(5.4) The Lagrangian for a free particle is $L=-mc^2/\gamma$. Find an expression for $L,\,p$ and H when $v\ll c$.

We have

$$p = \gamma mv \tag{5.23}$$

$$H = \gamma mc^2 \tag{5.24}$$

For $v \ll c$, γ is near unity.

$$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}} \approx 1$$

Then for $\gamma = 1$ we have

$$L = -mc^2$$

$$p = mv$$

$$H = mc^2$$