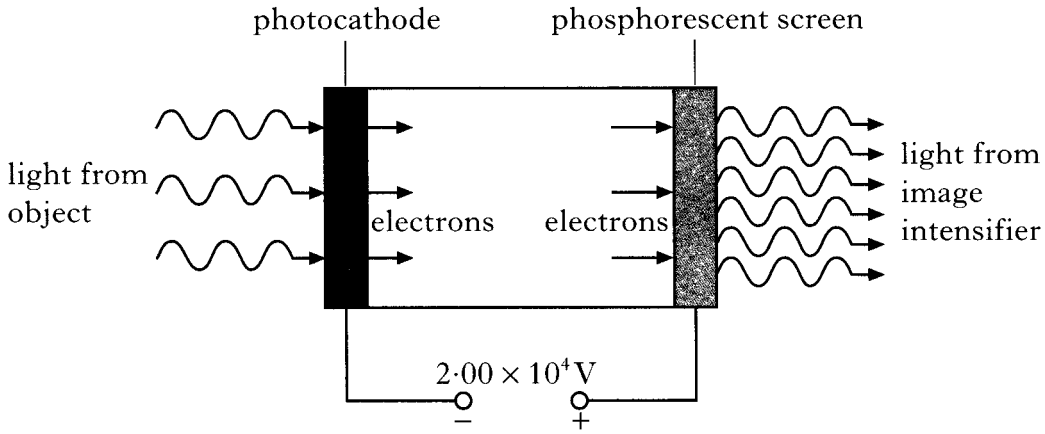


(i) The intensity of the spot of light on the screen is 1020 Wm^{-2}.
Calculate the power of the laser beam.

(ii) 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.

2002 Q28

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 irradiance than the light that was incident on the photocathode.



The voltage between the photocathode and the phosphorescent screen is 2.00×10^4 V.

The minimum frequency of the incident light that allows photoemission to take place is 3.33×10^{14} Hz.

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

(b) (i) Show that the work function of the photocathode material is 2.21×10^{-19} J.

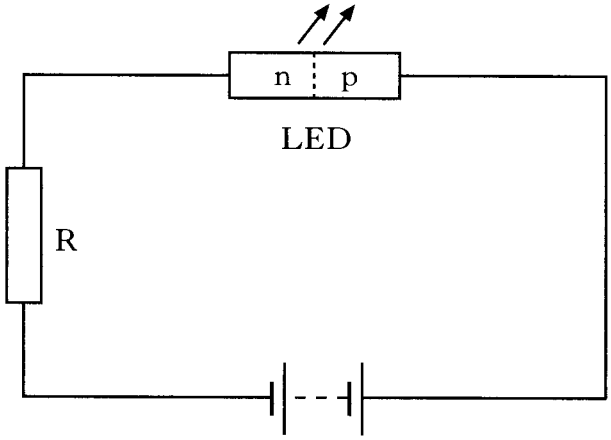
(ii) Light of frequency 5.66×10^{14} Hz is incident on the photocathode.
Calculate the maximum kinetic energy of an electron emitted from the photocathode.

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

2002 Q29

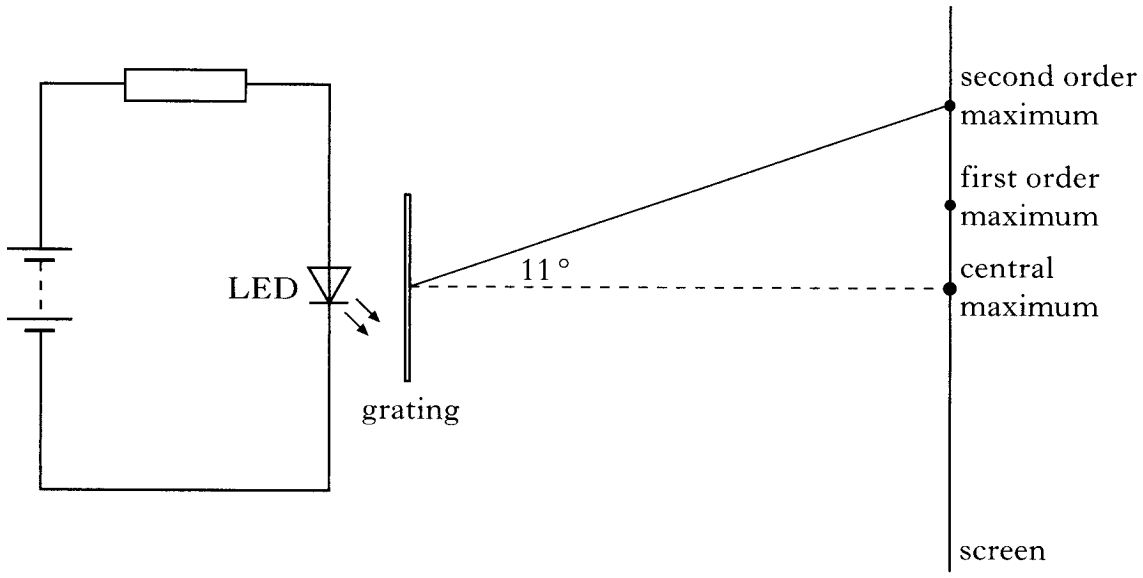
(a) A sample of pure semiconducting material is doped by adding impurity atoms. How does this addition affect the resistance of the semiconducting material?

(b) The circuit below shows a p-n junction diode used as a light emitting diode (LED).



(i) Explain in terms of the charge carriers how the LED emits light.

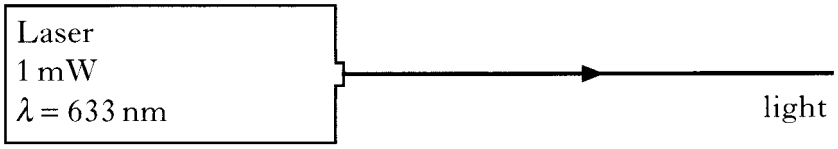
(ii) Monochromatic light from the LED is incident on a grating as shown. The spacing between lines in the grating is 5.0×10^{-6} m.



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

2004 Q28.

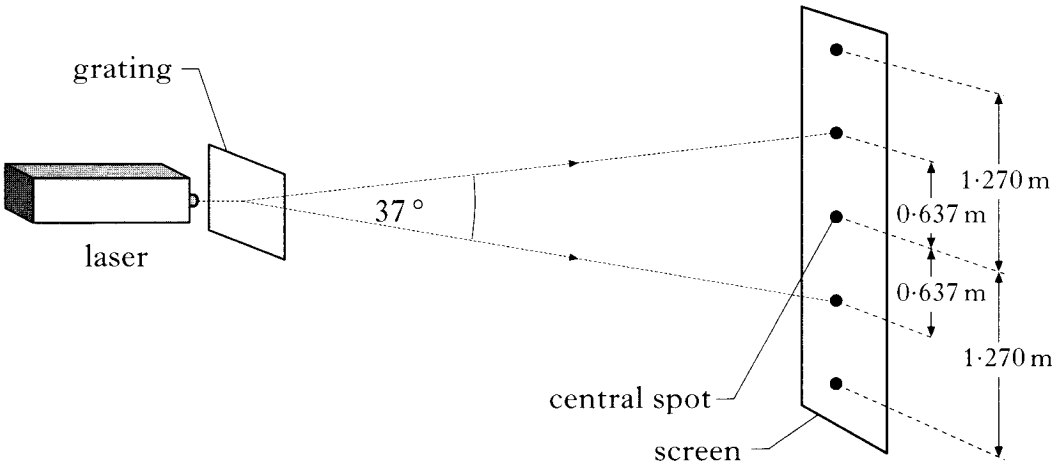
The term LASER is short for "Light Amplification by the Stimulated Emission of Radiation".



(a) (i) Describe what is meant by *Stimulated Emission*.

(ii) Explain how amplification is produced in a laser.

(b) 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.

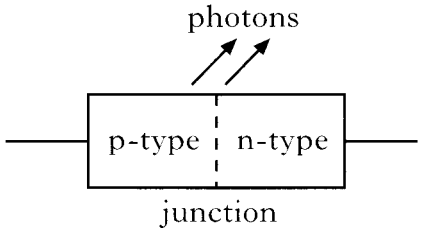


Calculate the number of lines per metre on the grating.

(c) 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.

2004 Q29.

An LED consists of a p-n junction as shown.



(a) Copy the diagram and add a battery so that the p-n junction is forward-biased.

(b) Using the terms electrons, holes and photons, explain how light is produced at the p-n junction of the LED.

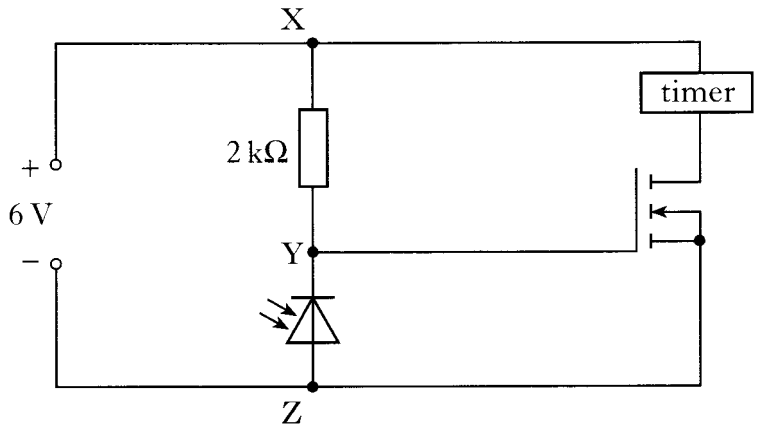
(c) The LED emits photons, of energy 3.68×10^{-19} J.

(i) Calculate the wavelength of a photon of light from this LED.

(ii) Calculate the minimum potential difference across the p-n junction when it emits photons.

2005 Q21.

(b) The light gate consists of a lamp shining onto a photodiode.
The photodiode forms part of the circuit shown.

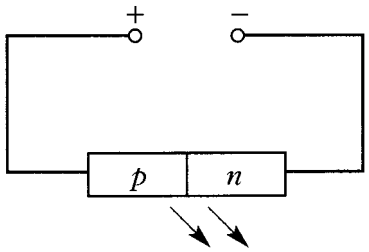


(i) In which mode is the photodiode operating?

(ii) Explain why the timer only operates while the light beam is broken.

2006 Q27.

(a) Light of frequency 6.7×10^{-14} Hz is produced at the junction of a light emitting diode (LED).



(i) Describe how the movement of charges in a forward-biased LED produces light.
Your description should include the terms: *electrons; holes; photons* and *junction*.

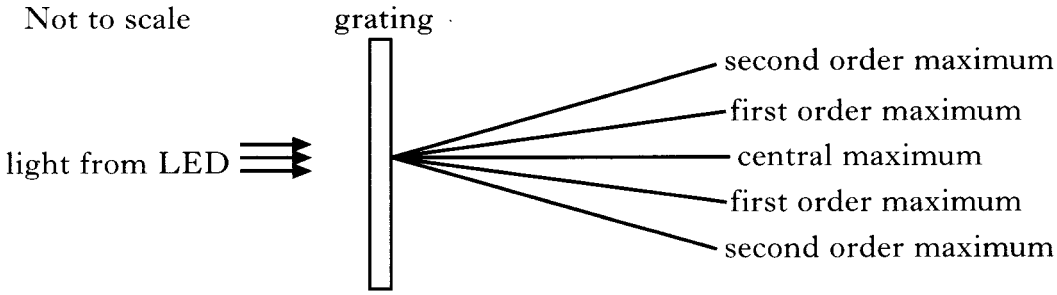
(ii) (A) Calculate the wavelength of the light emitted from the LED.
(B) Use information from the data sheet on *below* to deduce the colour of this light.

(iii) The table below gives the values of the work function for three metals.

Metal	*Work function*/ J
caesium	$3{\cdot}4 \times 10^{-19}$
strontium	$4{\cdot}1 \times 10^{-19}$
magnesium	$5{\cdot}9 \times 10^{-19}$

Light from the LED is now incident on these metals in turn.
Show by calculation which of these metals, if any, release(s) photoelectrons with this light.

(b) Light from a different LED is passed through a grating as shown below.



Light from this LED has a wavelength of 6.35×10^{-7} m.
The spacing between lines in the grating is 5.0×10^{-6} m.
Calculate the angle between the central maximum and the **second** order maximum.

SPECTRAL LINES

Element	*Wavelength*/nm	*Colour*
Hydrogen	656	Red
	486	Blue-green
	434	Blue-violet
	410	Violet
	397	Ultraviolet
	389	Ultraviolet
Sodium	589	Yellow

Element	*Wavelength*/nm	*Colour*
Cadmium	644	Red
	509	Green
	480	Blue

Lasers

Element	*Wavelength*/nm	*Colour*
Carbon dioxide	9550 } 10590 }	Infrared
Helium-neon	633	Red

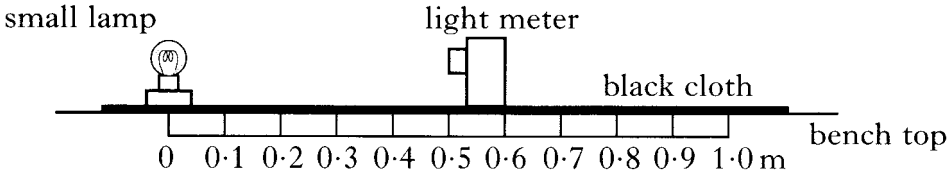
2006 Q28.

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?

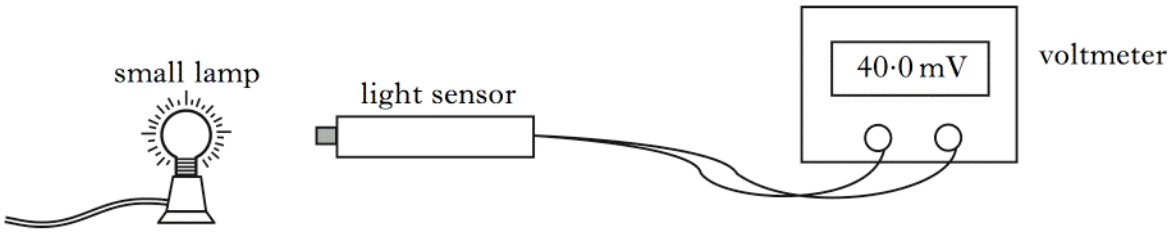
(b) Use **all** the data to find the relationship between irradiance ***I*** and distance ***d*** from the source.

(c) What is the purpose of the black cloth on top of the bench?

(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.

2008 Q28.

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 8.0×10^{-5} m^2.
Calculate the irradiance of light on the sensor.

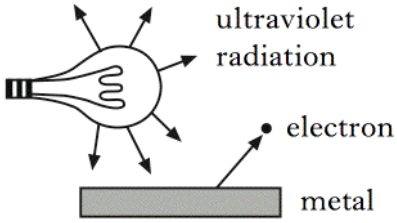
(b) The small lamp is replaced by a different source of light. Using this new source, a student investigates how irradiance varies with distance. The results are shown.

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.

2009 Q29.

Ultraviolet radiation from a lamp is incident on the surface of a metal. This causes the release of electrons from the surface of the metal.



The energy of each photon of ultraviolet light is 5.23×10^{-19} J.

The work function of the metal is 2.56×10^{-19} J.

(a) Calculate:

(i) the maximum kinetic energy of an electron released from this metal by this radiation;

(ii) the maximum speed of an emitted electron.

(b) The source of ultraviolet radiation is now moved further away from the surface of the metal.
State the effect, if any, this has on the maximum speed of an emitted electron.
Justify your answer.