$$\left\langle \frac{p^2}{2m} \right\rangle = \int_{-\infty}^{\infty} \frac{p^2}{2m} P(p)\, dp$$

$$P(p)\, dp = \frac{e^{-\frac{E_k}{k_B T}}\, dp}{\int_{-\infty}^{\infty} e^{-\frac{E_k}{k_B T}}\, dp}$$

$$\therefore = \int_{-\infty}^{\infty} \frac{p^2}{2m} \cdot \frac{e^{-\frac{E_k}{k_B T}}\, dp}{\int_{-\infty}^{\infty} e^{-\frac{E_k}{k_B T}}\, dp}$$

$$\left(\int_{-\infty}^{\infty} e^{-\frac{E_k}{k_B T}}\, dp = \int_{-\infty}^{\infty} e^{-\frac{p^2}{2m k_B T}}\, dp = \sqrt{2\pi m k_B T} \right)$$

$$= \int_{-\infty}^{\infty} \frac{p^2}{2m} \cdot \frac{e^{-\frac{E_k}{k_B T}}}{\sqrt{2\pi m k_B T}}\, dp$$

$$= \frac{1}{2m\sqrt{2\pi m k_B T}} \int_{-\infty}^{\infty} p^2 \cdot e^{-\frac{p^2}{2m k_B T}}\, dp$$

$$= \frac{1}{2m\sqrt{2\pi m k_B T}} \cdot m k_B T \cdot \sqrt{2\pi m k_B T}$$

$$= \frac{k_B T}{2} \quad //$$

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