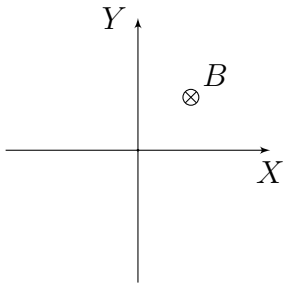
# T5. Cyclotron resonant scattering features

The X-ray spectrum of neutron stars contains absorption lines that allow direct measurement of the magnetic field strength near the surface of neutron stars: cyclotron resonant scattering features.

Their nature is related to the fact that a charged particle (e.g., an electron) performs periodic motion in a magnetic field and, under certain conditions, interacts strongly with the incident EM wave.




Let's discuss an electron with charge $-e$ and mass $m$ moving in the plane $XY$ perpendicular to the uniform magnetic field $B$.

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| **A1** | Obtain the equations of motioin for the electron in the form $$\begin{cases} \ddot{X} = \dots \\ \ddot{Y} = \dots \end{cases}$$ |

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| **A2** | Integrate the second equation with respect to time, and using substitution, obtain the equation of harmonic oscillations $$\ddot{X} + \omega_0^2 X = C.$$ Express $\omega_0$ in terms of $m$, $e$ and $B$. |

Let's imagine that an EM wave with complex amplitude $E$ and frequency $\omega$ falls normally to the $XY$ plane on an electron moving in this way. Wave polarization is linear along the $X$ axis.

Then the motion of the electron can be considered within the framework of perturbation theory. Let $X(t)$ and $Y(t)$ be the solutions to the initial problem (without the EM wave), and $X(t) + x(t)$ and $Y(t) + y(t)$ be the solutions to the complete problem.

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| **A3** | Similarly to question **A1**, obtain the equation of motion for $x(t)$ and $y(t)$. |

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| **A4** | Similarly to question **A2**, eliminate $y$ and obtain the equation of forced oscillations for $x(t)$. |

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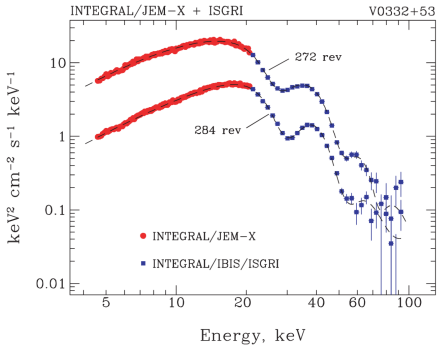
| **A5** | What is the frequency of EM wave $\omega$ when the resonance takes place? |

In the X-ray spectra of objects with strong magnetic fields, the resonance under consideration is observed as an absorption line in a smooth dependence $\Phi(E)$, where $\Phi$ is the flux density of photons with energy $E$ arriving from the object under study.




$\Phi(E)$ fot the V0332+53 pulsar. S. Tsygankov et al. 2006.

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| **A6** | From the quantum point of view explain the presence of several cyclotron resonant scattering features. Obtain the value of the mean magnetic field $B$ on the surface of the V0332+53 pulsar. |