Particle Physics Workshop: The World of Particles and their Interactions

This document gives detailed guidelines for teachers on the tasks described in the accompanying power point presentation of the Particle Physics Workshop.

Task 1: Happy Families game

Resources

One pack of 30 trump cards per group of 5 students maximum (from document "trump cards"). Each pack contains:

- 6 quarks,
- 6 anti-quarks
- 6 leptons
- 6 anti-leptons
- 6 bosons

How to play [1]

The aim of the game is to collect as many families (groups of 6 cards that belong to the same family) as possible.

1. Deal out all the cards so that every player gets an almost equal number of cards; this will depend on the number of players.
2. The dealer starts by asking another player for a card needed to complete a family.
3. If the other player has the card, they must give it to this player.
4. The player may continue asking for cards until they make a mistake.
5. When a mistake is made the player who was asked for their card takes their turn to request cards.
6. During the game, players can request and retake the cards taken from them in previous rounds.
7. When a player gathers a family they must put the 6 cards face down on the table in front of them.
8. The player who collects the most families is the winner.

Task 2: Make your own particle!

Resources

To make the standard model that includes matter and antimatter:

- 30 Plastic coloured balls
    - 12 must have the same colour for quarks and anti-quarks
    - 12 must have another colour for leptons and anti-leptons
    - 6 must have a third colour for bosons
        - http://www.theworks.co.uk/p/outdoor-toys/mega-box-of-balls/5021813115458
        - http://www.argos.co.uk/static/Product/partNumber/3665514.htm
- Coloured pencils for designing the particle before making it (must include the same variety of colours as the plastic balls available)
- Black thin permanent markers (for writing on the particles)
- A box of various decorations
    - http://www.theworks.co.uk/p/embellishments/bumper-craft-pack/5052089001978)
- 2kg of plasticine
    - http://www.easycomposites.co.uk/products/newplast-plasticine-modelling-clay.aspx
- Scales to measure 5 grams
- Sellotape (to close the particle once it is stuffed)
- double-sided sellotape (to stick the features on the particle)
- Scissors and art knife for cutting the balls open
- Black and white card to be used for a feature that distinguishes matter (white) from antimatter (black)
- Top trump cards (30 in total) for designing the particles
- Worksheet "The world of particles with mass" for reference

Designing the particles

The whole class must decide what colour balls they will assign for each particle family i.e. quarks and anti-quarks one colour, leptons and anti-leptons another and finally bosons a third colour. Each student will make one particle from a total of 30 particles.

1. Teacher distributes trump cards, one per student.
2. Students look at the box of decorations to give them an idea of what is available.
3. They read the particle information on the trump card in order to get inspiration for their design.
4. They decide what they want their particle to look like.
   (a) For example: what will a strange particle look like?
   (b) What will a charm particle look like?
5. Students working on a particle-antiparticle pair must sit near each other because they will be making these decisions together, since their particles will be **identical** with the exception of one feature (e.g. hat, cape, base stand) which will be made in white card for the particle and in black card for the antiparticle.
6. Students draw the particle features they chose on the trump card.

Giving mass to the particles

Students take one of the plastic balls (the right colour) and read the information about the mass of the particle they are making, from the worksheet "The world of particles with mass". They will add mass to their particle by filling the ball with plasticine following the rules below:

- If the particle is "very light" they do not put any plasticine in it;
- If the particle is "light", they cut-open the ball along its waist and put 5 grams of plasticine inside it. Then they close the ball and stick it with sellotape;
- If the particle is "heavy", they cut-open the ball along its waist and half-fill it with plasticine (about 100g). Then they close the ball and stick it with sellotape;
- If the particle is "very heavy", they cut-open the ball along its waist and fill it up entirely with plasticine (about 200g). Then they close the ball and stick it with sellotape.

Adding features to the particles

1. Students look at the particle trump card and the design they chose.
2. They then take the features they have chosen from the box of decorations and use double-sided sellotape to stick these features on the ball-particle.

3. They add the final matter-antimatter feature in white or black card, which will distinguish the particle from its antiparticle.
4. Finally they write the name of the particle at its back (as seen below).

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Task 3:Snap game

Resources

One pack of 30 trump cards per group of 5 students maximum (from document "trump cards"). Each pack contains:

- 6 quarks
- 6 anti-quarks
- 6 leptons
- 6 anti-leptons
- 6 bosons

How to play [2]

The rules of likes are listed in the trump cards. This game can be run for a limited amount of time; the winner is the person with the largest number of cards.

1. Anyone may deal.
2. The cards are shuffled and dealt out to the players as equally as possible. Players do not look at their cards but keep them in a face down stack in front of them.
3. The player to dealer's left begins and the turn to play passes clockwise.
4. At your turn you simply turn the top card of your face-down pile and place it face-up alongside. In this way each player forms a pile of face-up cards beside their face-down pile.
5. If at any moment two of the face-up piles have particles that **like each other** at the top (for example electron and Z), anyone who notices this shouts "snap!".
6. The first person who shouted "snap!" takes both matching face-up piles and adds them face-down to the bottom of their face-down pile.
7. The game then continues as before, beginning with the player to the left of the last one who turned a card.
8. If you have no face-down cards left when it comes to your turn, you simply turn over your face-up pile to make a new face-down pile and turn over the top card as before.
9. If you have no cards left at all, you are out of the game.
10. The last player in is the winner.

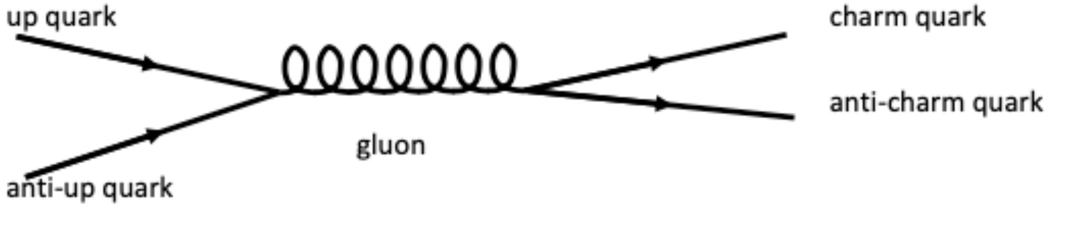
11. When turning up cards, you are not allowed to peek at your card before the other players can see it. To ensure this, cards should be turned over facing away from the player, so that if it is turned too slowly the turning player will see it last.
12. If a player shouts "snap" in error when there is no match, that player's face-up pile is taken away and put in the centre of the table, where it becomes a **snap pool**. If this happens several times there can be several snap pools.
13. If the top card-particle of any player's pile **likes** the top card-particle of one of the snap pools, the first player who calls "snap pool" takes both piles.

Task 4: Particle interaction

Theoretical background for the teacher

- When particles meet they interact with each other. During this interaction many events can happen:
  - pairs of matter-antimatter particles can disappear and turn into pure energy (annihilation);
  - pure energy can turn into pairs of matter-antimatter particles (creation);
  - pairs of particles can disappear and turn into other particles;
  - a particle can disappear and turn into a pair of other particles.
- Interactions follow the rules of likes and dislikes:
  - Quarks and anti-quarks like gluons and photons
  - Leptons and anti-leptons like photons, W and Z
  - Gluons like quarks and anti-quarks
  - Higgs likes everybody apart from photons, gluons and neutrinos
  - W and Z like quarks, anti-quarks, leptons, anti-leptons and Higgs
  - Photons like quarks, anti-quarks, leptons, anti-leptons and W

  For example:
  - a gluon will turn into a pair of particles that it likes, such as quark and anti-quark;
  - a gluon will never turn into a pair of particles that it dislikes, such as lepton and anti-lepton;
  - a pair of leptons will turn into a particle that they like, e.g. a Z boson;
  - a pair of leptons will never turn into a particle that they dislike, e.g. a gluon.
- We can show every interaction using a diagram, called a Feynman diagram which was introduced by the physicist Richard Feynman. Every Feynman diagram tells a story; you read the diagram starting from the left and following the lines towards the right. For example, the diagram below shows that an up quark and an anti-up quark annihilated and produced a gluon. The gluon then turned into a charm quark and an anti-charm quark.



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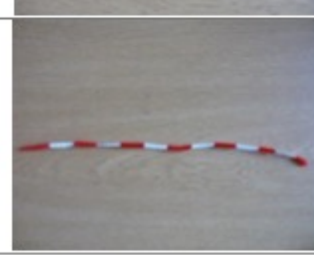
- During particle interactions the total charge is conserved. This means that the combined charge at the start is the same as the combined charge in the middle and at the end. For example, the total charge of the up (+2/3) and anti-up quark (-2/3) when added together is zero. The gluon charge is also zero. The total charge of the charm (+2/3) and anti-charm quark (-2/3) when added together is also zero.
- Feynman diagrams use lines of particular shape for specific particles as seen in the table below:

particle	shape for drawing	pipe cleaner shape
quarks and leptons		
photons		
gluons		
W+ or W- or Z		

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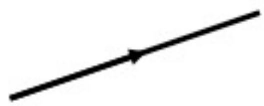
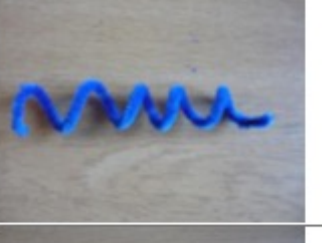
- Feynman diagrams use lines of particular shape for specific particles as seen in the table below:

particle	**shape for drawing**	**pipe cleaner shape**
quarks and leptons		
photons		
gluons		
W+ or W- or Z