1. From the view of duality transform, all particles in the universe may be considered to have only electric charge, only magnetic charge, or a constant proportion of both charges. If we view them to have only electric charge and zero magnetic charge, the force is given by the usual electromagnetic theory

$$\mathbf{F}_{\text{e-only-view}} = q_e\mathbf{E} + q_e\mathbf{v}\times\mathbf{B} \tag{1}$$

If we change our view so they all have a fixed proportion of electric and magnetic charge, a duality transform corresponding to ξ will be applied, i.e.,

$$Z_0 q_e = \cos\xi Z_0 q_e' + \sin\xi q_m' \quad\Longrightarrow\quad q_e = \cos\xi q_e' + \sin\xi\frac{q_m'}{Z_0} \tag{2}$$

$$0 = q_m = -\sin\xi Z_0 q_e' + \cos\xi q_m' \quad\Longrightarrow\quad \frac{q_m'}{Z_0} = q_e'\frac{\sin\xi}{\cos\xi} \tag{3}$$

$$\mathbf{E} = \cos\xi\mathbf{E}' + \sin\xi\frac{Z_0}{\mu_0}\mathbf{B}' \tag{4}$$

$$\frac{Z_0}{\mu_0}\mathbf{B} = -\sin\xi\mathbf{E}' + \cos\xi\frac{Z_0}{\mu}\mathbf{B}' \quad\Longrightarrow\quad \mathbf{B} = -\sin\xi\frac{\mu_0}{Z_0}\mathbf{E}' + \cos\xi\mathbf{B}' \tag{5}$$

The same force should be produced in this mixed view, i.e.,

$$\begin{aligned}
\mathbf{F}_{\text{mixed-view}} =&\mathbf{F}_{\text{e-only-view}} = q_e\mathbf{E} + q_e\mathbf{v}\times\mathbf{B} \qquad \text{use (2),(4),(5)}\\
=&\left(\cos\xi q_e' + \sin\xi\frac{q_m'}{Z_0}\right)\left(\cos\xi\mathbf{E}' + \sin\xi\frac{Z_0}{\mu_0}\mathbf{B}'\right) +\\
&\mathbf{v}\times\left(\cos\xi q_e' + \sin\xi\frac{q_m'}{Z_0}\right)\left(-\sin\xi\frac{\mu_0}{Z_0}\mathbf{E}' + \cos\xi\mathbf{B}'\right)\\
=&\cos^2\xi q_e'\mathbf{E}' + \sin\xi\cos\xi\frac{q_m'}{Z_0}\mathbf{E}' + \sin\xi\cos\xi\frac{q_e' Z_0}{\mu_0}\mathbf{B}' + \sin^2\xi\frac{q_m'}{\mu_0}\mathbf{B}' +\\
&\mathbf{v}\times\left(-\sin\xi\cos\xi\frac{q_e'\mu_0}{Z_0}\mathbf{E}' + \cos^2\xi q_e'\mathbf{B}' - \sin^2\xi\frac{q_m'\mu_0}{Z_0^2}\mathbf{E}' + \sin\xi\cos\xi\frac{q_m'}{Z_0}\mathbf{B}'\right) \qquad \text{use (3)}\\
=&q_e'\mathbf{E}' + \frac{q_m'\mathbf{B}'}{\mu_0} + q_e'\mathbf{v}\times\mathbf{B}' - q_m'\epsilon_0\mathbf{v}\times\mathbf{E}'
\end{aligned} \tag{6}$$

2. The invariance of **F** under duality transform is nothing more than a statement of invariance of inner product between two 2D vectors under 2D rotation.

The duality transform equations (6.151), (6.152) allow us to treat

$$\mathbf{u}_1 = \begin{bmatrix} Z_0 q_e \\ q_m \end{bmatrix} \qquad \mathbf{u}_2 = \begin{bmatrix} \mathbf{E} \\ \frac{Z_0}{\mu_0}\mathbf{B} \end{bmatrix} \qquad \text{and} \qquad \mathbf{u}_3 = \begin{bmatrix} \frac{Z_0}{\mu_0}\mathbf{B} \\ -\mathbf{E} \end{bmatrix} \tag{7}$$

as 2D vectors. Note the third vector is obtained by rotating the second by $\xi = \pi/2$, hence is a vector too. Under duality transform (i.e., 2D rotation by any ξ), the inner products between pairs of these vectors are preserved, i.e., the following quantities are invariant under duality transform

$$\langle\mathbf{u}_1,\mathbf{u}_2\rangle = Z_0 q_e\mathbf{E} + \frac{Z_0}{\mu_0}q_m\mathbf{B} \tag{8}$$

$$\langle\mathbf{u}_1,\mathbf{u}_3\rangle = \frac{Z_0^2}{\mu_0}q_e\mathbf{B} - q_m\mathbf{E} = \frac{q_e\mathbf{B}}{\epsilon_0} - q_m\mathbf{E} \tag{9}$$

$$\langle\mathbf{u}_2,\mathbf{u}_3\rangle = 0 \tag{10}$$

Thus the claim of (6)'s invariance under duality can be deduced from the invariance of (8) and (9).

3. Consider the scattering process described in figure 6.6. Let (e_1, g_1) be the particle held still at the origin and let (e_2, g_2) be the particle that flies by. The pulse in the y direction must incorporate the full force (4) in this case where similar arguments leading to (6.155) yield

$$\Delta p_y = \frac{e_1 g_2 - e_2 g_1}{2\pi b} \quad\Longrightarrow\quad \Delta L_z = \frac{e_1 g_2 - e_2 g_1}{2\pi} \tag{11}$$

Note the negative sign comes from the negative sign of the last term of (6).

By applying the postulate that any change in angular momentum must be integeral multiple of $\hbar$, we obtain the generalized Dirac quantization condition

$$\frac{e_1 g_2 - e_2 g_1}{\hbar} = 2n\pi \tag{12}$$