This question is about quarks.
An interaction between an electron and a positron can lead to the production of hadrons via the reaction

\[ e^- + e^+ \rightarrow u + \bar{u} \]

where \( u \) is an up quark. This process involves the electromagnetic interaction.

1a. Draw a Feynman diagram for this interaction. [2 marks]

**Markscheme**

particles correctly labelled and interaction correctly shown;
arrow directions correct;

1b. Outline, with reference to the strong interaction, why hadrons are produced in the reaction. [2 marks]

**Markscheme**

strong (colour) interaction increases with separation requiring high energy;
high energy allows creation of hadrons/quarks;
confinement requires the formation of two quarks, not one;

This question is about the standard model and the Pauli exclusion principle.

2a. State one conservation law that would be violated, if the following reactions were to occur. [2 marks]

(i) \( \pi^0 \rightarrow e^+ + \mu^- \)

(ii) \( p^+ + n \rightarrow e^+ + e^- + \nu_e + \bar{\nu}_e \)

**Markscheme**

(i) electron lepton number/muon lepton number/family lepton number;
Do not accept just “lepton number” as this is conserved.

(ii) electric charge;
The reaction $\bar{\nu}_\mu + e^- \rightarrow \bar{\nu}_\mu + e^-$ is an example of a neutral current reaction. Draw a Feynman diagram for this reaction labelling all the particles involved. The arrow provided indicates the direction of time.

**Markscheme**

arrows for $e^-$ point forward in time and arrows for $\bar{\nu}_\mu$ point backwards in time;
vertices $\nu_\mu Z e_\nu$ and $e^- Z e_\nu$; (inspect carefully, many draw $e^- Z e_\nu$ vertices)
$Z$ particle;
Award each marking point independently.
Award [2 max] if the diagram is rotated 90º.
Allow particles to be expressed in words.