شرح النموذج الكمي للذرة والليزر

تم تحميل هذا الملف من موقع المناهج الإماراتية	
موقع المناهج ⇦ المناهج الإماراتية ⇦ الصف الثاني عشر المتقدم ⇦ فيزياء ⇦ الفصل الأول ⇦ ملفات متنوعة ⇦ الملف	
تاريخ إضافة الملف على موقع المناهج: 2026-10-30 17:22:28	
ملفات ا كتب للمعلم ا كتب للطالب ا اختبارات الكترونية ا اختبارات ا حلول ا عروض بوربوينت ا أوراق عمل منهج انجليزي ا ملخصات وتقارير ا مذكرات وبنوك ا الامتحان النهائي ا للمدرس	المزيد من مادة فيزياء:
إعداد: عبدالرحمن بدر	

التواصل الاجتماعي بحسب الصف الثاني عشر المتقدم					
صفحة المناهج الإماراتية على فيسبوك					
المواد على تلغرام	التربية الاسلامية	اللغة العربية	اللغة الانجليزية	الرياضيات	

المزيد من الملفات بحسب الصف الثاني عشر المتقدم والمادة فيزياء في الفصل الأول	
1	أسئلة وزارية سابقة
2	شرح ومسائل محلولة حول قانون كولوم وقانون نيوتن في الجذب
3	أسئلة تدريبية على القوى الكهروستاتيكية ومبدأ التراكب
4	ملزمة Model s'Bohr of the atom شرح نموذج بور للذرة وتجربة رذرفورد
5	أوراق عمل وتدريبات الوحدة الثالثة الجهد الكهربائي

تحميل تطبيق المناهج للهواتف الذكية	
تطبيق المناهج على Store App (آبل)	تطبيق المناهج على Play Google (أندرويد)

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LESSON 4

THE QUANTUM MODEL OF THE ATOM

PHYSICS- G 12 ADVANCED

إعداد المهندس عبدالرحمن بدر

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LESSON 4

THE QUANTUM MODEL OF THE ATOM

FOCUS QUESTION

How do lasers work?

From Orbits to an Electron Cloud

Bohr's model of quantized electron orbits could not correctly predict electron energies for atoms with **more than one electron**.

Recall that **de Broglie** proposed that particles have **wave properties**. The de Broglie wavelength of a particle with momentum mv is

$$\lambda = \frac{h}{mv}$$

The angular momentum of an electron in a Bohr orbit is mvr. Thus, Bohr's required quantized angular-momentum condition,

$$mvr = \frac{nh}{2\pi}$$

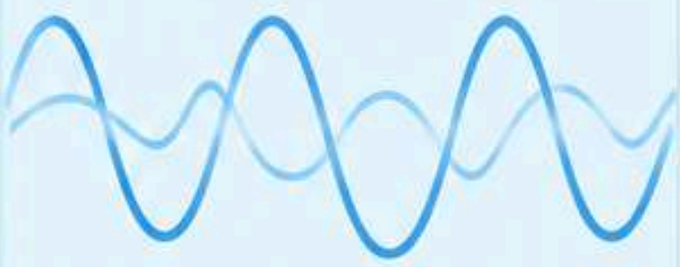
Combining these two relationships gives

$$2\pi r = n\lambda$$

This means that the circumference of a stable Bohr orbit ($2\pi r$) must be equal to a whole number multiple (n) of the de Broglie wavelength (λ).

Key Idea

- Only **whole-number wave cycles** ($n = 1, 2, 3, \ldots$) fit around a stable orbit.
- If the number of cycles is **not an integer**, the waves do not fit together and the orbit is **not stable**.



de Broglie Waves

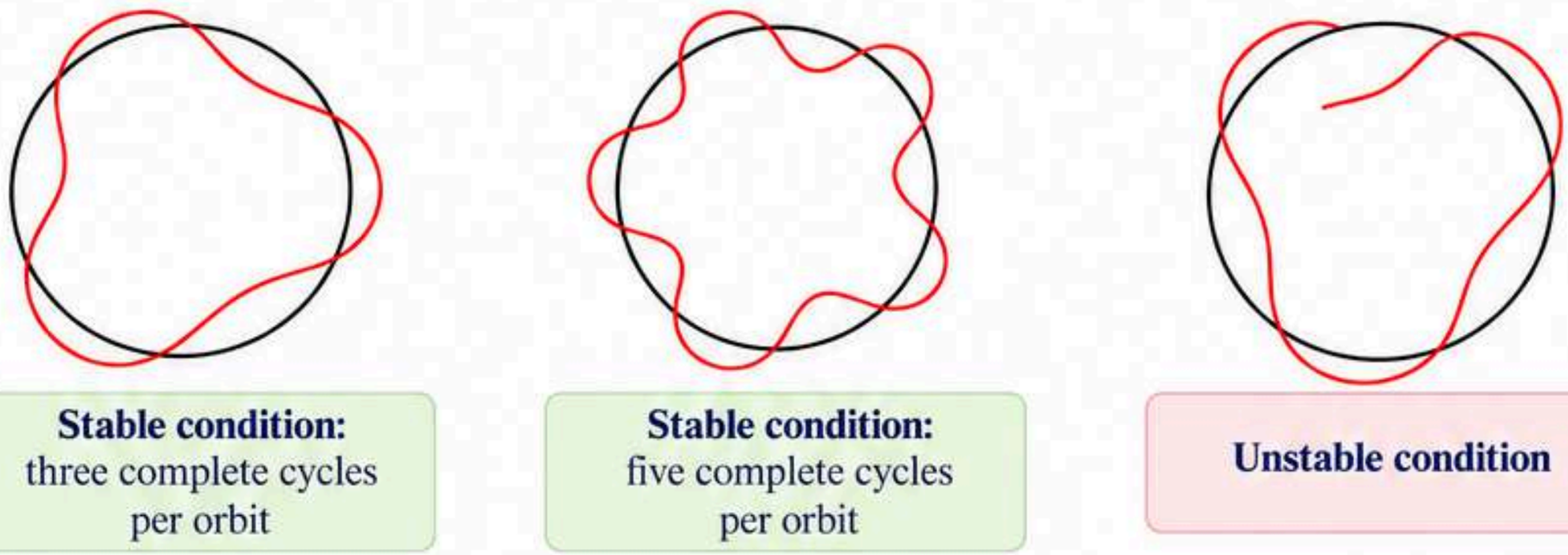


Figure 25 In the Bohr model of the atom, stable electron orbits around the nucleus must have a circumference equal to a whole-number multiple (n) of the de Broglie wavelengths.

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The Quantum Model of the Atom

1 Schrödinger and the Wave Model

In 1926, Austrian physicist **Erwin Schrödinger** extended de Broglie's wave model to create a **quantum theory** of particles, such as electrons, based on waves.

However, **the electron itself is not a wave.** The wave describes the probability of finding an electron in a particular location or having a particular momentum or energy.

Erwin Schrödinger
(1887–1961)

2 The Uncertainty Principle

Heisenberg proposed that it is impossible to measure exactly both the position and momentum of a particle at the same time. You can only know them approximately.

Uneertainty Principle

- It is impossible to measure exactly both the position and momentum of a particle at the same time.

3 The Quantum Model of the Atom

Building on Heisenberg's ideas, the modern **quantum model** of the atom predicts only the **probability** that an electron is in a specific region.

The quantum model predicts that the most probable distance between the electron and the nucleus for a hydrogen atom equals the radius predicted by the Bohr model.

4 The Electron Cloud

The probability of the electron being at any specific radius can be calculated, and a three-dimensional plot will then show regions of equal probability. The region in which there is a high probability of finding the electron is called the **electron cloud**.

Electron Cloud for Hydrogen

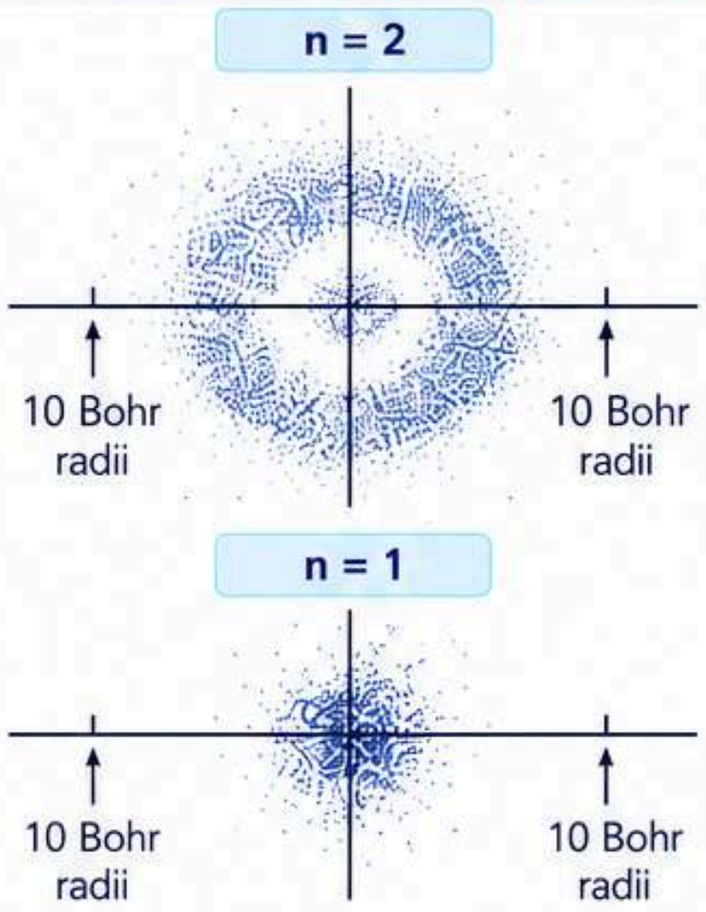

Figure 26 The density of dots in these plots corresponds to the probability of finding the electron in a hydrogen atom in the first and second energy levels.

5 Get It?

Explain the meaning of the electron cloud.

Answer: The electron cloud is the region around the nucleus where there is a **high probability** of finding the electron. It represents the **most likely locations** of the electron, not a fixed path or orbit.

6 Quantum Mechanics and Its Applications

- Even though the quantum model of the atom is difficult to visualize, it was an early success in the development of **quantum mechanics**, the study of the wave properties of matter.
- Quantum mechanics is a useful tool for physicists, chemists, biologists, and engineers.
- It has been used to develop new chemicals, new computer chips, new solar power cells, and new medicines.
- Quantum mechanics also helped analyze the details of atoms' emission and absorption of light, leading to the development of a new type of light source.

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Lasers: Coherent and Incoherent Light

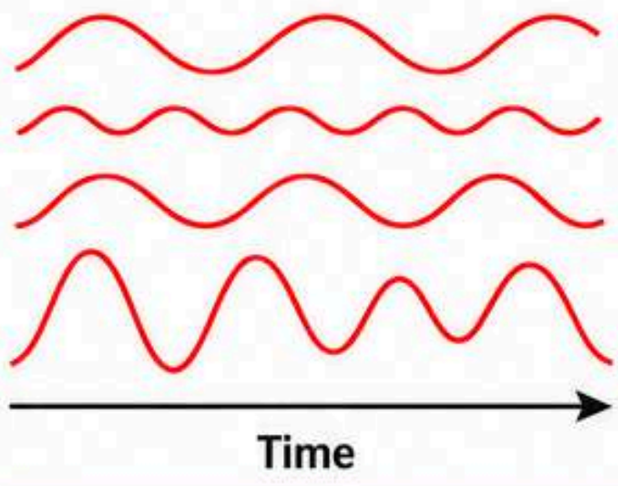
1 Incoherent Light

Most of the light you see is a jumble of uncoordinated waves having **many different wavelengths**. It is like music from a choir in which every member is singing a different song.

Light emitted by an incandescent source such as a filament lightbulb has a **continuous range of wavelengths**, whereas light produced by an atomic gas consists of only **a few distinct wavelengths**.

Light from each of these sources travels in all directions. The waves are not necessarily all at the same point in their cycle at the same time. Such out-of-step light waves are called **incoherent light**.

Incoherent Light



Key Points

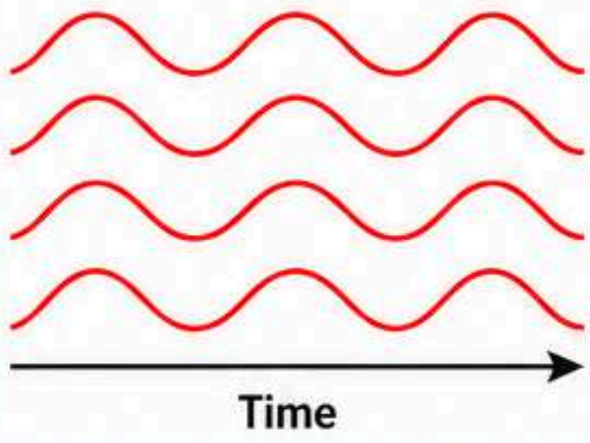
- Waves are out of phase (not synchronized).
- Many different wavelengths may be present.
- Common sources: incandescent bulbs, the Sun, and most everyday light sources.

2 Coherent Light

Waves that are **in phase** are said to be coherent. Light waves that are coherent are referred to as **coherent light.**

Incoherent Light	Coherent Light
Waves are out of phase (not synchronized).	Waves are in phase (synchronized).
Many different wavelengths may be present.	Waves have the same wavelength and keep a constant phase relationship.

Coherent Light



Key Points

- Waves are in phase (synchronized).
- Waves have the same wavelength and keep a constant phase relationship.
- Produced by lasers and some other sources.

3 Excitation and Light Emission (General Process)

Light is emitted by atoms when an electron moves from a higher energy level to a lower energy state.

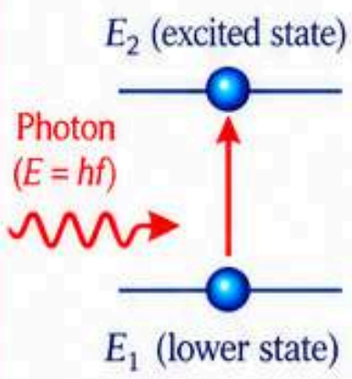
Atoms can be excited to the higher energy state by **thermal excitation** or **electron collision**.

In a third process, a **photon with exactly the right energy** can collide with an atom and excite it.

This describes ordinary excitation and emission. Laser light is explained separately by stimulated emission.

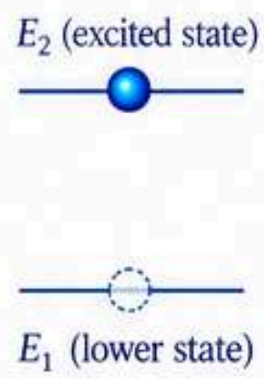
1 Absorption of a photon

A photon with exactly the right energy collides with an atom and excites it to a higher energy state.



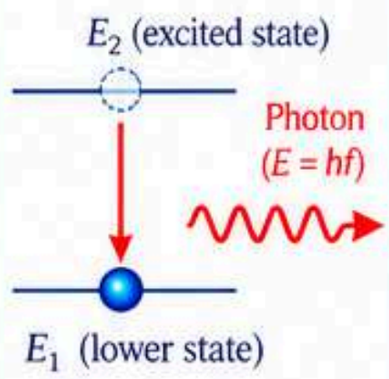
2 Excited atom

The atom is in a higher energy state after absorbing the photon.



3 Spontaneous emission of light

The excited atom moves to a lower energy state, emitting a photon.



Laser operation relies on **stimulated emission**, which produces photons matching the stimulating photon.

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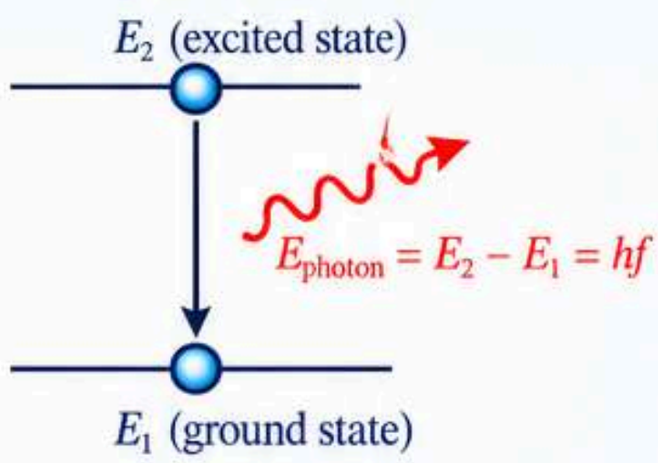
Spontaneous and Stimulated Emission

1 Spontaneous Emission

- An atom in an excited state normally returns to a lower (ground) state after a short time, **emitting a photon whose energy equals the difference between the two energy levels.**
- This process occurs **spontaneously** (without an external photon).
- The emitted photon has a **random direction** and a **random phase**, so it is not coordinated with other photons.

Spontaneous Emission



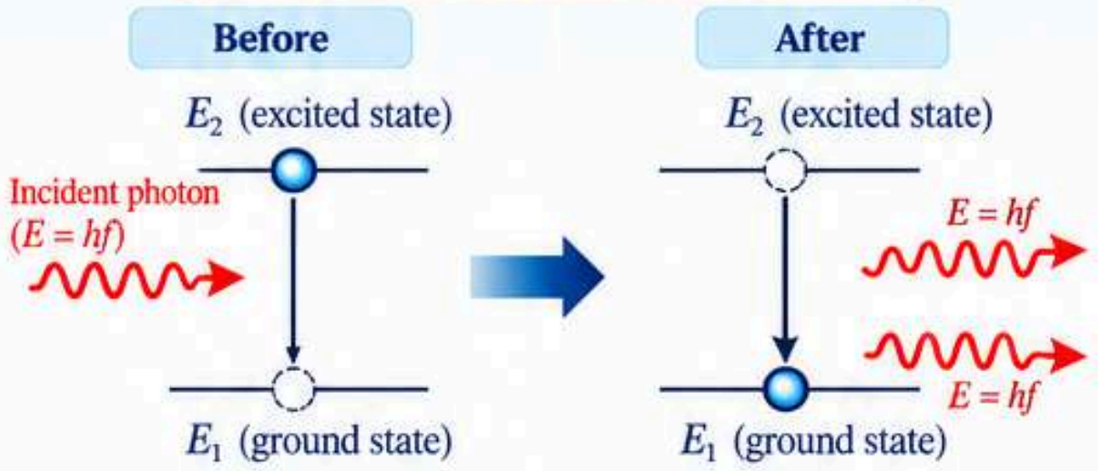
Key Points

- Emission occurs spontaneously.
- Photon energy: $E_{photon} = E_2 - E_1 = hf$
- Random direction and random phase (not coordinated with other photons).

2 Stimulated Emission

- In 1917, Einstein showed that a photon with energy exactly equal to the energy difference between the excited and ground states can strike an excited atom and **stimulate it to drop to the lower state.**
- The atom emits a **second photon.**
- The incident photon is not changed.
- The two photons leaving the atom have the **same energy, frequency, wavelength, phase (in step), and travel in the same direction.** This is called **stimulated emission.**

Stimulated Emission



Properties of the Two Emitted Photons (and the Incident Photon)

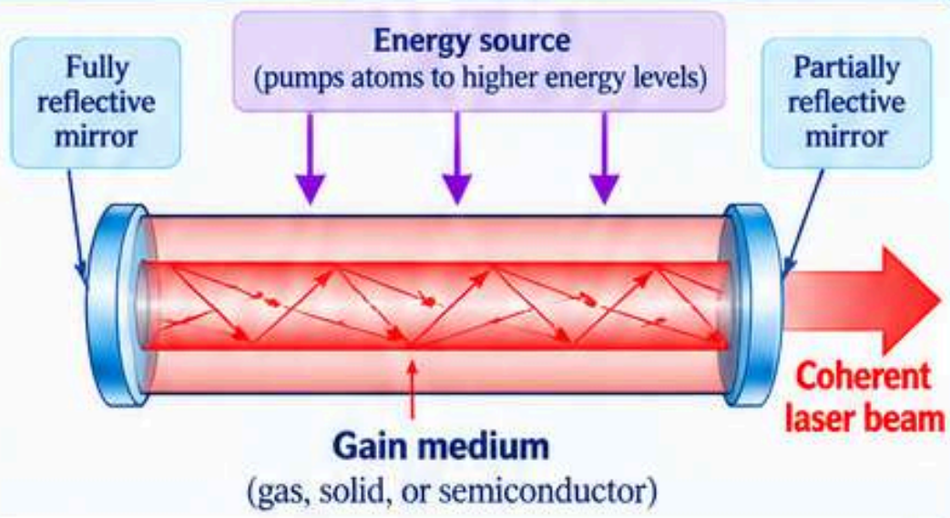
- Same energy: $E = E_2 - E_1 = hf$
- Same frequency (f)
- Same wavelength (λ)
- Same phase (in step/coherent)
- Same direction
- The incident photon is not changed (after the interaction).

3 Conditions for Laser Action

For stimulated emission to produce a large number of photons (a strong beam of light), certain conditions must be met:

1. Other atoms must be in the excited state (population inversion).
2. Atoms must remain in the excited state long enough to be struck by a photon.
3. Photons must be contained so that they can strike other excited atoms repeatedly.

Basic Laser Setup (Resonant Cavity)



What is a laser?

- In 1960, a device was invented that met the above conditions to produce coherent light.
- The word LASER is an acronym for **Light Amplification by Stimulated Emission of Radiation.**
- An atom that emits light when it is stimulated in a laser is said to **lase.**
- Laser light results from **stimulated emission,** not simply from ordinary excitation or spontaneous emission.

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Atom Excitation and Lasing

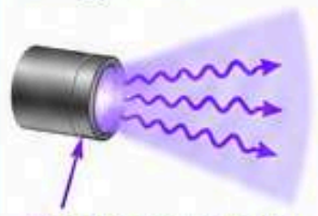
Atom Excitation (Pumping)

- The atoms in a laser can be excited, or **pumped**.
- One method uses an intense flash of light with a **wavelength shorter** than that of the laser. These shorter-wavelength, **higher-energy photons** collide with the lasing atoms, exciting them to higher energy states.
- When one of the excited atoms decays to a lower energy state by emitting a photon, an avalanche of photons can begin. This results in the emission of a **brief flash, or pulse**, of laser light.
- Alternatively, lasing atoms can be excited through **collisions with other atoms**. In helium-neon lasers, an electric discharge excites helium atoms. These excited helium atoms collide with neon atoms, pumping them to excited states and causing them to lase.
- This method can produce a **continuous beam** rather than pulsed flashes.

How Atom Excitation Leads to Lasing

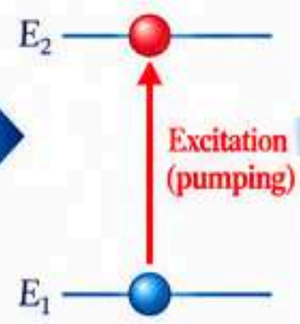
1 Energy source (pumping)

An intense flash of shorter-wavelength light or collisions with other atoms excites the lasing atoms to higher energy states.



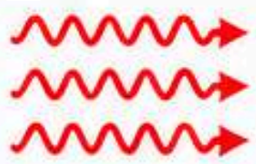
2 Excited atoms in the gain medium

The atoms are pumped to higher energy states (excited atoms).



3 Emission starts (laser light)

When an excited atom decays, photons are emitted and can trigger more stimulated emission, producing an avalanche of photons.



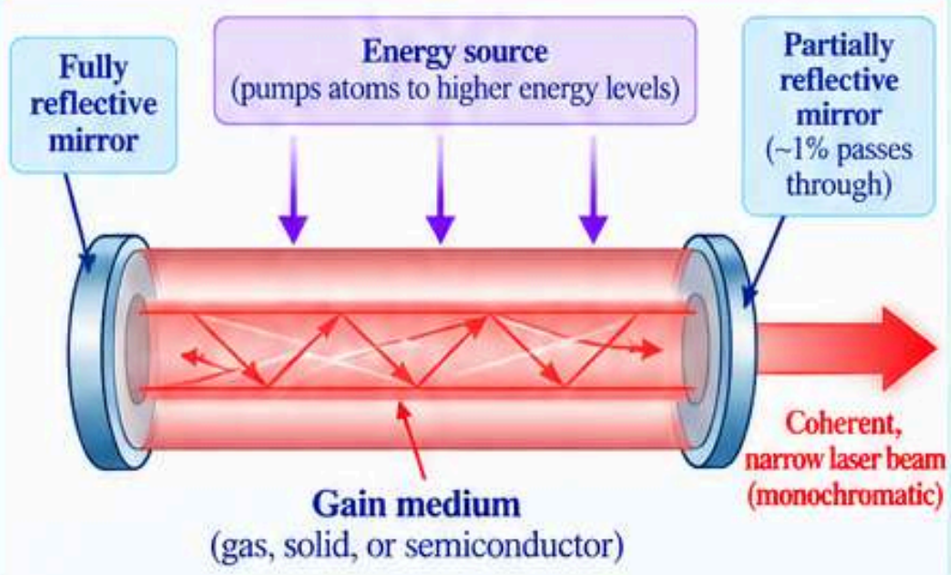
Results in a **brief pulse** or a **continuous beam** depending on the pumping method.

Pumping creates excited atoms, but the key process that produces a strong, coherent beam is **stimulated emission**, not ordinary excitation alone.

Lasing: Amplification Inside a Resonant Cavity

- The lasing atoms and their emitted photons are contained within a chamber that has **parallel mirrors** at each end, one of which allows only **about 1%** of the light hitting it to pass through.
- Photons emitted toward the mirrors are **reflected back into the gas**, where they strike more excited atoms and cause more photons to be released by **stimulated emission**.
- All the stimulated photons are emitted in step with the photons that trigger them, so laser light is **coherent**.
- The laser light is usually of **one wavelength (monochromatic)**.
- The parallel mirrors produce a **highly directional, intense beam** with a small diameter. The beam diverges very little and can be focused to a fine point.
- Stimulated emission can be switched on and off to produce **brief, high-power light pulses**.
- These characteristics of laser light make it particularly well-suited to many different applications.

Basic Laser Setup (Resonant Cavity)



Remember

1. **Pumping** creates excited atoms.
2. **Stimulated emission** amplifies matching photons.
3. The **resonant cavity** helps build a coherent, directional beam.

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Laser Applications

1 Lasers in CD, DVD, and Blu-ray Players

If you have used a CD, DVD, or Blu-ray player, then you have used a laser. These lasers, as well as the ones used in laser pointers, are made of **semiconducting solids.**

The laser in a CD player is made of layers of **gallium arsenide (GaAs)** and **gallium aluminum arsenide (GaAlAs)**. The lasing layer is only **1–2 nm thick**, and each side of the crystal is only **200 nm thick**.

The atoms in the semiconducting solid are **pumped by an electric current**, and the resulting photons are amplified as they bounce between the polished ends of the crystal.

Laser in a DVD Player

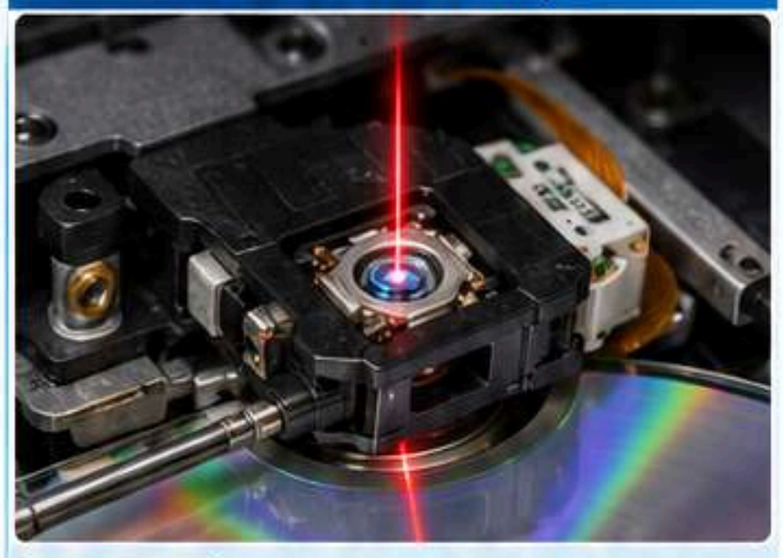


Figure 29 The laser used in this DVD player emits light with a wavelength of about 650 nm.

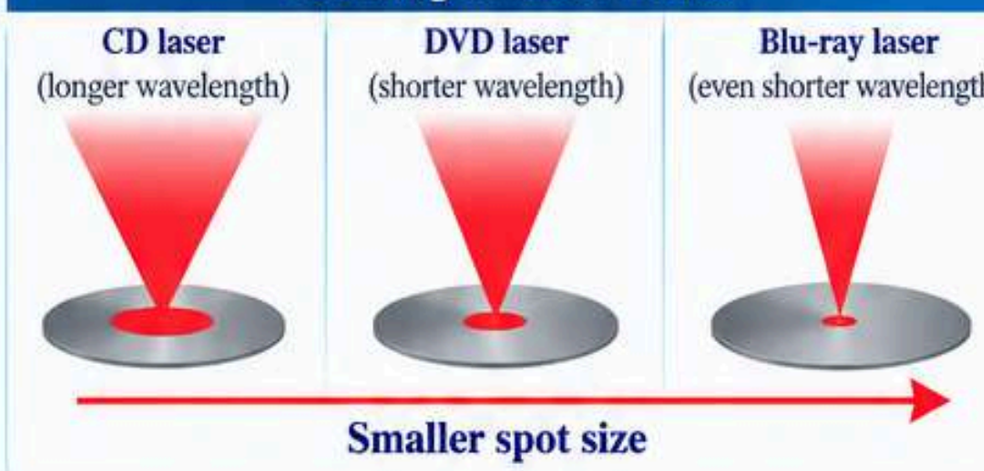
طبقة جانبية: 200 nm
طبقة الليزر: 1–2 nm
طبقة جانبية: 200 nm

2 Wavelength and Data Storage

Shorter wavelength laser beams, such as those used in the DVD player, can focus on **smaller spots**. This allows DVDs to store **more data than CDs**.

Blu-ray players use even **shorter wavelength** lasers than DVD players so that they can store **five times more data than DVDs**.

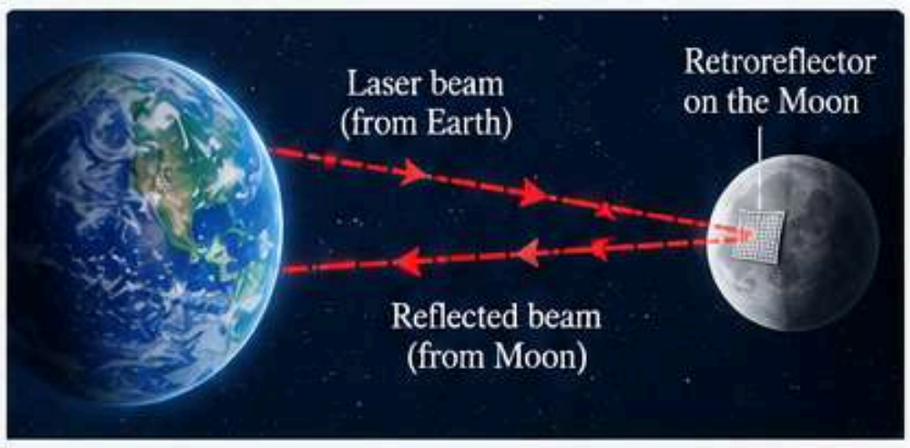
Focusing of Laser Beams



3 Lasers in Surveying and Measuring Distances

Because laser beams are **narrow and highly directional,** they are used in applications such as **surveying,** for example, checking the straightness of long tunnels and pipes.

Lasers reflecting off mirrors left on the Moon are used to measure the distance from **Earth to the Moon** and to measure the **movement of Earth's tectonic plates**.



Get It? Identify the characteristics of laser light that make it well-suited to surveying and measuring large distances.

4 Other Applications of Lasers

Because lasers can emit light bursts **as brief as 10^{-15} s,** they can be used to investigate **very fast changes** in the structures of atoms or molecules.

Other scientists are trying to produce energy from **high temperature plasmas** using very large lasers that produce **petawatt (10^{15} watts) pulses.**

Key Point

Very short laser pulses and very high power lasers allow scientists to study extremely fast processes and to produce energy from high-temperature plasmas.

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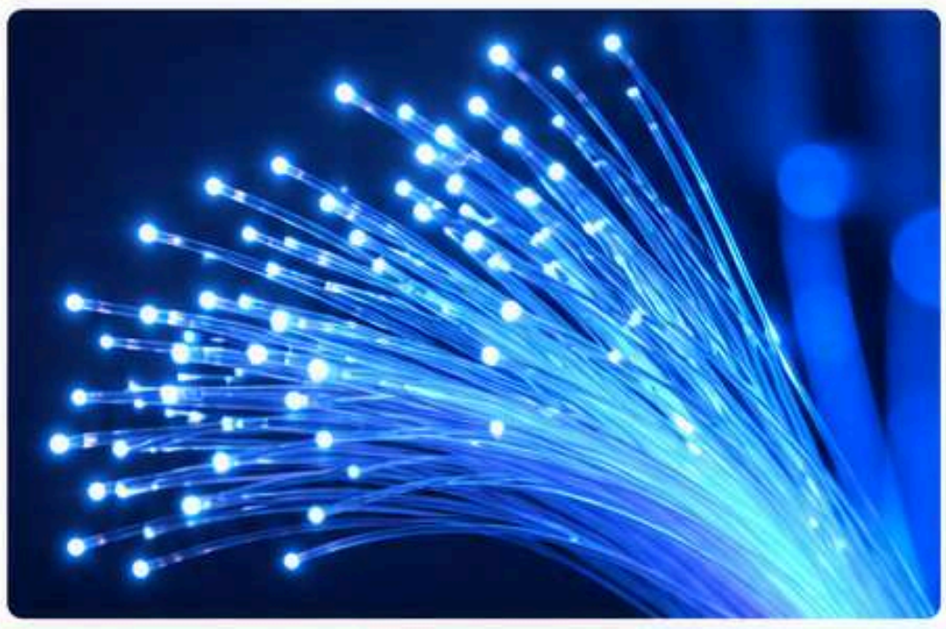
Laser Applications

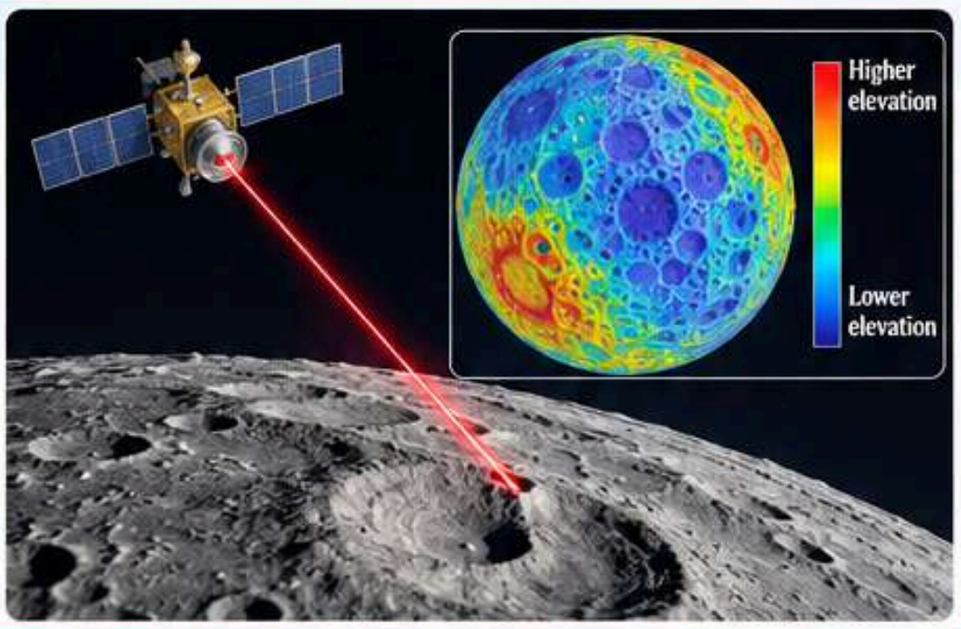
1 Fiber-Optic Communications

Laser light is commonly used in **fiber-optic communications**. This technology is based on an understanding of waves and their interactions with matter. A fiber optic cable uses **total internal reflection** to transmit light over long distances with **little loss of signal energy**. The laser is **rapidly switched on and off**, transmitting information as a series of **pulses** through the fiber. All over the world, optical fibers have **replaced copper wires** for the transmission of telephone calls, computer data, and television signals.



2 Lunar Research

The Lunar Reconnaissance Orbiter pointed a laser at the surface of the Moon and recorded the time required for the laser's light to bounce off the Moon's surface and return to the satellite. The data collected during this mission produced **topographical maps accurate to within 10 cm**. In addition to providing **clues about the Moon's history**, these maps can be used to select **safe landing sites** for future robotic and crewed missions to the Moon.



3 Laser Printers

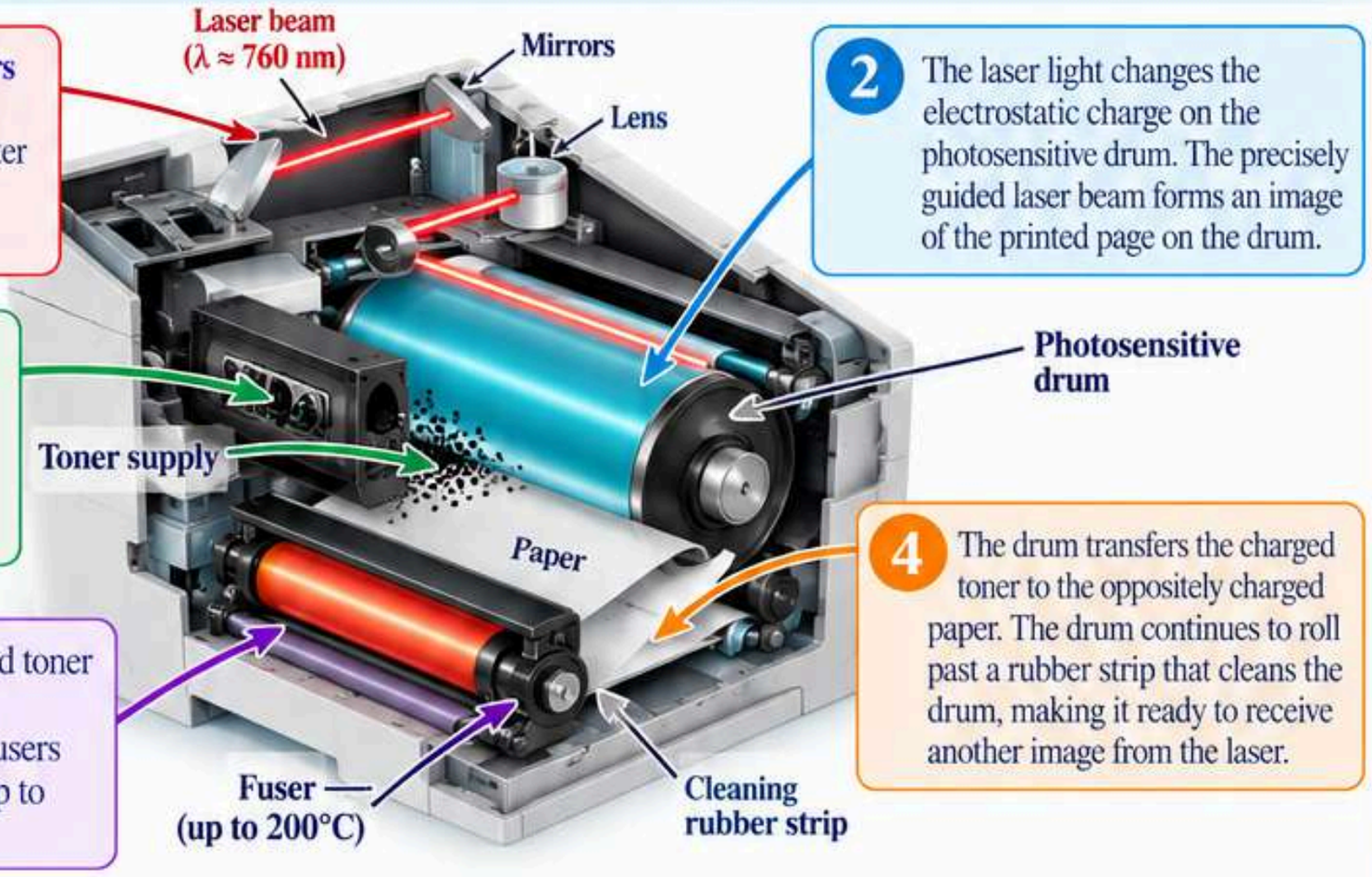
1 A series of **lenses and mirrors** directs the laser beam to scan over the drum. A typical printer laser has a wavelength of about **760 nm**.

2 The laser light changes the electrostatic charge on the photosensitive drum. The precisely guided laser beam forms an image of the printed page on the drum.

3 As the drum rolls past the toner supply, droplets of toner are attracted to the regions of the drum hit by the laser.

4 The drum transfers the charged toner to the oppositely charged paper. The drum continues to roll past a rubber strip that cleans the drum, making it ready to receive another image from the laser.

5 The fuser heats the paper and toner so the toner melts and sticks permanently to the paper. Fusers can reach temperatures of up to **200°C**.



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Check Your Progress — Questions & Answers

47 Bohr Model Limitations

Although it was able to accurately predict the behavior of hydrogen, in what ways did Bohr's atomic model have serious shortcomings?

Answer: Bohr's model could not correctly predict electron energies or explain the spectra of atoms with **more than one electron**, such as helium. It also did not fully explain why the laws of electromagnetism do not apply to electrons inside atoms.

48 Pumping Atoms

Explain whether green light could be used to pump a red laser. Why could red light not be used to pump a green laser?

Answer: Yes. Green light has a **shorter wavelength** and higher-energy photons than red light, so it can supply the energy needed to excite atoms for a red laser. Red photons have less energy than green photons, so they cannot provide the higher energy needed to pump a green laser.

49 Laser Light

What are four characteristics of laser light that make it useful?

Answer: Laser light is **coherent** (waves are in phase), **monochromatic** (one wavelength), highly directional (it **diverges very little**), and **intense** (high intensity).

50 Critical Thinking

Suppose an electron cloud were reduced to almost the size of the nucleus. Use the Heisenberg uncertainty principle to explain why this process would require adding a tremendous amount of energy.

Answer: Confining the electron to an extremely small region makes its position very uncertain only within a tiny range, so the **uncertainty in its momentum** must become very large. This gives the electron a very large kinetic energy; therefore, a tremendous amount of energy would be required.

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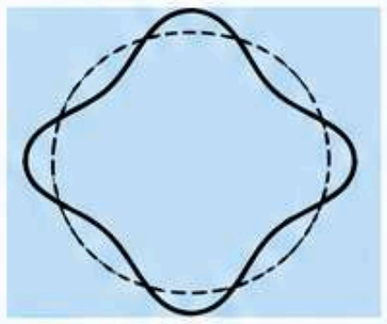
1 **Bohr's required quantized angular momentum condition is written as:**

يمكن حساب الزخم الزاوي من العلاقة

A $mvr = h/2\pi$ B $mvr = nh/2\pi$ C $mvr = \pi/nh$ D $mv = nh/2\pi r$

2 **The adjacent figure shows the waves associated with an electron in a certain orbit. The orbital number of this electron is:**

يوضح الشكل المجاور الموجات المرتبطة بإلكترون في مدار معين.
رقم المدار لهذا الإلكترون هو:



A 2 B 4 C 6 D 8

3 **Heisenberg's Uncertainty Principle states it is impossible to measure exactly both the:**

ينص مبدأ عدم اليقين لهايزنبرغ على أنه من المستحيل قياس كل من:

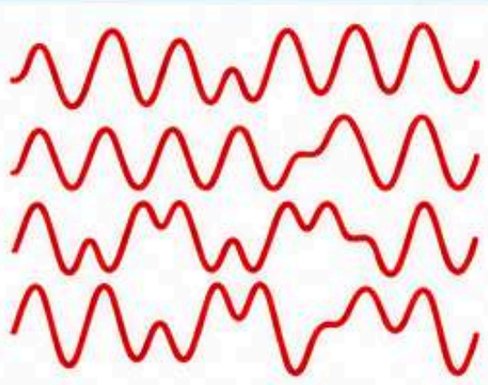
A **Charge and mass at the same time** — الشحنة والكتلة في آن واحد

B **Position and momentum of a particle at the same time** — موقع الجسم وزخمه في آن واحد

C **Energy and wavelength at the same time** — الطاقة والطول الموجي في آن واحد

D **Spin and charge at the same time** — الدوران المغزلي والشحنة في آن واحد

4 **Light emitted by an incandescent source, consisting of a continuum of uncoordinated wavelengths, is known as:**



يُعرف الضوء المنبعث من مصدر متوهج، والذي يتكون من طيف متصل من أطوال موجية غير متناسقة، باسم:

A **Polarized light** — الضوء المستقطب

B **Monochromatic light** — الضوء أحادي اللون

C **Incoherent light** — الضوء غير المترابط

D **Coherent light** — الضوء المترابط

5 **What occurs during spontaneous emission?**

ماذا يحدث أثناء الانبعاث التلقائي؟

A An atom absorbs a photon.

B An excited atom drops to the ground state, emitting a photon.

C Two photons collide.

D An electron is ejected from the atom.

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6 **Which is a required condition for a laser?** ما هو الشرط الأساسي لعمل الليزر؟

A Atoms must drop to the ground state instantly.

B There must be only one atom in the excited state.

C Atoms must remain in the excited state long enough to be struck by a photon.

D Photons must have varying wavelengths.

7 **The angular momentum of an electron in a hydrogen atom when it is in the second energy level is:**

الزخم الزاوي لإلكترون ذرة الهيدروجين عندما يتواجد في المستوى الثاني:

A $\frac{h}{\pi}$

B $\frac{h}{2\pi}$

C $\frac{2h}{\pi}$

D $\frac{4h}{\pi}$

8 **An electron in a hydrogen atom is in a stable energy level. The electron absorbs a photon with energy (20.4×10^{-19} J) and transitions to an excited energy level. The angular momentum of the electron in the excited energy level is:**

الإلكترون في ذرة الهيدروجين في مستوى استقرار. امتص إلكترون فوتونًا طاقته (20.4×10^{-19} J) وانتقل إلى مستوى طاقة مثارة. الزخم الزاوي للإلكترون في المستوى الذي انتقل إليه هو:

A $\frac{h}{2\pi}$

B $\frac{h}{\pi}$

C $\frac{3h}{2\pi}$

D $\frac{4h}{2\pi}$

9 **One of the following values for the angular momentum of an electron in a hydrogen atom does not allow it to remain in the atom's orbits**

إحدى القيم الآتية للزخم الزاوي لإلكترون ذرة الهيدروجين لا تسمح له بالبقاء في مدارات الذرة

A 2.11×10^{-34} J.s

B 1.06×10^{-34} J.s

C 3.50×10^{-34} J.s

D 4.24×10^{-34} J.s

10 **A DVD player uses a laser with a shorter wavelength than a CD player. What is the primary advantage of this?**

يستخدم مشغل أقراص DVD ليزرًا بطول موجي أقصر من مشغل أقراص CD. ما هي الميزة الأساسية لذلك؟

A It makes the DVD spin faster. يجعل قرص DVD يدور بسرعة أكبر.

B It prevents the DVD from overheating. يمنع ارتفاع درجة حرارة قرص DVD.

C The laser can be focused to a smaller spot, allowing more data storage. يمكن تركيز الليزر على بقعة أصغر، مما يسمح بتخزين بيانات أكبر.

D It allows the player to use less electricity. يسمح للمشغل باستهلاك طاقة أقل.

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11 What is 'LASER' refers to? — ماذا يقصد بكلمة «الليزر»؟

A	Linear Alignment of Stimulated Energy Rays	محاذاة خطية لأشعة الطاقة المحفزة
B	Light Amplification by Spontaneous Emission of Radiation	تضخيم الضوء عن طريق الانبعاث التلقائي للإشعاع
C	Light Amplification by Stimulated Emission of Radiation	تضخيم الضوء عن طريق الانبعاث المحفز للإشعاع
D	Light Absorption by Stimulated Emission of Radiation	امتصاص الضوء عن طريق الانبعاث المحفز للإشعاع

12 What property of laser light allows it to be used for measuring the distance to the Moon with high precision? — ما هي الخاصية التي تسمح باستخدام ضوء الليزر لقياس المسافة إلى القمر بدقة عالية؟

A	It travels faster than normal light.	سرعته الفائقة مقارنة بالضوء العادي.
B	Its high temperature.	درجة حرارته العالية.
C	Its bright color.	لونه الساطع.
D	Its ability to diverge very little.	قدرته على التشتت بشكل طفيف جدًا.

13 What is the physical significance of the quantum number in the de Broglie standing wave condition? — ما الدلالة الفيزيائية للعدد الكمي في شرط الموجة المستقرة لدي برولي؟

A	It represents the number of full wavelengths in the orbit's circumference.	يمثل عدد الأطوال الموجية الكاملة التي تتسع لها محيط المدار.
B	It represents the number of nodes in the electron's standing wave.	يمثل عدد العقد في الموجة المستقرة للإلكترون.
C	It represents the number of electrons in the orbit.	يمثل عدد الإلكترونات في المدار.
D	It represents the radius of the nucleus.	يمثل نصف قطر النواة.

14 An atom drops from an energy level of −7.64 eV to a lower level and emits a photon with a wavelength of 273 nm. What is the energy of the lower level? — تنتقل ذرة من مستوي طاقة مقداره (−7.64 eV) إلى مستوي طاقة أدني، فتصدر فوتونا طول موجته (273 nm). ما هي طاقة لمستوي الطاقة الأدنى؟

A	−3.36 eV	B	−4.54 eV	C	−11.0 eV	D	−12.2 eV

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15 **An electron in an atom transitions from the higher energy level E_2 to the lower energy level E_1, then the wavelength of the emitted photon is**

الإلكترون في ذرة ما ينتقل من مستوي الطاقة الأعلى E_2 إلى مستوي الطاقة الأقل E_1، فإن الطول الموجي للفوتون المنبعث يساوي

A $\frac{c}{h(E_2 - E_1)}$

B $\frac{hc}{(E_2 - E_1)}$

C $\frac{(E_2 - E_1)}{hc}$

D $\frac{hc}{E_2} - \frac{hc}{E_1}$

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