

Maths Problem Solving
for
Higher Achieving Students

NUMBER

Ian Bull

SAMPLE PAGES

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About this book

According to education research, approximately 10% of our students can be classified as being gifted and talented and if another 15% can fit into a high-achieving class then about a quarter of the students in our classes are in need of enrichment materials in the mathematics curriculum. These students need challenge above and beyond the normal mathematics curriculum — they need to be presented with materials and experiences to develop their higher order thinking skills.

This book uses a 3-tiered structure to provide students with experience in the problem-solving process to meet this need.

The student activities are provided in task-card format, and can be either written on the board, projected on an electronic whiteboard (using the CD), or photocopied and given out to the class. Detailed solutions to all questions are provided.

Section 1

These tasks are initially teacher-led to get the whole group on track with the spirit or essence of the activity. Each task provides three levels of instruction.

Introductory lesson – teaching suggestions, notes and examples

An introductory task is given for teachers to use as a problem-solving class lesson. Some notes are provided, as well as some key questions to stimulate discussion. This section can be used to explore the context and concepts required for the task.

Application activity

The application activity builds on the concepts and ideas started in the introduction lesson. It can be used by the majority of students in the class to consolidate the ideas covered in the introductory lesson.

Extension task 1

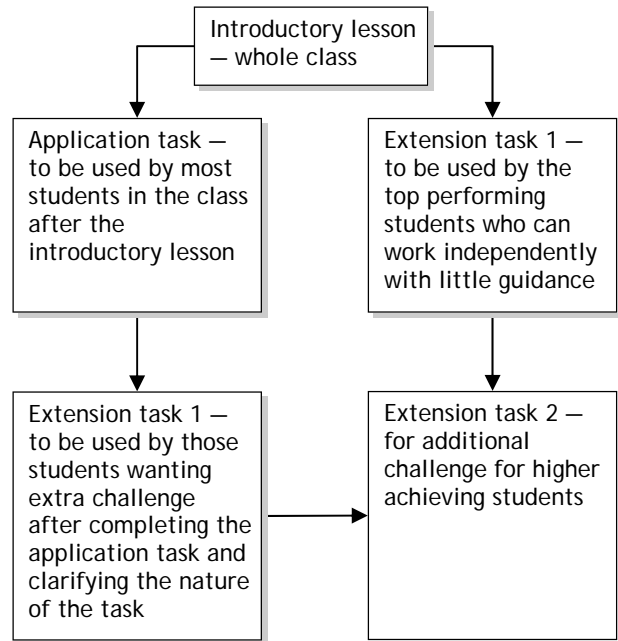
- The first extension task presents students with some challenging questions connected to the ideas presented in the introductory task. These tasks require a deeper more sophisticated degree of thought.

The tasks can be given to:

- students who have been identified as being gifted, talented and higher achieving, and so can work with the extension activity straight after the introductory lesson
- students who have completed the introductory lesson and application task and want to work, or are capable of now working, on more complex tasks

Extension task 2

Students who have completed extension task 1 and would like some more challenge can be given the second extension task. In this way, all students of the class have plenty of materials to work through at appropriate levels.

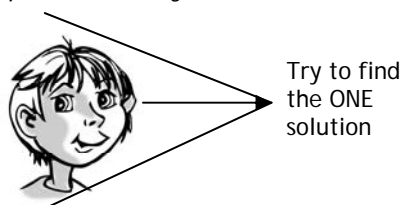


Using the tasks from section 1

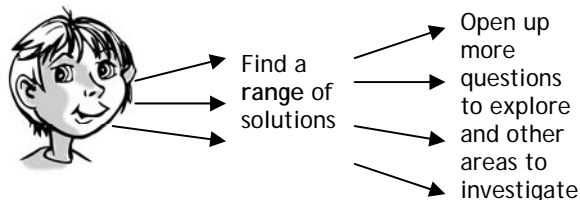
Section 2

The tasks in this section require students to make the first move in understanding the context of the question. An open-ended problem is one that has more than one answer. This for students and teachers means that the pursuit of THE single answer to a question does not take the whole focus of the investigation. Rather than applying a funnelled search for a solution to a problem, students need to be encouraged to have a broad-minded approach.

Closed problem-solving



Open-ended problem-solving



Students need to alter their frame of thinking and look at the question in its entirety to identify multiple stages and multiple solutions from the start. Successful strategies such as making lists of possible outcomes, working backwards from the solution, drawing a diagram or picture to show the possibilities, making a model or looking for patterns may all be appropriate.

Students need to understand the task, find an initial solution, examine the nature of that solution and look for other related situations that lead to find more solutions. By adopting this approach, students can be encouraged to make up their own investigations and design their own tasks which can be shared with the group.

Section 3

The questions in this task don't need to be given in sequence with sections 1 or 2 – in fact they can be used singularly or in total at any point. As they are different in structure to tasks from the other sections, they provide challenge in a different form.

A command of language, written or verbal, is a fundamental component of everything that we do. Before a problem can be solved it needs to be understood on a holistic level, leading to the uncovering of smaller details of the problem which need to be specifically understood. The quicker the problem-type can be recognised through language, the quicker it can be categorised to branch/branches of mathematics, allowing the solution process in turn to begin.

Comprehending a problem, using a logical approach to analyse it and then applying mathematics to work through it and expressing the solutions in a clear and coherent manner shows why literacy is a key factor in the solving of all problems.

The questions in this section are similar to reading-comprehension problems undertaken in other subject disciplines, with each requiring a mathematical component to complete the task. The questions range from astronomical facts to the disciplines of geography and biology.

The hints make it quick and easy for teachers to become acquainted with the task without having to work through the whole sheet. Teachers can either copy the hint sections or deliver them verbally to get students back on track with the task.

The CD

The CD resource contains electronic versions of the task cards for the Introductory Lessons and the Application tasks for Section 1. The electronic files are presented in the Interactive Whiteboard formats for SMART Notebook™, RM Easiteach® and PROMETHEAN as well as Microsoft Office PowerPoint.

These electronic files also contain additional class activities, as well as extra introduction examples for some tasks. These extra resources allow a more careful coverage of the ideas and concepts. Additional resource sheets are included for some tasks in Section 1 and may be used in conjunction with each activity.

The interactive whiteboard files enhance the focus of the lessons, and allow all students the opportunity of engaging with the activity. I have used this method extensively with my own teaching at St Kevin's College and have found it to be an extremely powerful way to engage students' interest and focus their attention on each task.

Lesson 1: Digits and number puzzles

Aims

- To work with numbers in a puzzle to make a particular sum
- To find the number of different digits used to make numbers

Method

Present the Whole Class Introduction and Lesson Tasks. Work through the questions on the board or use an interactive whiteboard or PowerPoint file. Discuss how students used different methods to find their answers – trial and error can be used but students should be encouraged to find patterns and use other strategies. The counters on page 11 can be cut out and used for this.

Resources

Book: Whole class introductory lesson; Lesson tasks; Application task; Extension Tasks 1 & 2; Task cards (pp. 10-11) and Resource materials (puzzle grids, digit cards and counters, pp. 12-13).
 CD: interactive whiteboard and PowerPoint presentation of the class lesson and application task.

Whole class introduction – key points

Number puzzles

Number puzzles can be solved by trying numbers until the puzzle works. With practice it is possible to minimise the guessing – using one answer to help find the answer to the next question is a smarter way to work and should be encouraged.

Digits

When trying to find the number of digits needed to make a group of numbers, the long way is to write the numbers – try to find a shortcut by finding patterns.

Solutions

Lesson tasks

- The number triples are: (1, 2, 6) (1, 3, 5) (2, 3, 4) – as well as all the orders, so the full set is (1, 2, 6) (1, 6, 2) (2, 1, 6) (2, 6, 1) (6, 2, 1) (6, 1, 2) and (1, 3, 5) (1, 5, 3) (3, 1, 5) (3, 5, 1) (5, 1, 3) (5, 3, 1) and (2, 3, 4) (2, 4, 3) (3, 2, 4) (3, 4, 2) (4, 2, 3) (4, 3, 2).
 - The number sets are: (1, 3, 6) (1, 6, 3) (3, 6, 1) (3, 1, 6) (6, 1, 3) (6, 3, 1) (2, 3, 5) (2, 5, 3) (3, 2, 5) (3, 5, 2) (5, 2, 3) (5, 3, 2) (1, 4, 5) (1, 5, 4) (4, 5, 1) (4, 1, 5) (5, 4, 1) (5, 1, 4)
 - The number sets are: (1, 5, 6) (1, 6, 5) (5, 6, 1) (5, 1, 6) (6, 5, 1) (6, 1, 5) (2, 4, 6) (2, 6, 4) (4, 2, 6) (4, 6, 2) (6, 2, 4) (6, 4, 2) (3, 4, 5) (3, 5, 4) (4, 3, 5) (4, 5, 3) (5, 3, 4) (5, 4, 3).
- The number sets are: [100, 101, 102, 103, 104, 105, 106, 107, 108]. Counting the digits means that Jodie needs: 10 zeros, 10 ones, 1 two, 1 three, 1 four, 1 five, 1 six, 1 seven and 1 eight. As a check there must be $9 \times 3 = 27$ digits and the digit count in the answer is 27.

Application task

- The number sequences from bottom left clockwise are: {0, 6, 4, 10} {6, 0, 10, 4} {1, 5, 5, 9} {5, 1, 9, 5} {2, 4, 6, 8} {4, 2, 8, 6} {3, 3, 7, 7}
 - The number sequences from bottom left clockwise are: {0, 4, 4, 8} {1, 3, 5, 7} {2, 2, 6, 6} {3, 1, 7, 5} {4, 0, 8, 4}
- There is only one answer for this one: {5, 1, 2, 3, 4} clockwise from the bottom left.

Task cards pp. 10-11

1: Digits and number puzzles LESSON TASKS

1. Choose from the numbers {1, 2, 3, 4, 5, 6}. Use each number only once each time.

(a) Place the numbers into the circles to make the numbers add to 9.

(b) Place the numbers into the circles to make the numbers add to 10.

(c) Place the numbers into the circles to make the numbers add to 12.

2. Jodie needs to put numbers on houses which go from 100 to 108. How many of each digit does she need?

1: Digits and number puzzles APPLICATION TASKS

1. Write a number in each circle to give the total for each side.

(a) (b) (c)

2. Place the numbers {1, 2, 3, 4, 5, 6, 7, 8, 9} into the circles so that each line adds up to:

(a) 17 (b) 20

3. Jordan needs to put numbers on houses that go from 1 to 40. How many of each type of digit does he need? **2 4 13**

1: Digits and number puzzles EXTENSION TASK 1

1. Louisa wants to place numbers in the puzzle so that the numbers in each circle have the same sum. The number 1 is a part of each circle. Place the numbers into the puzzle so that the sum of the numbers in each circle is the same.

(a) {2, 3, 4, 5, 6, 7} (b) {4, 5, 6, 8, 9, 10}

2. Find the number of the digits from 0 to 9 that are needed for house numbers from 1 to 100. Explain how you found your answer without listing the numbers.

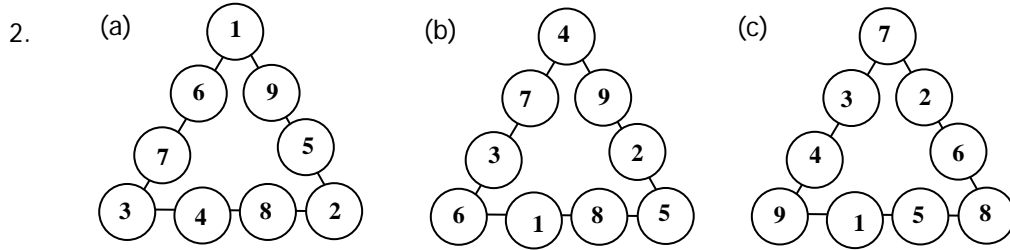
1: Digits and number puzzles EXTENSION TASK 2

1. (a) Place the numbers {1, 2, 3, 4, 5} into the puzzle so that the sum of the numbers in each circle is equal.

(b) Place the numbers {1, 2, 3, 4, 5, 6, 7} into the puzzle so that the sum of the numbers in each circle is equal.

(c) Place the numbers {1, 2, 3, 4, 5, 6, 7, 8, 9} into the puzzle so that the sum of the numbers in each circle is equal.

2. Four circles are arranged so that they overlap to give thirteen areas. Place the numbers from 1 to 13 so that the sum of the numbers in each circle is equal.

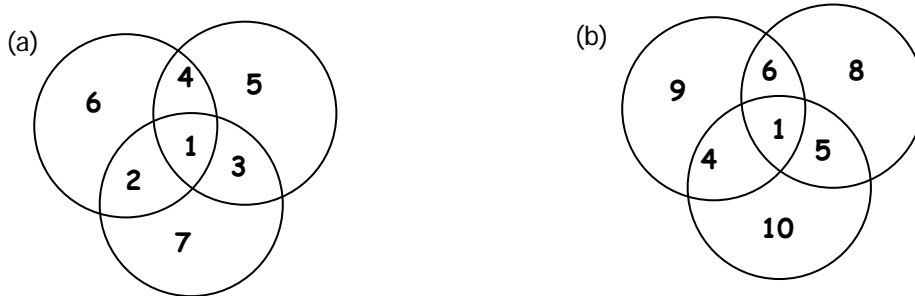


3.

| | | | | | | | | | | |
|---------------|---|----|----|----|---|---|---|---|---|---|
| Digit | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Number needed | 4 | 14 | 14 | 14 | 5 | 4 | 4 | 4 | 4 | 4 |

Extension task 1

1. Note the symmetry in each solution – the numbers are placed either clockwise or anticlockwise to make the correct sums.



2. For the numbers from 1 to 99

There must be 9, zeros – one zero for 10, 20 ... 80, 90

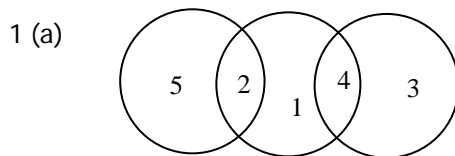
For each digit there are 10 in each line plus 9 more for the start of the numbers in each line and 1 more for the digit in the ten – for example, for the twos: for the twenties line: 21, 22, 23, 24, 25, 26, 27, 28, 29 – there are 10 twos and there are also 9 more for 2, 12, 32, 42, 52, 62, 72, 82 & 92 and one more 2 for 20: $10 + 9 + 1 = 20$.

There must be $9 + 9 \times 20 = 189$ digits plus a 1 and 2 zeros for the 100.

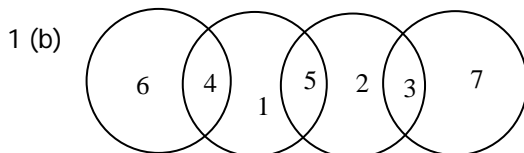
The final digit count is 192 as follows:

| | | | | | | | | | |
|----|----|----|----|----|----|----|----|----|----|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 11 | 21 | 20 | 20 | 20 | 20 | 20 | 20 | 20 | 20 |

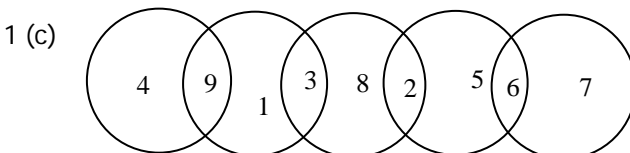
Extension task 2



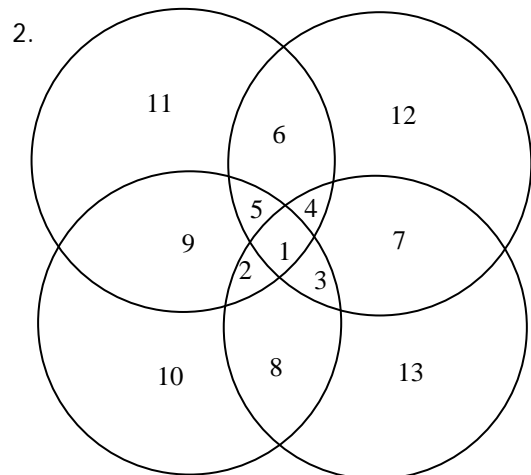
Sum for each circle is 7



Sum for each circle is 10



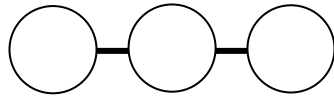
Sum for each circle is 13



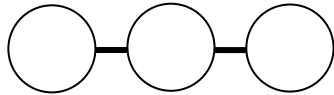
1: Digits and number puzzles

LESSON TASKS

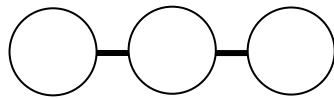
- Choose from the numbers {1, 2, 3, 4, 5, 6}.
(Use each number only once each time.)
(a) Place the numbers into the circles so that they add to 9.



- (b) Place the numbers into the circles so that they add to 10.



- (c) Place the numbers into the circles so that they add to 12.

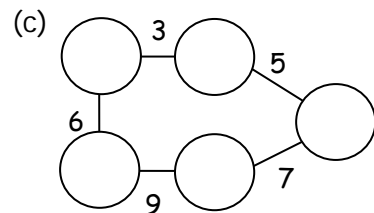
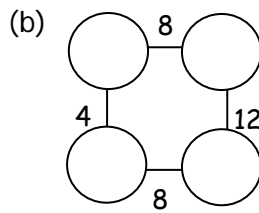
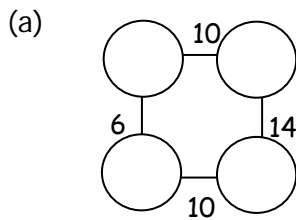


- Jodie needs to put numbers on houses that go from 100 to 108.
How many of each digit does she need?

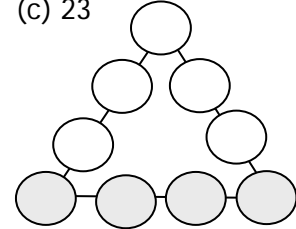
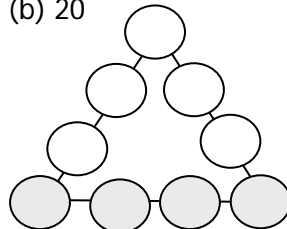
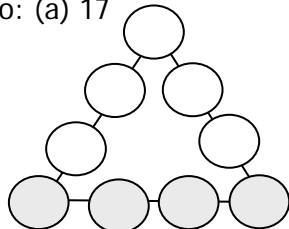
1: Digits and number puzzles

APPLICATION TASKS

- Write a number in each circle to give the total for each side.



- Place the numbers {1, 2, 3, 4, 5, 6, 7, 8, 9} into the circles so that each line adds up to: (a) 17 (b) 20 (c) 23



- Jordan needs to put numbers on houses that go from 1 to 40. How many of each type of digit does he need?



1: Digits and number puzzles

EXTENSION TASK 1

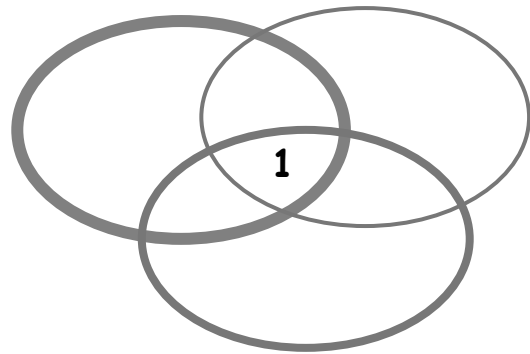
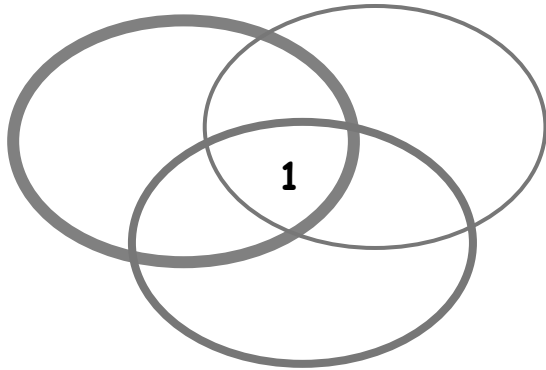
1. Louisa wants to place numbers in the puzzle so that the numbers in each circle have the same sum.

The number 1 is a part of each circle.

Place the numbers into the puzzle so that the sum of the numbers in each circle is the same.

(a) {2, 3, 4, 5, 6, 7}

(b) {4, 5, 6, 8, 9, 10}

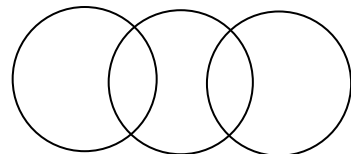


2. Find the number of the digits from 0 to 9 that are needed for house numbers from 1 to 100. Explain how you found your answer **without listing the numbers**.

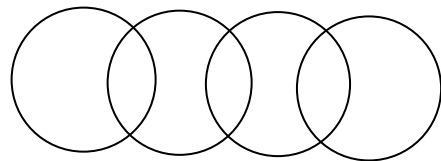
1: Digits and number puzzles

EXTENSION TASK 2

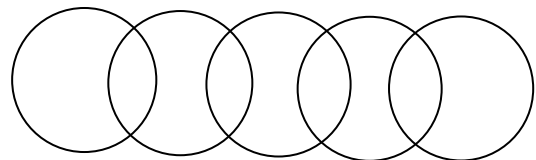
1. (a) Place the numbers {1, 2, 3, 4, 5} into the puzzle so that the sum of the numbers in each circles is equal.



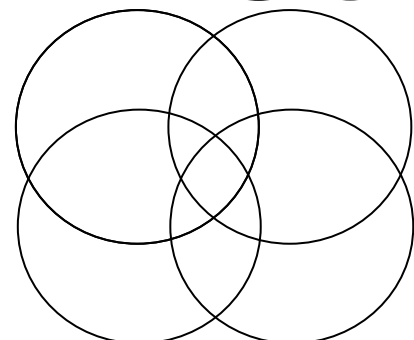
- (b) Place the numbers {1, 2, 3, 4, 5, 6, 7} into the puzzle so that the sum of the numbers in each circles is equal.



- (c) Place the numbers {1, 2, 3, 4, 5, 6, 7, 8, 9} into the puzzle so that the sum of the numbers in each circles is equal.



2. Four circles are arranged so that they overlap to give thirteen areas. Place the numbers from 1 to 13 so that the sum of the numbers in each circles is equal.



1: Customers at the milkbar

Aim

- To work with multiples of 6 and 9 in a practical sense

Task card p. 78

OPEN-ENDED TASK 1

Customers at the milk bar

The first five multiples of 3 are 3, 6, 9, 12, 15. The first five multiples of 2 are 2, 4, 6, 8, 10. The second multiple of 3 is the same as the third multiple of 2. This is the first common multiple of 2 and 3 which is 6.

- In the opening of a milk bar every 6th customer receives a free drink and every 9th customer gets a free lolly.
 - If 200 customers came into the shop on the first morning how many drinks and lollies were given out? Explain how you got your answer.
 - How many customers received both a drink and a lolly? Explain how you got your answer.
- During the afternoon, 20 customers received both a drink and a lolly.
 - How many customers could have visited the shop in the afternoon?
 - How many drinks could have been given out?
 - How many lollies could have been given out?

Activity background

Question 1, part (a) Every 6th, 12th, 18th customer etc. (multiples of 6) are given drinks, and every 9th, 18th, 21st customer (multiples of 9) are given lollies. With 200 customers coming into the shop the multiples of 6 and 9 need to be worked with up to 200.

Part (b) The approach to be encouraged is the deduction of the common multiples of 6 and 9 without listing them all. With the prime factors of 6 being 2×3 and the prime factors of 9 being 3×3 then the common multiples of 6 and 9 must be the even multiples of 9: $(2 \times 3 \times 3)$.

Question 2 involves the idea that multiples of 6 or 9 are found between the common multiples of 6 and 9. As twenty people get both a drink and a lolly then at least 360 customers (the 20th common multiple of 6 and 9) must have visited the shop. But as there are multiples of 6 (drink) or 9 (lolly) after the 20th common multiple of 6 and 9, to just before the 21st common multiple of 6 and 9 then there could be a different number of drinks and lollies given out in total.

Hint

Write a list of multiples of 6 and 9 and look at the types of numbers which are both multiples of 6 and 9 at the same time — these get both a drink and a lolly.

- As every 6th customer receives a free drink, then the 6th, 12th, 18th ... customers will receive a free drink and the 9th, 18th, 27th ... will receive a free lolly.
 - The first customer to receive a free drink and lolly is the 18th customer.
- Twenty customers got a free drink and a lolly, but they are not the 20th customers to walk through the door. These customers both share the multiples of 6 and 9 to get both the lolly and drink. More customers will probably come in after the 20th customer got the free drink and lolly just before the 21st customer comes in to get both a drink and a lolly.

Solution

- $200 \div 6 = 33\frac{1}{3}$, so 33 drinks were given out and $200 \div 9 = 22\frac{2}{9}$ so 22 lollies were given out.
 - Common multiples between 6 and 9 are: {18, 36, 54, 72, 90, 108, 126, 144, 162, 180, 198} so 11 people got a drink and a lolly. The common multiples were found by seeing that 6 has factors {1, 2, 3, 6} and 9 has the factors {1, 3, 9} so each multiple had to be an even multiple of 9 — such as $9 \times 2 = 18$ which 9 can go into as $18 = 2 \times (3 \times 3)$ and 6 can as $18 = 3 \times (3 \times 2)$.
- Continuing the even multiples of 9, the 20th even multiple of 9 is 360 ($20 \times (2 \times 9)$), so the 360th customer would be the 20th person to receive a drink and a lolly. The 21st customer to receive a drink and a lolly would be the $21 \times (2 \times 9) = 378$, so the number of customers could range from 360 to 377 (can't be 378 as we are told that only 20 customers receive both a drink and a lolly not 21 customers).
 - The smallest number of drinks to be given out would be $360 \div 9 = 60$, while the greatest number of drinks would be $377 \div 6 = 62\frac{5}{6}$ or 62, so the number of drinks to be given out could be 60, 61 or 62.
 - The smallest number of lollies to be given out would be $360 \div 9 = 40$, while the greatest number of lollies would be $377 \div 9 = 41\frac{8}{9}$ or 41, so the number of lollies to be given out could be 40 or 41.

Customers at the milk bar

OPEN-ENDED TASK 1

The first five multiples of 3 are 3, 6, 9, 12, 15. The first five multiples of 2 are 2, 4, 6, 8, 10. The second multiple of 3 is the same as the third multiple of 2. This is the first common multiple of 2 and 3 which is 6.

1. In the opening of a milk bar every 6th customer receives a free drink and every 9th customer gets a free lolly.
 - (a) If 200 customers come into the shop on the first morning how many drinks and lollies were given out? Explain how you got your answer.
 - (b) How many customers received both a drink and a lolly? Explain how you got your answer.

2. During the afternoon, 20 customers received both a drink and a lolly.
 - (a) How many customers could have visited the shop in the afternoon?
 - (b) How many drinks could have been given out.
 - (c) How many lollies could have been given out?



Selling mugs

OPEN-ENDED TASK 2

Forgetful Freddy makes mugs in his Flemington pottery. He makes three sizes:

- a small mug which sells for \$2.25
- a medium sized mug for \$4.50
- a large mug which sells for \$6.75



At the start of the day, he has 200 mugs in the shop and at the end of the day he has 188 mugs, some of which he may have given away for free — he can't remember how many.

If he took \$33.75 for the day, how many mugs of each size did he sell and how many could he have given away?

1: The solar system

Hints

- Find the difference (subtract) the diameters of the orbits of Mercury and Venus from the Earth's diameter.
- Jupiter spins once every 10 Earth hours. Take the number of Earth days in a year to be 365.25
- Find the difference between the temperatures.
- The diameter of a circle is twice its radius.
- Pluto takes 248 Earth days to revolve around the Sun.
- Find the number of Earth days that Mercury spins on its axis and compare it to the number of Earth days in an Earth year.
- Mars is smaller than the Earth. Divide the diameter of Mars by the diameter of the Earth and multiply by 100 to make it a percentage.

Task card p. 92

The solar system **WORDED QUESTION 1**

The Sun is a star whose surface temperature is 6000°C. It is mostly composed of hydrogen and helium.

Mercury is a small planet with a diameter of 4865 km. It spins once every 59 Earth days and its surface temperature is 350°C.

Venus has a diameter of 12 100 km and has an atmosphere of carbon dioxide. Its surface temperature is 480°C.

The Earth's diameter is 12 765 km with an atmosphere mostly of oxygen and nitrogen.

Mars is smaller than the Earth with a diameter of 6760 km and its surface is a reddish colour.


Jupiter is the largest planet in our solar system with a diameter of 142 700 km. It spins very quickly, once every 10 Earth hours.

Saturn is also a huge planet with a diameter of 120 500 km.

Uranus (diameter 47 400 km) has a low surface temperature of -216°C.

Neptune is slightly bigger than Uranus with a diameter of 48 400 km.

Pluto, with a diameter of about half of the Earth's, takes 248 Earth days to complete an orbit around the Sun.



- How much bigger is the Earth's diameter compared to:
 - Mercury?
 - Venus?
- How many times does Jupiter spin in one Earth year?
- How much hotter is the temperature of Venus compared to (a) Mercury? (b) Uranus?
- What is the radius of Pluto?
- How many Earth years does it take for Pluto to complete an orbit around the Sun?
 - Two times?
 - Five times?
 - Ten times?
- What percentage of an Earth year does it take Mercury to spin?
 - Two times?
 - Five times?
- What percentage of the Earth's diameter is Mars's diameter?

Solution

- (a) $12\,765\text{ km} - 4865\text{ km} = 7900\text{ km}$ (b) $12\,765\text{ km} - 12\,100\text{ km} = 665\text{ km}$
- $365.25 \times 24 \div 10 = 876.6$
- (a) $480^\circ\text{C} - 350^\circ\text{C} = 130^\circ\text{C}$ (b) $480^\circ\text{C} - (-216^\circ\text{C}) = 480 + 216 = 696^\circ\text{C}$
- $120\,765\text{ km} \div 2 = 6382.5\text{ km}$
- (a) $2 \times \frac{248}{365.25} = 1.36$ (b) $5 \times \frac{248}{365.25} = 3.39$ (c) $10 \times \frac{248}{365.25} = 6.79$
- (a) $2 \times 59 = 118$, $\frac{118}{365.25} = 32\%$ (b) $5 \times 59 = 295$, $\frac{295}{365.25} = 81\%$
- $\frac{6760}{12\,765} \times 100 = 53\%$

The solar system

WORDED QUESTION 1

The **Sun** is a star whose surface temperature is 6000°C . It is mostly composed of hydrogen and helium.

Mercury is a small planet with a diameter of 4865 km. It spins once every 59 Earth-days and its surface temperature is 350°C .

Venus has a diameter of 12 100 km and has an atmosphere of carbon dioxide. Its surface temperature is 480°C .

The **Earth's** diameter is 12 765 km with an atmosphere mostly of oxygen and nitrogen.

Mars is smaller than the Earth with a diameter of 6760 km and its surface is a reddish colour.

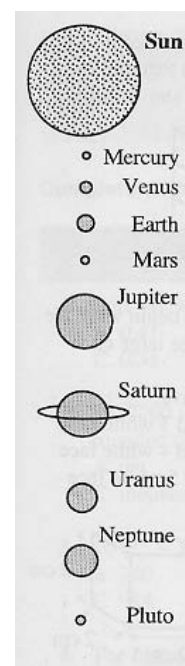
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