1) the η is a pseudo scalar meson $S_\eta = 0$ (spin)
$P_\eta = -1$, $\pi^\pm$ are also pseudo scalar meson.
$S_\pi = 0$ $P_\pi = -1$.

Conservation of angular momentum

$$\vec{S}_\eta = \underbrace{\vec{S}_{\pi^-} + \vec{S}_{\pi^+}}_{\vec{S}_{\pi^+\pi^-}} + \vec{\ell}_{\pi^+\pi^-}$$

Sin $S_\eta = S_\pi = 0$ →

$$|S_{\pi^+} - S_{\pi^-}| \leq S_{\pi^+\pi^-} \leq S_{\pi^+} + S_{\pi^-}$$
$$0 \leq S_{\pi^+\pi^-} \leq 0 \implies S_{\pi^+\pi^-} = 0$$

$$|S_\eta - S_{\pi^+\pi^-}| \leq \ell_{\pi^+\pi^-} \leq S_\eta + S_{\pi^+\pi^-}$$
$$0 \leq \ell_{\pi^+\pi^-} \leq 0 \implies \ell_{\pi^+\pi^-} = 0$$

The Parity of the $\pi^+\pi^-$ system is

$$P_{FIN} = P_{\pi^+} \cdot P_{\pi^-} \cdot (-)^{\ell_{\pi^+\pi^-}} =$$
$$= (-1)^2 \times (-1)^0 = 1$$

while $P_{INIT} = P_\eta = -1$

$\Rightarrow$ Parity is not conserved in $\eta \to \pi^+\pi^-$
so, it is not allowed in strong nor em int

the decay $\eta \to \pi^+\pi^-\pi^0$ can conserve parity since still $l_{\pi^+\pi^-}=0$ by conservation of angular momentum so

$$P_{FIN} = (-1)^3 = -1 = P_\eta$$

But looking at G parity

$$G\text{parity}\ \eta = 1$$
$$G\text{parity}\ \pi = -1$$

So
$$G_{INIT} = G_\eta = 1$$
$$G_{FIN} = (-1)^3 = 1 \neq G_{INT}$$

G-parity is conserved in strong interactions but not is em interactions.

$\eta \to \pi^+\pi^-\pi^0$ can be a em process but not as strong process

②

a) $p \longrightarrow e^+ \pi^0$

~~Q~~	1	=	1+0
B	1	≠	0+0
L	0	≠	1+1
S	0	=	0+0
C	0	=	0+0
L_e	0	≠	1+0

→ B in not conserved so this proces is forbidden by any SM interaction (and better this way or we would not be here ☺)

b) $\tau^- \longrightarrow e^- \mu^+ \mu^-$

Q	−1	=	−1 + 1 −1
B	0	=	0+0+0
L	1	=	1 −1 + 1
L_τ	1	≠	0+0+0
L_e	0	≠	1+0+0
L_μ	0	=	0 −1 + 1

→ L_e, L_τ are not conserved but L is conserved

If we neglect m_ν this is forbbiden

Including $m_\nu \neq 0$ this can be a weak process weather neutrinos are Dirac or Majorana.

c) $\bar{p}\, p \to \bar{n}\, n + \pi^+$

Q $-1+1 \neq 0+0+1$ ✗ ← Does not conserve charge. It is forbidden by all interactions.

B $-1+1 = -1+1+0$

L $0+0 = 0+0+0$

S $0+0 = 0+0+0$

C $0+0 = 0+0+0$

L_i $0 = 0$

d) $\mu^+ \mu^- \to \nu_\tau \bar{\nu}_\tau$

Q $+1-1 = 0+0$

B $0+0 = 0+0$

L $-1+1 = 1-1$

L_μ $-1+1 = 0+0$

L_τ $0+0 = 1-1$

this process conserves all quantum #'s (and also angular momentum) so it is allowed by the the SM interactions but it includes νs which have no Q nor colour ⇒ it must be a weak process

and it is allowed unexpected mu

(e) $n\, n \rightarrow p\, p\, e^- e^-$

$Q \quad 0+0 = 1+1-1-1$

$B \quad 1+1 = 1+1+0+0$

$L \quad 0+0 \neq 0+0+1+1$ ← L is not conserved

$L_e \quad 0+0 \neq 0+0+1+1$

If $m_\nu = 0$ this process is not allowed by any SM interaction. If $m_\nu \neq 0$ it would be a weak process but only if $\nu = \bar{\nu} \Rightarrow$ Majorana neutrinos

f) $\Lambda_c^+ \rightarrow \Sigma^+ \pi^0$

$Q \quad 1 = 1+0$

$B \quad 1 = 1+0$

$S \quad 0 \neq -1+0$

$C \quad -1 \neq 0+0$

this process involves hadrons but it does not conserve strangeness nor charm so it must be a weak decay. It is allowed irrespective of $m_\nu = 0$