$\boxed{E46-29}$

MAX

$\boxed{31/25}$

$$E_k = 3.0 \cdot 10^6 eV = 3.0 \cdot 1,602 \cdot 10^{-13} J$$

$$V_0 = 10 \cdot 10^6 eV = 10^7 eV = 1,602 \cdot 10^{-12} J$$

$$m_p = 1,67 \cdot 10^{-27} kg$$

$$m_d = 3,35 \cdot 10^{-27} kg$$

$$L = 1 \cdot 10^{-14} m$$

$$\hbar = \frac{6.626 \cdot 10^{-34}}{2\pi} Js$$

$$T = 16 \cdot \frac{E_k}{V_0}\left(1 - \frac{E_k}{V_0}\right) \cdot e^{-2\varkappa L}, \quad \varkappa = \frac{\sqrt{2m(U_0 - E)}}{\hbar}$$

a) $$T_p = 16 \cdot \frac{3,0 \cdot 1,602 \cdot 10^{-13} J}{1,602 \cdot 10^{-12} J}\left(1 - \frac{3,0 \cdot 1,602 \cdot 10^{-13} J}{1,602 \cdot 10^{-12} J}\right) \cdot$$

$$e^{-2 \cdot 10^{-14} m \cdot \frac{2\pi\sqrt{2 \cdot 1,67 \cdot 10^{-27} kg \left(1,602 \cdot 10^{-12} J - 3,0 \cdot 1,602 \cdot 10^{-13} J\right)}}{6,626 \cdot 10^{-34} Js}}$$ (1)

$$= \left[\underbrace{\frac{J}{J}\left(1 - \frac{J}{J}\right)}_{=1} \cdot e^{m \cdot \frac{\sqrt{\frac{kg^2 m^2}{s^2} - \frac{kg^2 m^2}{s^2}}}{Js}} = 1 \cdot e^{\frac{kg m^2}{s} / \frac{kg m^2}{s}} = 1 \cdot e^1\right]$$

you can also separately calculate the units, which is maybe shorter

$$= \boxed{3,0 \cdot 10^{-5}}$$ (1)

Are all those numbers really neccessary to write?

(1)

b)

$$T_d = 16\,\frac{3{,}0\cdot 1{,}602\cdot 10^{-13}\,J}{1{,}602\cdot 10^{-12}\,J}\left(1-\frac{3{,}0\cdot 1{,}602\cdot 10^{-13}\,J}{1{,}602\cdot 10^{-12}\,J}\right)\cdot$$

$$e^{-2\cdot 10^{-14}m\cdot 2\pi\frac{\sqrt{2\cdot 3{,}35\cdot 10^{-27}kg\left(1{,}602\cdot 10^{-12}-3{,}0\cdot 1{,}602\cdot 10^{-13}\,J\right)}}{6{,}626\cdot 10^{-34}\,J}}$$ (1)

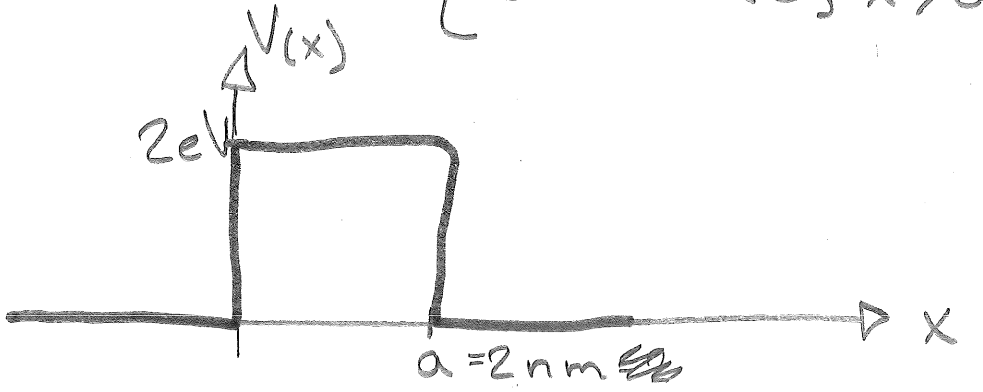
$$= \boxed{2{,}5\cdot 10^{-7}}$$ (1)

4/4

OHLEN!

$\boxed{3-5}$

$$V(x) = \begin{cases} V_0 & 0<x<a \\ 0 & x<0,\ x>a \end{cases}$$



$\boxed{E < V_0}$

$V_0 = 2eV = 2\cdot 1{,}602\cdot 10^{-19}\,J$

$a = 2nm = 2\cdot 10^{-9}\,m$

$\hbar = \frac{6{,}602\cdot 10^{-34}}{2\pi}\,Js$

$m_e = 9{,}11\cdot 10^{-31}\,kg$

$T = 0{,}01$

2

$$\boxed{T(E) = e^{-2\varkappa \cdot a}}$$

$$\varkappa = \frac{\sqrt{2m(V_0 - E)}}{\hbar}$$

$$\boxed{T(E) = e^{-2 \cdot 2 \cdot 10^{-9}\,\text{m} \cdot 2\pi \cdot \frac{\sqrt{2 \cdot 1{,}602 \cdot 10^{-19} - E}}{6{,}602 \cdot 10^{-34}\,\text{Js}}}}$$

Approximativt uttryck för T(E).

$$\ln T = -2a \cdot \frac{\sqrt{2m(V_0 - E)}}{h} \cdot 2\pi$$

4/4

$$\Leftrightarrow \quad \frac{\ln T\left(\frac{1}{T}\right) \cdot h}{4a \cdot \pi} = \sqrt{2m(V_0 - E)}$$

$$\Leftrightarrow \quad -\left(\frac{\ln\left(\frac{1}{T}\right) \cdot h}{4a\pi}\right)^2 \cdot \frac{1}{2m} + V_0 = E$$

1

\# är 1,9eV kanske en bättre avrundning. Då vi inte kan använda 2 värdesiffror blir mitt svar något lägre än 2eV

T = 0,01 ger:

$$E = 2 \cdot 1{,}602 \cdot 10^{-19}\,\text{J} - \frac{1}{2 \cdot 9{,}11 \cdot 10^{-31}\,\text{kg}}\left(\frac{6{,}602 \cdot 10^{-34}\,\text{Js} \cdot \ln\left(\frac{1}{0{,}01}\right)}{4\pi \cdot 2 \cdot 10^{-9}\,\text{m}}\right)^2$$

1   1

$$= \left[\text{J} - \frac{1}{\text{kg}}\left(\frac{\text{kgm}^2 \cdot \text{s}}{\text{s}^2 \cdot \text{m}}\right)^2 = \text{J}\right] = 3{,}1234 \cdot 10^{-19}\,\text{J} \approx \boxed{1{,}949\,\text{eV}}$$

Med en värdesiffra blir svaret 2eV = V_0, därför#

su

3

OHLEN

4-1

a) $E_0 = 0{,}1 eV = 0{,}1 \cdot 1{,}602 \cdot 10^{-19} J$

$h = 6.602 \cdot 10^{-34} Js$

$m_e = 9.11 \cdot 10^{-31} kg$

$a = ?$

$$E_n = \frac{h^2 \cdot n^2}{8 m a^2} \Leftrightarrow a = \frac{h \cdot n}{\sqrt{8 E_n m_e}}$$ (1)

a) $n = 1$

$$a = \frac{h}{\sqrt{8 \cdot E_1 \cdot m_e}} = \frac{6{,}602 \cdot 10^{-34} Js}{\sqrt{8 \cdot 1{,}602 \cdot 10^{-20} J \cdot 9{,}11 \cdot 10^{-31} kg}} = \left[\frac{Js}{\sqrt{\frac{kg^2 m^2}{s}}} = \frac{kgm^2}{kg\,m} = m \right]$$ (1)

$= 1{,}939 \cdot 10^{-9} m \approx \boxed{2 \cdot 10^{-9} m}$ (1)

b) $$\Delta E = E_2 - E_1 = \frac{h^2 \cdot 2^2}{8 m_e \cdot a^2} - \frac{h^2}{8 m_e \cdot a^2} = \frac{3 h^2}{8 m_e \cdot a^2} =$$ (1)

$$= \frac{3 (6.602 \cdot 10^{-34} Js)^2}{8 \cdot 9{,}11 \cdot 10^{-31} kg \cdot (1{,}939 \cdot 10^{-9} m)^2} = \left[\frac{\left(\frac{kg m^2}{s}\right)^2}{kg \cdot m^2} = \frac{kg m^2}{s^2} = J \right] =$$

$= 4{,}807 \cdot 10^{-20} J \approx \boxed{5 \cdot 10^{-20} J}$ (1)

5/5

4

M47-2

$$E_n = \frac{h^2 \cdot n^2}{8mL^2} \Leftrightarrow L = \sqrt{\frac{h^2 \cdot n^2}{8m \cdot E_n}}, n \in \mathbb{N}$$

Eftersom $n^2 > 0$ är kommer

L vara större eller lika med

2

$$\sqrt{\frac{h^2}{8mE_n}} \Leftarrow (n=1)$$

$\boxed{\text{Svar: A}}$ 1

3/3

M47-3

$E_1 = E_2$

$n_1 = 1$, $n_2 = 2$, $m_1 = m_2$

$$\frac{h^2 \cdot 1^2}{8m_1L_1^2} = E_1 = E_2 = \frac{h^2 \cdot 2^2}{8m_2L_2^2}$$

sentence?

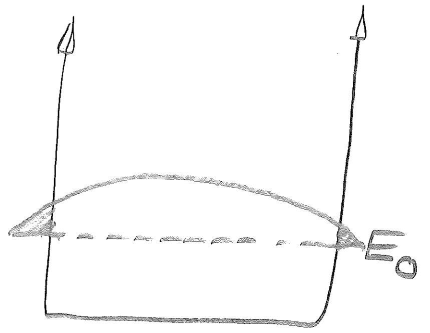
$$\Leftrightarrow \frac{1}{L_1^2} = \frac{4}{L_2^2} \Leftrightarrow \frac{L_2^2}{L_1^2} = 4 \Leftrightarrow \boxed{\frac{L_2}{L_1} = 2}$$

1/2

$\boxed{\text{Svar: C}}$ 1

$\boxed{M47-4}$

a)



Den minsta kinetiska energin motsvarar, pga tunnling, en längre våglängd än som krävs vid E_0. Energin måste vara större än noll för att vi ska kunna uppfatta elektronen som en våg... (1)

Svar: B (1)

2/2

$\boxed{E47-3}$ $h = 6{,}626 \cdot 10^{-34}\,Js$, $m_e = 9{,}11 \cdot 10^{-31}\,kg$

$L = 253\,pm = 253 \cdot 10^{-12}\,m$

$n = 1$

$$\Delta E = E_4 - E_1 = \frac{h^2 \cdot 4^2}{8 m_e L^2} - \frac{h^2 \cdot 1^2}{8 m_e L^2} = \frac{h^2}{m_e L^2}\left(2 - \frac{1}{8}\right) =$$ (1)

$$= \frac{h^2}{m_e L^2} \cdot \frac{15}{8} = \frac{(6{,}626 \cdot 10^{-34}\,Js)^2}{9{,}11 \cdot 10^{-31}\,kg\,(253 \cdot 10^{-12}\,m)^2} = \left[\frac{kg^2 m^4}{s^2} \cdot \frac{1}{kg\,m^2} = J\right] =$$ (1)

$$= \boxed{1{,}41 \cdot 10^{-17}\,J}$$ (1)

3/3

(6)

E47-4

$E_1 = 2{,}6\,eV$

$L' = 2 \cdot L$

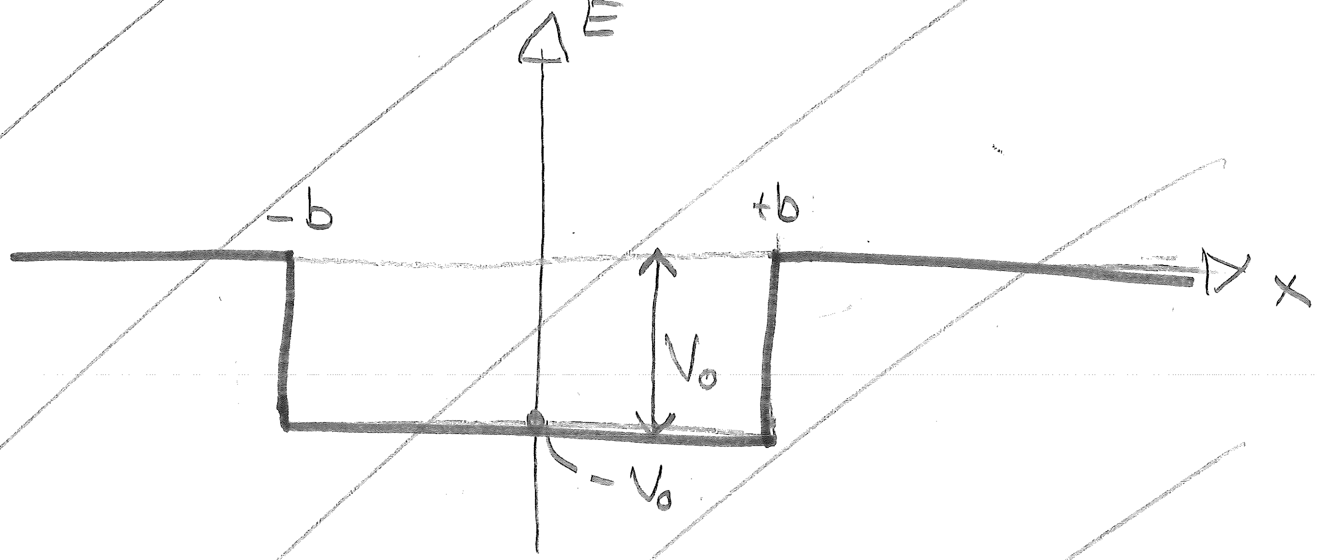
$$E_1' = \frac{h^2}{8m \cdot L'^2} = \frac{h^2}{8m(2L)^2} = \frac{h^2}{8m \cdot L_1^2} \cdot \left(\frac{1}{4}\right) = \boxed{\frac{1}{4} \cdot E_1}$$ ①

$$= \frac{1}{4} \cdot 2{,}6\,eV = \boxed{0{,}65\,eV}$$ ①

2/2

~~OHLEN~~

~~4-4~~ ~~Härled: $\tan\left(\sqrt{\frac{2mb^2(E+V_0)}{\hbar}}\right) = -\sqrt{(E+V_0)(-E)}$~~



~~$V(x) = \begin{cases} 0 & x \leq -b \\ -V_0 & -b < x < b \\ 0 & b < x \end{cases}$~~

Utanför brunnen $(x<-b, x>b)$
gäller följande enligt
tidsoberoende Schrödingerekvationen:

$$-\frac{\hbar^2}{2m}\cdot\phi'' + \phi\cdot \overset{(=0)}{V(x)} = E\cdot\phi$$

$$\Leftrightarrow -\frac{\hbar^2}{2m}\cdot\phi'' + E\phi = 0$$

- kan skrivas:

$$\phi''(x) + k^2\phi(x) = 0\,, \quad k = \sqrt{\frac{2mE}{\hbar^2}} = i\sqrt{\frac{2m(-E)}{\hbar^2}}$$

$\boxed{\text{FEL UPPGIFT}}$

Ohlén

$W = F\cancel{\Delta}s$, $s = \Delta a = \frac{1}{2}a$

$\boxed{4-3}$

$a' = \frac{1}{2}a$ (1)

$$E_1 = 1 \frac{h^2}{8m \cdot a^2}$$

$$E_1' = \frac{h^2}{8m(\frac{1}{2}a)^2} = \frac{h^2}{8m \cdot a^2} \cdot 4 = E_1 \cdot 4$$

$$\Delta E = E_1' - E_1 = E_1 \cdot 4 - E_1 = 3E_1 \quad (1)$$

$$\Delta E \overset{(1)}{=} F \cdot s = F \cdot \frac{1}{2}a$$

$$\Leftrightarrow F = \frac{2\Delta E}{a} = \frac{2 \cdot 3 \cdot E_1}{a} = \frac{6E_1}{a} = \frac{6 \cdot h^2}{8ma^3} = \boxed{\frac{3 \cdot h^2}{4ma^3}} \quad (1)$$

4/4

$\boxed{46-30}$

$E_k = 5{,}0\,eV = 5{,}0 \cdot 1{,}602 \cdot 10^{-19}\,J$

$V_0 = 6{,}0\,eV = 6{,}0 \cdot 1{,}602 \cdot 10^{-19}\,J$

$L = 0{,}70\,nm = 7{,}0 \cdot 10^{-10}\,m$

$I = 1{,}0 \cdot 10^{3}\,A$

$\hbar = \dfrac{6{,}626 \cdot 10^{-34}}{2\pi}\,Js$

$m_p = 1{,}673 \cdot 10^{-27}\,kg$

$q = 1{,}602 \cdot 10^{-19}\,C$ (laddning hos en proton)

$$T = 16 \frac{E_k}{V_0}\left(1 - \frac{E}{V_0}\right) \cdot e^{-2L \cdot \kappa} \quad , \kappa = \frac{\sqrt{2m_p(V_0 - E)}}{\hbar}$$

$N_{trans} = N_{in} \cdot T$

antal protoner per sekund

$$N_{in} = \frac{I}{q} = \frac{1{,}0 \cdot 10^{3}\,C/s}{1{,}602 \cdot 10^{-19}\,C} = \frac{1}{1{,}602} \cdot 10^{22}\,s^{-1}$$

$$T = 16 \frac{5{,}0 \cdot 1{,}602 \cdot 10^{-19}\,J}{6{,}0 \cdot 1{,}602 \cdot 10^{-19}\,J}\left(1 - \frac{5{,}0 \cdot 1{,}602 \cdot 10^{-19}\,J}{6{,}0 \cdot 1{,}602 \cdot 10^{-19}\,J}\right) \cdot e^{-2 \cdot 7{,}0 \cdot 10^{-10}\,m \cdot \sqrt{}}$$

$$\sqrt{\frac{2 \cdot 1{,}673 \cdot 10^{-27}\,kg\,(6{,}0 \cdot 1{,}602 \cdot 10^{-19}\,J - 5{,}0 \cdot 1{,}602 \cdot 10^{-19}\,J)}{6{,}626 \cdot 10^{-34}/2\pi\ Js}} =$$

$$= \left[\frac{J}{J}\left(1-\frac{J}{J}\right)\cdot e^{\left(\frac{\sqrt{\frac{kg^2m^2}{s^2}-\frac{kg^2m^2}{s^2}}}{Js}\right)} = 1\cdot e^1 \right] = 7{,}3\cdot 10^{-134}$$

(1)

$$N_{transm.} = T\cdot N_{in} = 7{,}3\cdot 10^{-134}\cdot \frac{1}{1{,}602}\cdot 10^{22}\,s^{-1} =$$

$= \quad s^{-1}$ ⟵ medel-antal transmitterade protoner per sekund

Medel-tiden för en proton att transmitteras:

$$\frac{1}{N_{transm.}} = \frac{1}{6{.}0\cdot 10^{-112}\,s^{-1}} = 6{.}0\cdot 10^{112}\,s = \frac{6{.}0\cdot 10^{112}\,s}{3{.}156\cdot 10^{7}\,s/år} =$$

$= \boxed{1{,}38\cdot 10^{104}\,år \approx 14000 \text{ googoler år}}$ (1)

≈ 1000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000 år

3/3