

$$1) \quad \pi(s, a; \theta) = \frac{e^{\phi(s, a)^T \theta}}{\sum_{b \in A} e^{\phi(s, b)^T \theta}}$$

$$\nabla_{\theta} \log \pi(s, a; \theta) = \underbrace{\nabla_{\theta} \log(e^{\phi(s, a)^T \theta})}_{\phi(s, a)} - \nabla_{\theta} \log\left(\sum_{b \in A} e^{\phi(s, b)^T \theta}\right)$$

$$= \phi(s, a) - \frac{1}{\sum_{b \in A} e^{\phi(s, b)^T \theta}} \sum_{b \in A} \phi(s, b) e^{\phi(s, b)^T \theta} =$$

$$= \phi(s, a) - \sum_{b \in A} \pi(s, b; \theta) \cdot \phi(s, b) = \phi(s, a) - \mathbb{E}_{\pi}[\phi(s, \cdot)]$$

2)

$$\nabla_{\omega} Q(s, a; \omega) = \nabla_{\theta} \log \pi(s, a; \theta)$$

$$\frac{\partial Q(s, a; \omega)}{\partial \omega_i} = \frac{\partial \log \pi(s, a; \theta)}{\partial \theta_i} \quad \forall_i$$

$$Q(s, a; \omega) = \sum_{i=1}^n [\phi_i(s, a) - \sum_{b \in A} \pi(s, b; \theta) \phi_i(s, b)] \cdot \omega_i = \sum_{i=1}^n \frac{\partial \log \pi(s, a; \theta)}{\partial \theta_i} \omega_i$$

3)

$$\mathbb{E}_{\pi} [Q(s, a; \omega)] = \sum_{a \in A} \pi(s, a; \theta) Q(s, a; \omega)$$

$$= \sum_{a \in A} \pi(s, a; \theta) \left(\sum_{i=1}^n \frac{\partial \log \pi(s, a; \theta)}{\partial \theta_i} \omega_i \right) =$$

$$= \sum_{a \in A} \sum_{i=1}^n \frac{\partial \pi(s, a; \theta)}{\partial \theta_i} \omega_i = \sum_{i=1}^n \sum_{a \in A} \frac{\partial \pi(s, a; \theta)}{\partial \theta_i} \omega_i$$

$$= \sum_{i=1}^n \frac{\partial}{\partial \theta_i} \left[\sum_{a \in A} \pi(s, a; \theta) \right] \omega_i =$$

$$= \sum_{i=1}^n \frac{\partial 1}{\partial \theta_i} \cdot \omega_i = \underline{\underline{0}}$$