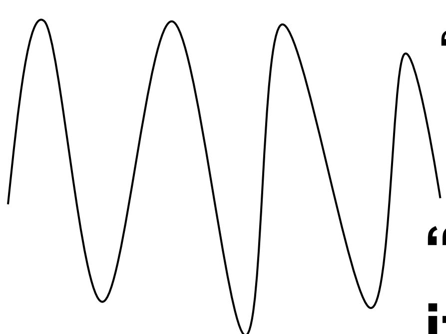
move groups to new locations

<u>Learning goals</u>-- relate position, velocity, energy to shapes of wave functions.
Include potential energy.

Be able characterize when quantum effects become important in very small structures.

Important note about something BAD book does (and sometimes so do I)

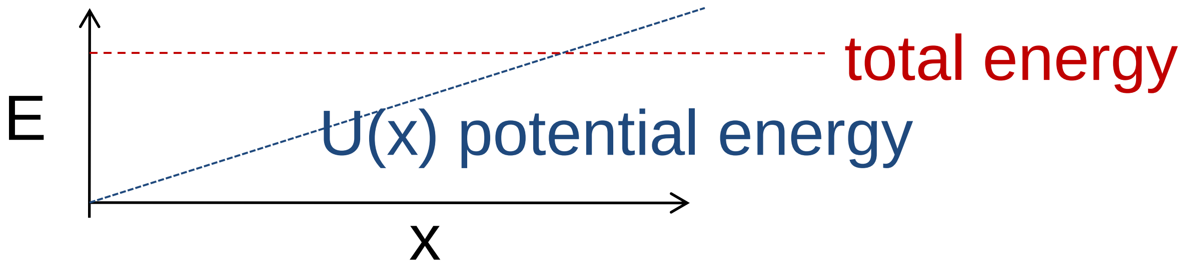


~~"picture of wave function $\psi(x)$"~~

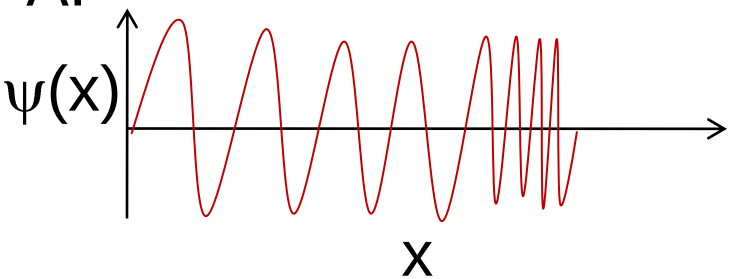
"picture of <u>real part</u> of wave function $\psi(x)$, it has an imaginary part, but it is not drawn"

Reading quiz.

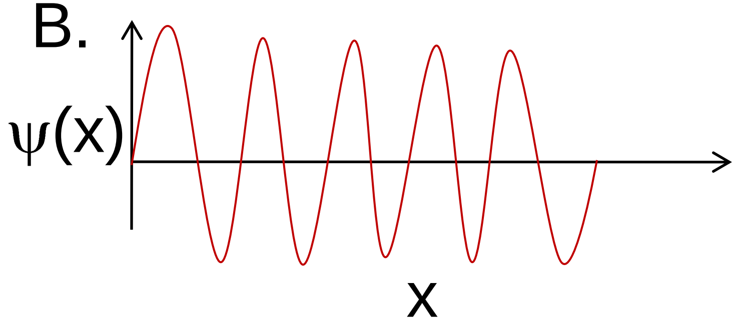
1. Which is best picture of real part of wave function in potential as shown with total energy as given?



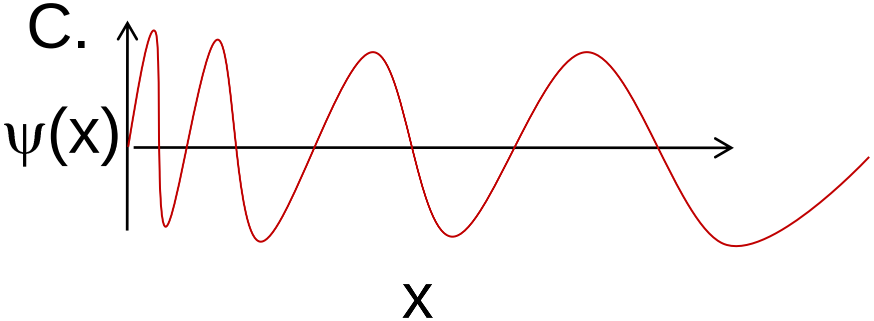
A.



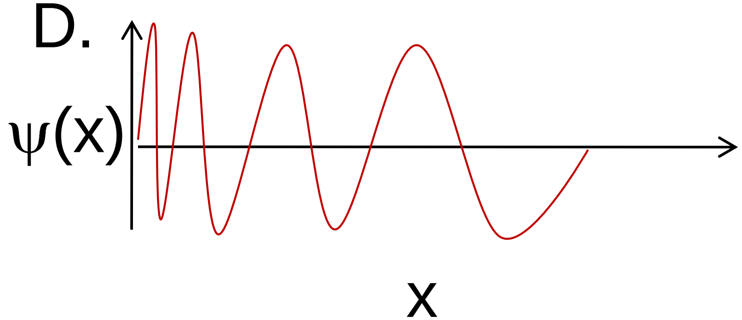
B.



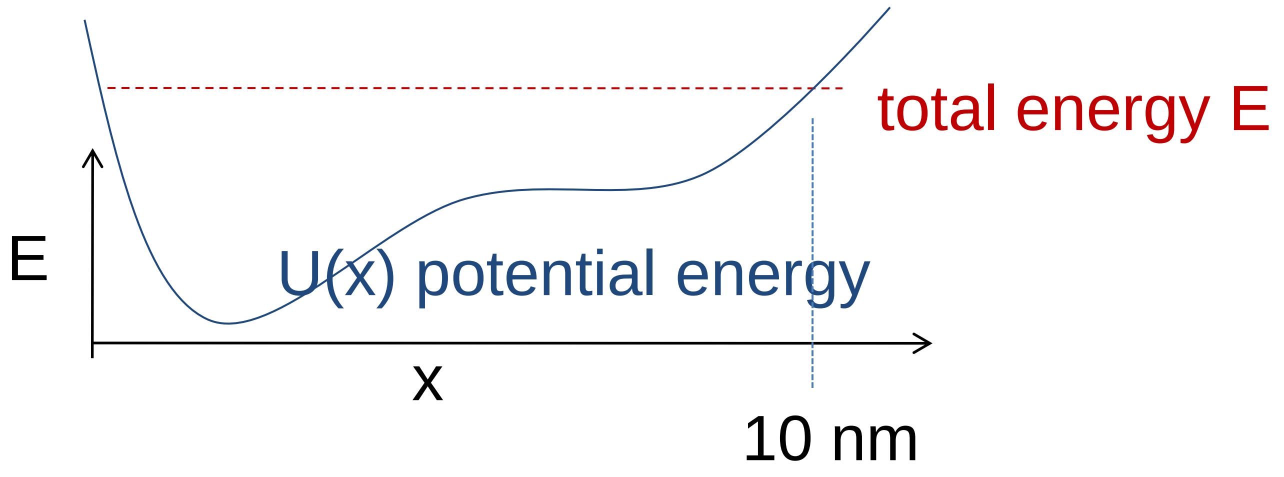
C.



D.



RQ 2.



The kinetic energy of an electron at x greater than 10 nm is

a. KE> 0, b. KE= 0, c. KE<0,

d. the question does not make sense

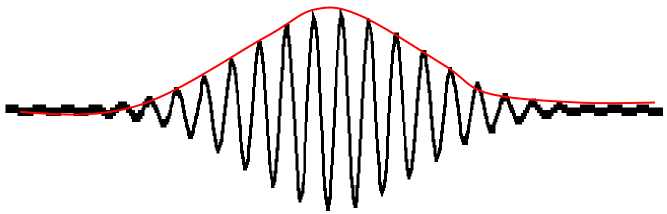
Home work problem difficulty.

A ruby laser emits a 100MW, 10ns long pulse of light with a wavelength of 690 nm.
How many atoms undergo stimulated emission to generate this pulse? (give answer to two sig digit, such as 1.1E1)

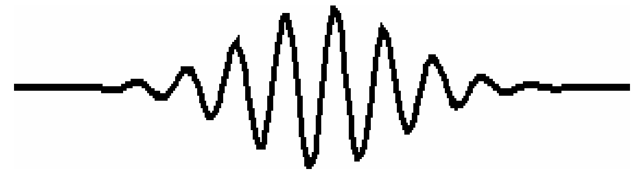
solution-- figure out how many photons in light pulse.
The how many atoms have stimulated emission for each photon

photons = energy in pulse (1J)/(energy/photon(=hc/λ)
= 1 J/(2.9 x 10^{-19} J) = 3.5 x 10^{18} photons

1 photon in, one atom stimulated emission, 2 photons out.
so gain one photon each stimulated emission. Energy conserved
so need 3.5 x 10^{18} atoms undergo stimulated emission



A



B

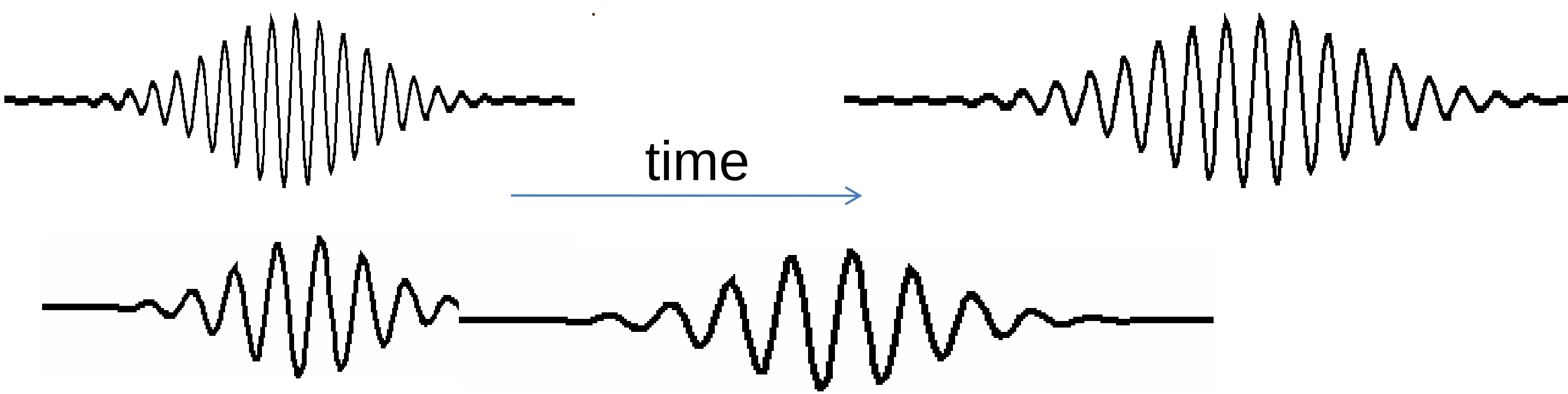
two wave packets for electron-- same envelope-- demo

Which wave packet <u>spreads out</u> most rapidly?

a. A spreads faster. b. both spread at the same rate.

c. B spreads faster.

ans. b. A is moving faster, but wave packet spreads according to <u>spread</u> in p. Both packets have same Δx, and so same Δp, and so same Δv.



$\psi 1$

$\psi 2$

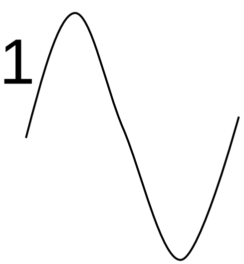
Have 100 copies each of two wave functions $\psi 1$ and $\psi 2$. Measure electron position for each one, get patterns above.
Which wave function has the most kinetic energy?

a. 1 has more,   b. both have same,   c. 2 has more

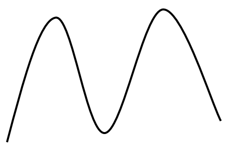
d. cannot tell

answer without discussing

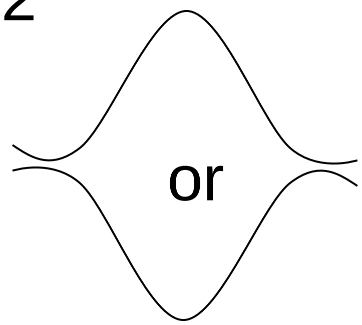
What look like? $\psi 1$



or

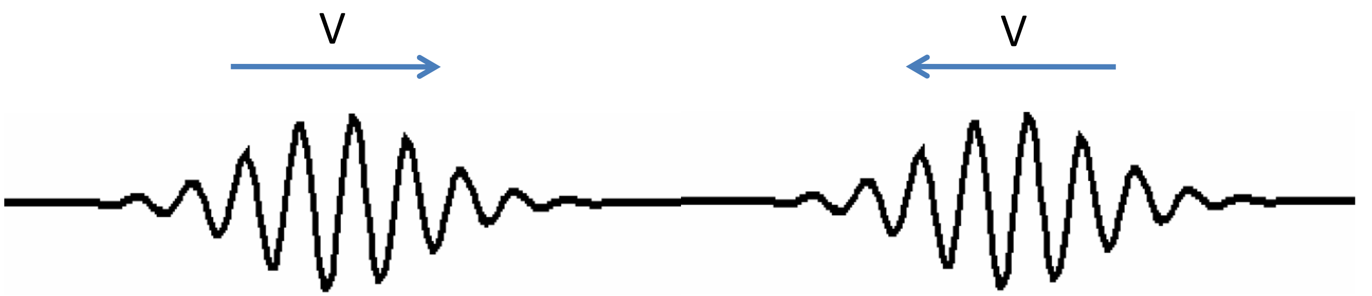


$\psi 2$



1 has more curvature to wave function, shorter characteristic wavelength, so more momentum, and more KE.

more on superposition

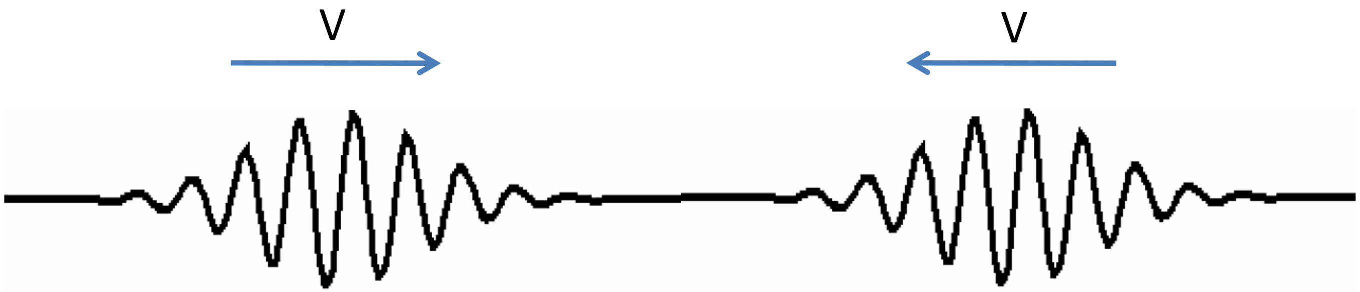


Is this a possible quantum state for a **single** electron?

A Yes

B No

ans. yes



1000 electrons are prepared in the same quantum state (above). What is the best interpretation for this quantum state?

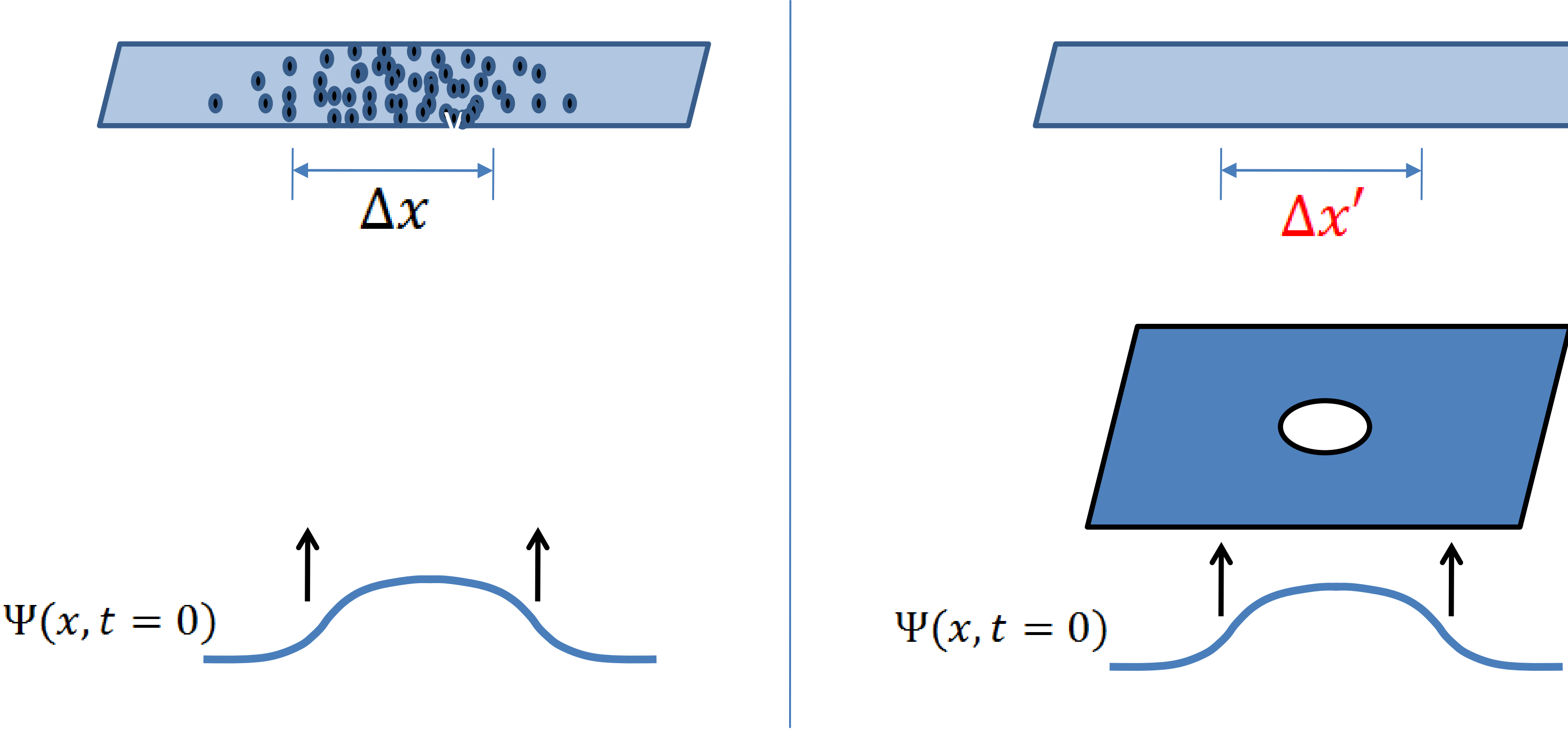
A The velocity of each electron is zero

B Half of the electrons are traveling to the left while the other half are traveling to the right.

C Each electron spends half of their time traveling to the right and half of their time traveling to the left

D Each electron is traveling right and left at the same time

ans. D.



On the **left**, we send 100 electrons upward toward the screen and detect their positions. The electrons are sent one at a time and are all in the same initial quantum state $\Psi(x, t = 0)$. On the **right**, the electrons pass thru a small hole on their way to the screen.
Do you expect $\Delta x'$ to be the same as Δx ?

A Yes

B No

ans. B no
screen changed
wave function

Be able characterize when quantum effects become important in very small structures.

When electrons behave noticeably differently than they would if could move like classical particles. Have any energy they wanted, etc.

How to think of an electron in a metal? How to model for using Schrodinger equation to find wave functions and behavior?

$$-\frac{\hbar^2}{2m}\frac{\partial^2\Psi(x,t)}{\partial x^2}+V(x,t)\Psi(x,t)=i\hbar\frac{\partial\Psi(x,t)}{\partial t}$$

How to think of an electron in a metal? How to model metal for using Schrodinger equation to find wave functions and behavior?

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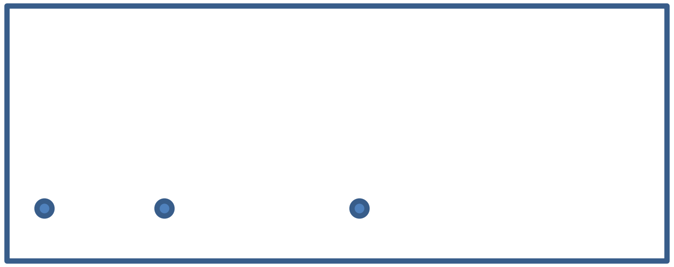
How did we model electron in metal when thinking about photoelectron effect?

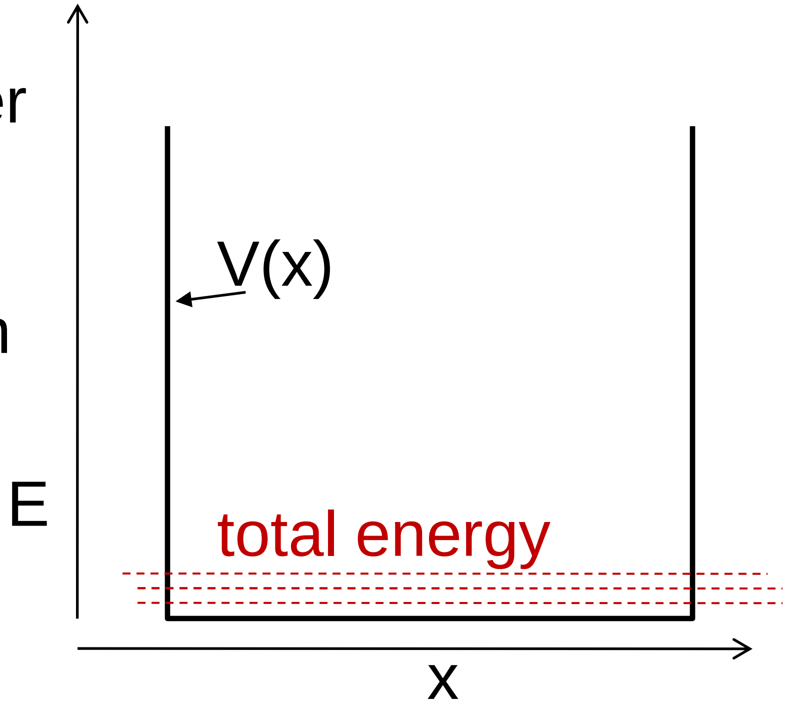
Electrons down in a pit, bottom electrons stuck to atoms but top ones able to move freely around in bottom of the pit. What would that say V(x,t) is?

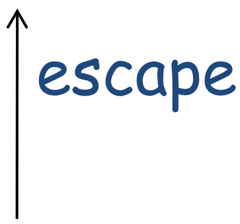


Electrons in metal down in a pit, deep electrons stuck to atoms, but top ones able to move freely around in bottom of the pit. What would that say V(x,t) is?

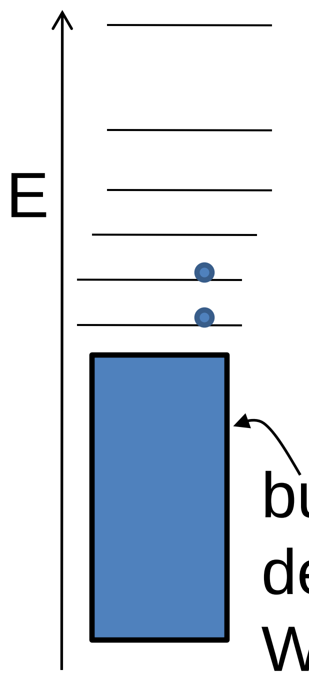
$$-\frac{\hbar^2}{2m}\frac{\partial^2\Psi(x,t)}{\partial x^2}+V(x,t)\Psi(x,t)=i\hbar\frac{\partial\Psi(x,t)}{\partial t}$$

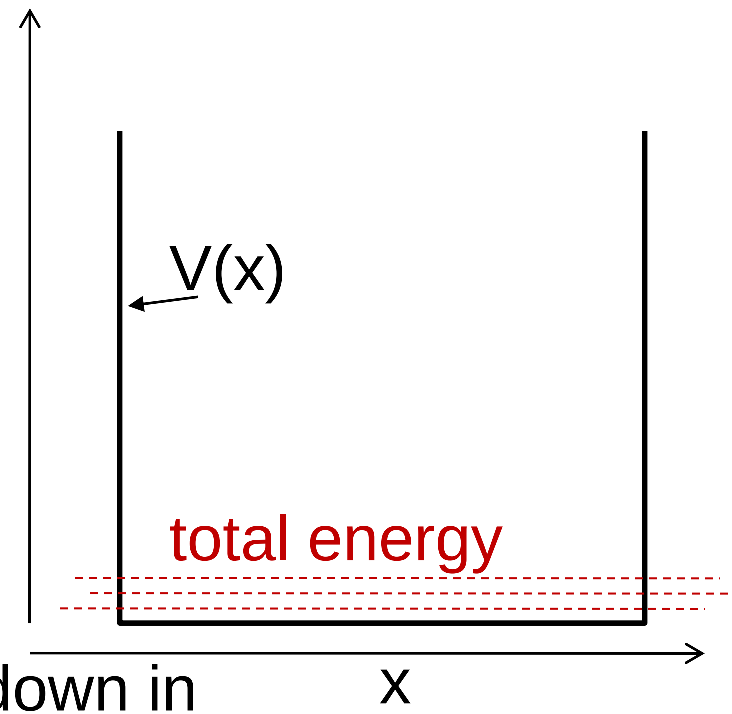
V(x) has no time dependence, and is constant Vin inside metal. Much higher V(outside) when outside metal.
Does that make sense with Ohms law, classical potential energy of electron in metal wire?



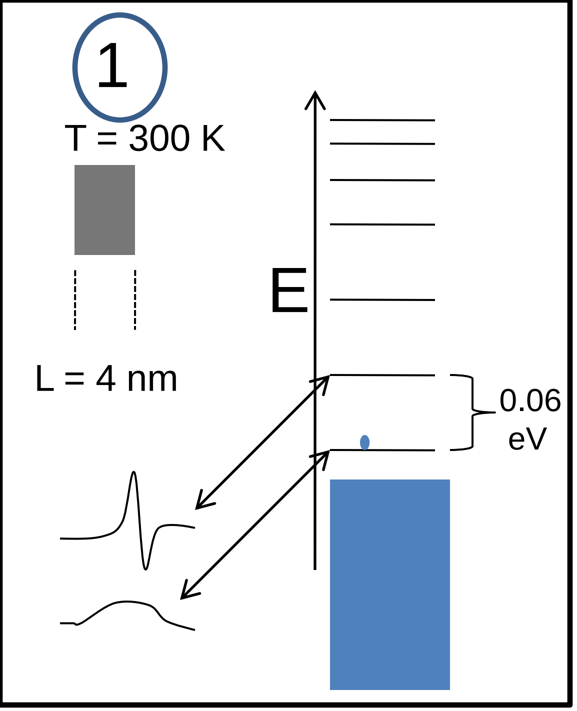


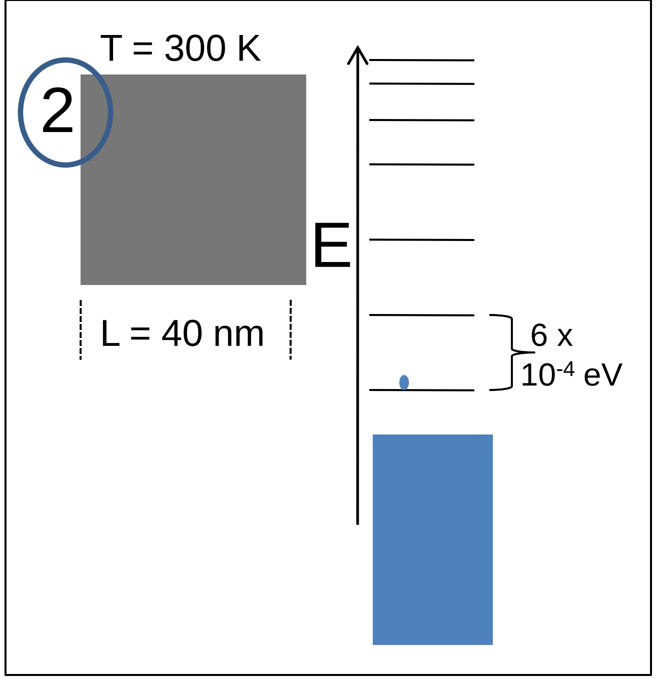
If V confines electron and no time dependence, get discrete energy levels, similar to atoms.

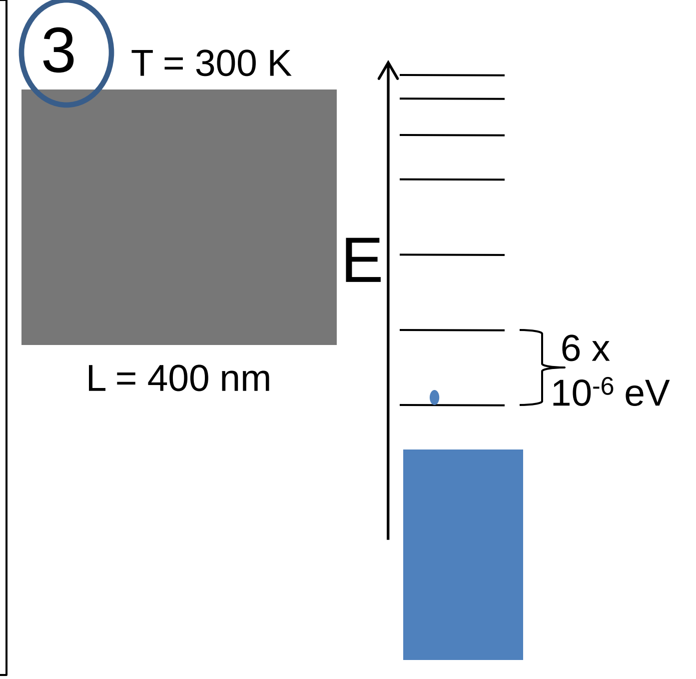


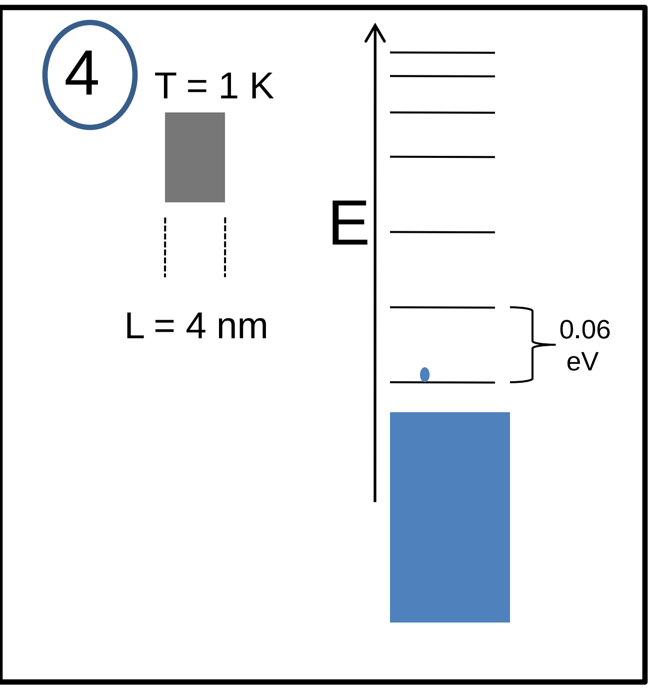


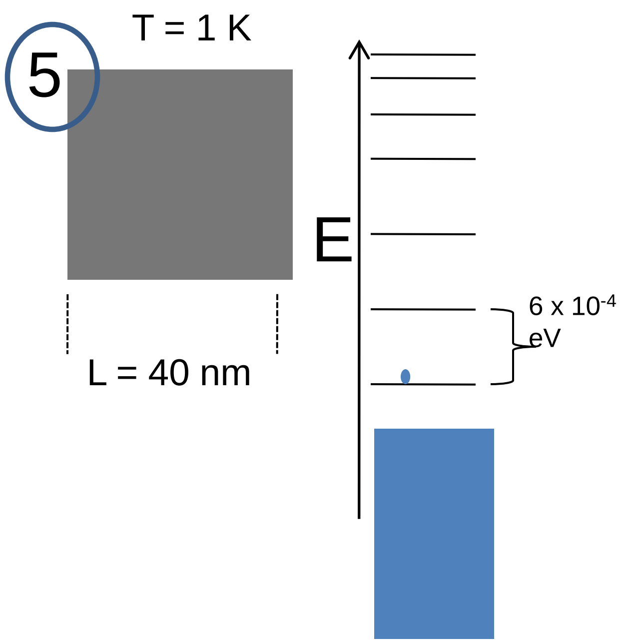
bunch of electrons stuck down in deep energy levels, never move or do anything. We just ignore.











You have to invent a "quantumticity" parameter. The value of this parameter will characterize if motion of electrons in small blocks of metal is going to be similar to motion in large block, or will be changed by quantum behavior. Parameter should work for all these cases, and any new case.
No single right answer. Will have groups share their parameters when done.