Draw for yourself the Bogoliubov dispersion relation within a homogeneous BEC of density ρ from the lecture and the behavior of the mode amplitudes u and v . How do we interpet the fact that $u \to 1$ and $v \to 0$ as $q \to \infty$?

The amplitudes u is for phonons and v for single particle excitations, thus this reflects the fact that at large wavenumbers q the BdG excitations are said to become single-particle like.

Since the number of atoms per excitation is $u^2 + v^2$, this reflects the fact that at large wavenumbers q the BdG excitations become collective excitations involving many particles.

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Correct Answer

Score: 1

Correct Answer: Since the number of atoms per excitation is $u^2 + v^2$, this reflects the fact that at large wavenumbers q the BdG excitations are said to become single-particle like.

Why does a superfluid not experience friction when moving past a barrier at a velocity smaller than the speed of sound?

- Because the condensed superfluid is so cold that excitations can never be excited, it cannot dissipate energy.
- Because there are no interactions between barrier and fluid that can create even lowest energy excitations, hence the fluid cannot dissipate energy.
- Because in any fluid moving past a barrier at less than its sound velocity there can be no creation of sound-waves, hence none of them can dissipate energy.
- Because it is energetically impossible to create even lowest energy excitations, hence the fluid cannot dissipate energy.

Correct Answer

Score: 1

Correct Answer: Because it is energetically impossible to create even lowest energy excitations, hence the fluid cannot dissipate energy.

Consider a BEC of atoms with mass $m = 3 \times 10^{-25}$ kg in an isotropic 3D trap with frequency $\omega = (2\pi)\ 10$ Hz. You measure a radially symmetric Gaussian thermal cloud with a shape $e^{-\frac{r^2}{2w^2}}$, where $w = 100\ \mu$m and r is the radius from the trap centre.

You can infer that the temperature of the BEC is 6.83 nK.

Be careful with UNITS! You may round to two SIGNIFICANT digits.

Correct Answer

Score: 1

Correct Answer: Answers in order of appearance of blanks:
from 5.46107 to 8.19161

Draw for yourself the Bogoliubov dispersion relation within a homogeneous BEC of density ρ from the lecture. At large q this becomes a parabola like the free particle dispersion, however the parabola is slightly shifted upwards. Find how much it is shifted upwards with the following steps:

(i) Substitute $q = \frac{1}{L}$ into the Bogoliubov dispersion relation.

(ii) Taylor expand the result to first order in L around 0 (This is like expanding q around "large q").

(i) Re-express the result in terms of q . You should find $\epsilon_q = \frac{\hbar^2 q^2}{2m} + \epsilon_{\text{shift}}$, where....

- $\epsilon_{\text{shift}} = \frac{\rho U_0}{2}$,
- $\epsilon_{\text{shift}} = \frac{\hbar^2 \rho^2}{2m} + \rho U_0$,
- $\epsilon_{\text{shift}} = \rho U_0$,
- $\epsilon_{\text{shift}} = 2\rho U_0$,

Correct Answer

✖

Score: 1

Correct Answer: $\epsilon_{\text{shift}} = \rho U_0$, Consider a BEC of atoms with mass $m = 1 \times 10^{-25}$ kg and s-wave scattering length $a_s = 4$ nm. The BEC has a density of $\rho = 5.000 \times 10^{19}\ m^{-3}$.

The BEC speed of sound is 1.67 mm/s.

Be careful with UNITS! You may round to two SIGNIFICANT digits.

Correct Answer

Score: 1

Correct Answer: Answers in order of appearance of blanks:
from 1.50466 to 1.83903

In the lecture we had discussed the Bogoliubov dispersion relation, Eq. (3.70), in the limits $q \to 0$ and $q \to \infty$. Use the expression to infer a value q_t for the transition between the two regimes found in the above limits.

The corresponding wave-length $2\pi/q_t$ is proportional to....

- the harmonic oscillator ground state width
- the thermal de-Broglie wavelength
- the system size
- the healing length

Correct Answer

Score: 1

Correct Answer: the healing length