(3)

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

$$\log \tilde{\pi}(s,a;\theta) = \phi(s,a)^T\theta - \log\left[\sum_{b\in\mathcal{A}} e^{\phi(s,b)^T\theta}\right]$$

$$\nabla_\theta \log \tilde{\pi}(s,a;\theta) = \phi(s,a) - \frac{1}{\sum_{b\in\mathcal{A}} e^{\phi(s,b)^T\theta}} \cdot \sum_{b\in\mathcal{A}} \phi(s,b)\, e^{\phi(s,b)^T\theta}$$

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

$$= \phi(s,a) - \sum_{b\in\mathcal{A}} \phi(s,b)\, \tilde{\pi}(s,b;\theta)$$

$$\boxed{\nabla_\theta \log \tilde{\pi}(s,a;\theta) = \phi(s,a) - \sum_{b\in\mathcal{A}} \phi(s,b)\, \tilde{\pi}(s,b;\theta)}$$

$$\boxed{\text{let } Q(s,a;w) = \phi(s,a)^T w - \left(\sum_{b\in\mathcal{A}} \phi(s,b)\,\tilde{\pi}(s,b;\theta)\right)^T w}$$

$$\mathbb{E}_{\tilde{\pi}}\left[Q(s,a;w)\right] = \sum_{a\in\mathcal{A}} \tilde{\pi}(s,a;\theta)\cdot Q(s,a;w)$$

$$= \sum_{a\in\mathcal{A}} \tilde{\pi}(s,a;\theta)\left[\phi(s,a)^T w - \left(\sum_{b\in\mathcal{A}} \phi(s,b)\,\tilde{\pi}(s,b;\theta)\right)^T w\right]$$

$$= \sum_{a\in\mathcal{A}}\left[\frac{e^{\phi(s,a)^T\theta}\,\phi(s,a)^T w}{\sum_{b\in\mathcal{A}} e^{\phi(s,b)^T\theta}} - \frac{e^{\phi(s,a)^T\theta}}{\cancel{\sum_{b\in\mathcal{A}} e^{\phi(s,b)^T\theta}}}\cdot\left[\sum_{b\in\mathcal{A}} \frac{\phi(s,b)\,\cancel{e^{\phi(s,b)^T\theta}}}{\sum_{c\in\mathcal{A}} e^{\phi(s,c)^T\theta}}\right]^T w\right]$$

$$= \sum_{a\in\mathcal{A}}\left[\frac{e^{\phi(s,a)^T\theta}\,\phi(s,a)^T w}{\sum_{b\in\mathcal{A}} e^{\phi(s,b)^T\theta}} - e^{\phi(s,a)^T\theta}\cdot\frac{\sum_{b\in\mathcal{A}} \phi(s,b)^T w}{\sum_{c\in\mathcal{A}} e^{\phi(s,c)^T\theta}}\right]$$

$$= \sum_{a\in\mathcal{A}}\left[\frac{e^{\phi(s,a)^T\theta}\cdot\phi(s,a)^T w - e^{\phi(s,a)^T\theta}\cdot\sum_{b\in\mathcal{A}}\phi(s,b)^T w}{\sum_{b\in\mathcal{A}} e^{\phi(s,b)^T\theta}}\right]$$

$$= 0$$