

## Conceptual Understanding Procedures (CUPs)

### *How do I use a CUP?*

This procedure is suitable for class sizes of about 10 to 25 students.

The aim is to improve students' understanding in selected areas of physics where students traditionally have difficulties. This is achieved by using a co-operative learning strategy designed to draw out and where necessary modify prior conceptions: the strategy also reinforces the value of the learner's active role in learning.

Examples of several exercises are included with detailed notes on the first three. The intent is that students discuss one of these exercises per session in the manner outlined below (see **5 Basic outline of a CUP session**). Each session needs about an hour. The exercises used are qualitative in order to focus students' attention on their understanding of concepts. Student responses are recorded in diagrammatic form both to allow students to represent the relative sizes of different physical quantities without resorting to mathematics and to readily convey their understanding to others.

### 1 Preparation

1. It is **ESSENTIAL** that the teacher think about possible student responses prior to each CUP session.
2. Ensure the items listed under **Hardware** below are available.
3. Plan the organisation of students into small groups—see **Organisation of small groups (Triplets)** below.
4. Each exercise requires about an hour period (but usually could be spread over two shorter sessions).

### 2 Hardware

1. A4 sheets on which is printed the exercise—one copy per student
2. A3 sheets with enlarged but exact replica of diagrams on A4 sheet—one copy per triplet (plus a few spares for emergencies)
3. Textas or other thick tipped pens—3 different colours per triplet
4. 'Blu-tack' or similar for sticking A3 sheets to wall/board
5. A wall/board on which A3 sheets can be placed and where the whole class can easily view the sheets.

### 3 Organisation of small groups (Triplets)

1. Students should be organised into mixed ability groups of three, which for convenience are called triplets. By 'mixed ability' is meant one high, one medium and one low ability as determined by whatever means the teacher wishes to use.
2. If the class cannot be divided evenly into threes, it is better to distribute the remaining students in groups of four rather than groups of two.

3. In mixed gender classes, female students should always be in a triplet with at least one other female.
4. Ideally the students should be in the same triplet for each CUP exercise.

#### **4 A need for trust**

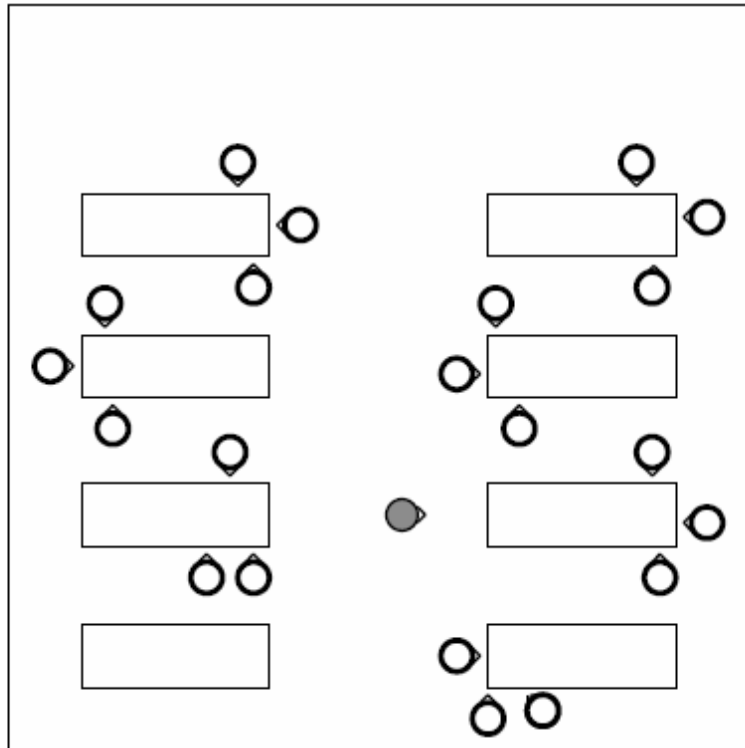
At the start of the first CUP session, the teacher needs to stress the importance of everyone contributing their ideas about the exercises because everyone has some misconceptions which impede their conceptual understanding: such understanding can only be improved if these misconceptions are exposed and addressed. The teacher needs to stress that everyone's opinions should be respected, even if one disagrees with them. ("These exercises are designed to help overcome some common misconceptions in mechanics. I hope we can listen to each other, discuss everyone's ideas, disagree, ask each other questions when something is not clear and work TOGETHER towards a solution.")

#### **5 Basic outline of a CUP session**

*Time: allow about an hour, nearly half of which is in triplet mode and the other half in whole class mode.*

1. Students are presented with the exercise on an A4 sheet of paper. The teacher should draw attention to any conventions (eg how to represent forces) to be used when answering the questions, and emphasise the need to draw LARGE diagrams when representing the answer of one's triplet on the A3 sheet.
2. The students spend a few minutes trying to solve the exercise BY THEMSELVES. This gives them a chance to get in touch with their own ideas before being presented with those of others. During this time they can write ideas etc on their A4 sheet.
3. Then the students move into their triplets and for the next 20 minutes or so present and listen to each other's ideas. The purpose of the discussion is to allow them to clarify what they think, discover faults in their reasoning and finally reach consensus on the answer which is then transferred to the A3 sheet, which the teacher will have distributed with three different coloured textas to each group. The students should draw their diagrams as large as possible using the textas provided for ease of viewing later. Each member of the triplet ought to be prepared to defend their triplet's answer to the whole class. During the triplets' discussions, the teacher should move around the room, clarifying points about the exercise if needed but avoiding getting involved in the discussions (see Figure 1).

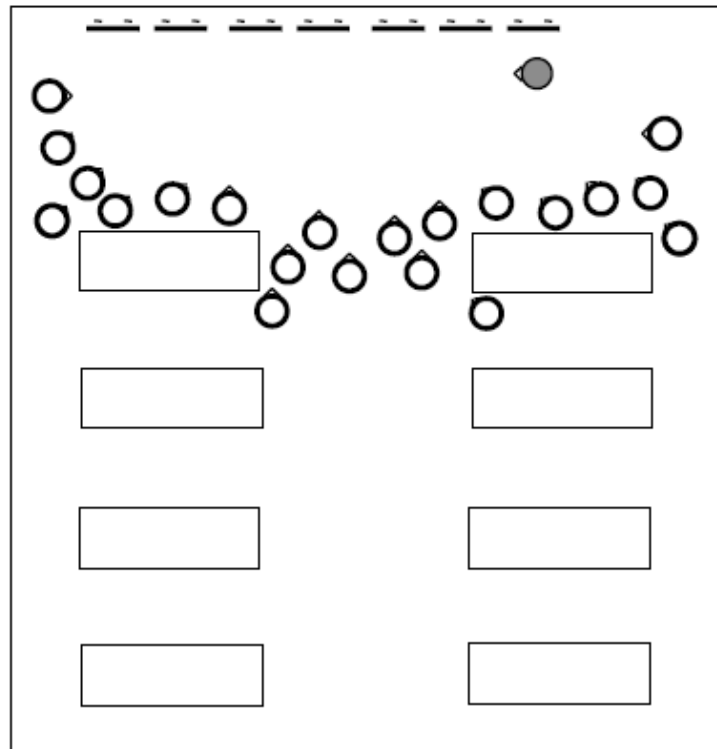
○ student  
 ● teacher



**Figure 1 Triplet mode**

4. After a suitable period of time, all the A3 responses should be stuck on the wall/board and the students invited to sit closer in a rough U-shape so they can easily view the A3 sheets (see Figure 2).

— triplets'  
 A3 sheets



**Figure 2 Whole class mode**

5. The teacher needs to scan the responses looking for similarities and differences—a number of responses will be the same—and could begin the discussion by choosing an A3 sheet where the diagrams seem representative of some of the responses and asking a member of the triplet to explain their answer. Students from other triplets with different diagrams are then invited to defend their responses. (“Has anyone got any comments to make on Sarah's reasoning/answer? ... David, your triplet's answer appears different here ... would you like to explain why?”) The process continues with students arguing their position until consensus is reached about the final answer.  
It is important that the teacher AVOIDS EXPLAINING/TELLING THEM the answer. A lot of thinking will be occurring; the teacher needs to allow a sufficient wait-time before asking follow-up questions.
6. At the end of the session each student needs to be fully aware of the agreed answer—to ensure this the teacher should repeat the answer (“So what you’ve all agreed is ...”) and perhaps write/draw this on a blank A3 sheet on the wall/board (but without further comment). If the end of the session arrives before consensus is reached, the teacher summarises the stage reached (“So most hold ... with another group supporting ...”), reassures the students that this is acceptable and that this will be resolved at their next physics class.

## 6 Further detail on the first three exercises

It is envisaged that one exercise per CUP session will be discussed, with all stages of an exercise being covered.

### Exercise 1 Driving to Hilary's

This is designed to help students’ understanding of displacement/time, distance travelled/time, velocity/time and acceleration/time graphs. It also requires them to make some inferences about the way displacement, distance travelled, velocity and acceleration change when a car stops and reverses.

This exercise should ideally occur after students have done some exercises like those requiring them to sketch such graphs from stories about the motion of different objects involving numerical data (eg “Angela drives home from netball at a constant velocity of 60 km/h. She stops at the traffic lights etc”) and/or those requiring them to ‘role-play’ situations represented by given graphs.

### Exercise 2 Throwing a hockey ball

This exercise is designed to help students’ understanding of velocity and acceleration, and in particular, their vector nature. The exercise should be given after these terms have been introduced but before they have encountered the acceleration due to gravity. The students should be familiar with representing velocity and acceleration as directed lines.

The exercise should help students to realise that when an object moving in a straight line reverses direction it has a zero velocity but a non-zero acceleration while changing direction.

The example used is a ball thrown straight up in the air. While students should be able to realise that there is some deceleration before and acceleration after the ball reaches the top of

its flight path, they will not necessarily infer that the ball is continuously decelerating/accelerating during its flight. Nor will they realise—and nor do they need to for this exercise—that the acceleration is constant (assuming negligible air resistance). Hence the teacher might like to return to this exercise after the acceleration due to gravity has been covered.

### **Exercise 3 Hitting a golf ball**

This exercise is concerned with identifying which forces in a given situation are equal and opposite in accordance with Newton's Third Law of Motion. Question 1 should bring out common misconceptions regarding these forces for an object resting on a surface. Question 2 is another version of the donkey pulling the cart problem (ie "If the cart pulls on the donkey with a force equal and opposite to the force that the donkey pulls on the cart, how does the cart move?"). In follow-up teaching, teachers may wish to generalise from the procedure used to solve the apparent paradox in this question—ie to work out the motion of an object, one needs to consider ALL the forces ACTING ON THAT OBJECT.