Magic Straws

Applying Maths
Case Study

Quick Milk Magic Straws- Fact Sheet

Magic straws are used to flavour milk. There are many different flavours available, such as chocolate, strawberry and vanilla.

The straws are sold in packs of 5, retailing at between 30p and £1 per packet.

The straws are made from plastic and are filled with approximately 2000 balls which flavour the milk as it is drunk. The balls dissolve as the milk is drunk.

The straws are cylindrical with a diameter of 0.5cm and 15cm in length.

Inflation Rates
In the table below are historical inflation rates.

Year	Rate (From previous)
2021	2.6%
2020	0.9%
2019	1.8%

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Question 1

Catlin is interested in the properties of Magic Straws.

a. The capacity of a Magic Straw is the volume of milk that can fit into it before any of the balls have dissolved. Estimate the capacity of one Magic Straw.

Catlin writes down a model for the length of time it takes to drink a glass of milk using a straw.

$$T = \frac{V}{C} \times \frac{D}{S}$$

T is the time (seconds), V is the volume of milk being drunk (ml), C is the capacity of the straw (ml), D is the distance travelled through the straw (cm), and S is the speed at which the milk is sucked (m/s).

b.
i. Show that this is a consistent model.
ii. Use Caitlyn's model to estimate the length of time it would take to drink 250ml of milk using a magic straw.
iii. Suggest one way in which the model could be improved.

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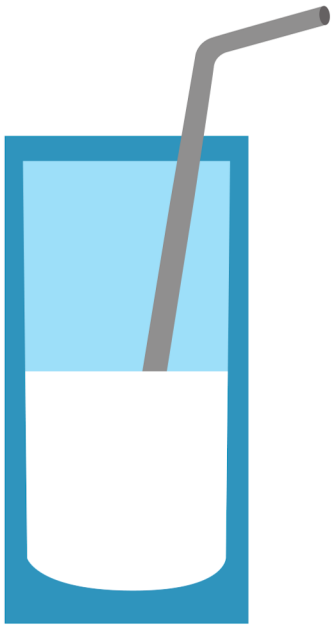
Question 1

Catlin decides to change her model to make it more sophisticated.

$$T = \frac{V}{A} \times \frac{D}{S}$$

Where $A = I + tK$. I is the initial capacity of the straw before any of the balls dissolve, and t is time in seconds. K is the rate at which the volume of balls decrease, measured in centimetre cube per second.

c. Is this a consistent model?



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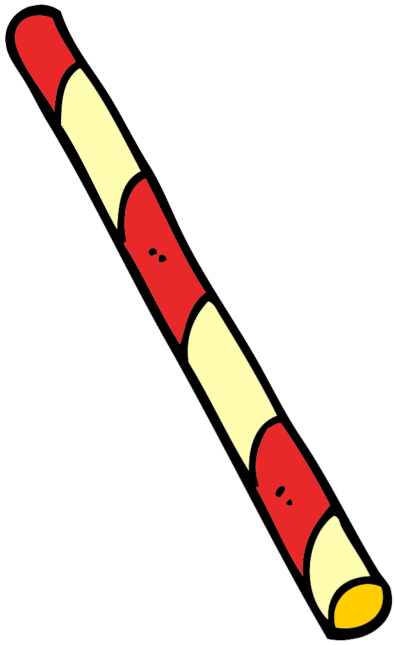
Question 1

Catlin studies the dissolution of the balls, and finds that the volume of each ball reduces by 10% per minute.

d. Describe the relationship between the volume of each ball and time.
e. Copy the axis below and sketch how the capacity of the straw changes over time.



Open the spreadsheet named "Magic Straw Model".

f.
i. Complete the spreadsheet to show how the capacity of the straw changes over time.
ii. Create a plot of capacity and time, and fit a model to your plot.
iii. Use your model to estimate the capacity of the straw after 28 minutes.

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Question 2

The CSV file “MagicPrices.csv” contains the prices of Magic Straws at a random sample of 40 shops, for two different years.

a. Adjust the 2021 prices to take inflation into account.
b. Represent the 2018 and adjusted 2021 amounts in a suitable diagram.

Catlin wishes to see whether prices of Magic Straws have increased significantly above inflation.

c.
i. Calculate the suitable measure of central location and spread for the 2018 and adjusted 2021 prices.

ii. What hypothesis test should Catlin use to compare the prices? State the hypotheses.

iii. Carry out the test and interpret the result.

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Question 3

Caitlin is concerned about the amount of plastic used in Magic Straws.

Caitlin and her friends decide to make their own, plastic free, versions of a Magic Straw. Below is a precedence table of her plan:

Activity	Description	Duration (Hours)	Proceeding Task
A	Purchase ingredients and materials	3	-
B	Make the chocolate balls	3.5	A
C	Make the edible straw	4.5	A
D	Design the packaging	6	A
E	Assemble the straws and put into packaging	2	B, C, D

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Question 3

a. Construct a PERT chart for this project.

b. State the critical path.

c. Explain the meaning of "slack time", using an example from Catlin's project.

d. Represent the project in a Gantt chart.

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Answers

1.
a. The model is the volume of a cylinder, subtract the volume of a sphere multiplied by the number of spheres. You need to estimate the radius of one of the balls. Assuming that the straws are fully packed with spheres of around 1mm diameter, you'll find the capacity of around 2ml.

b.i. One way to see this is to note that V and C have the same units, so the first fraction cancels. The second fraction is a distance divided by a speed, which will result in a time (in this case seconds).

b.ii. (250ml / 2ml) x (15cm/0.4m/s) =312.5s, so about 5 minutes. You'll need to estimate the speed at which the liquid travels through the straw. Here I use 0.4m/s. Your answer will vary!

b.iii The model doesn't take into account the fact that the capacity of the straw actually changes over time as the balls dissolve.

c. This model is consistent. A would be measured in cm cubes or ml, just like V.

d. The relationship is one of exponential decay.
e. You will replicate this graph in part f, see the answer spreadsheet below after you've finished part f.

f. See the spreadsheet "Magic Straw Model Answers." For part iii your answers will vary. Substitute 28 into the model you produce.

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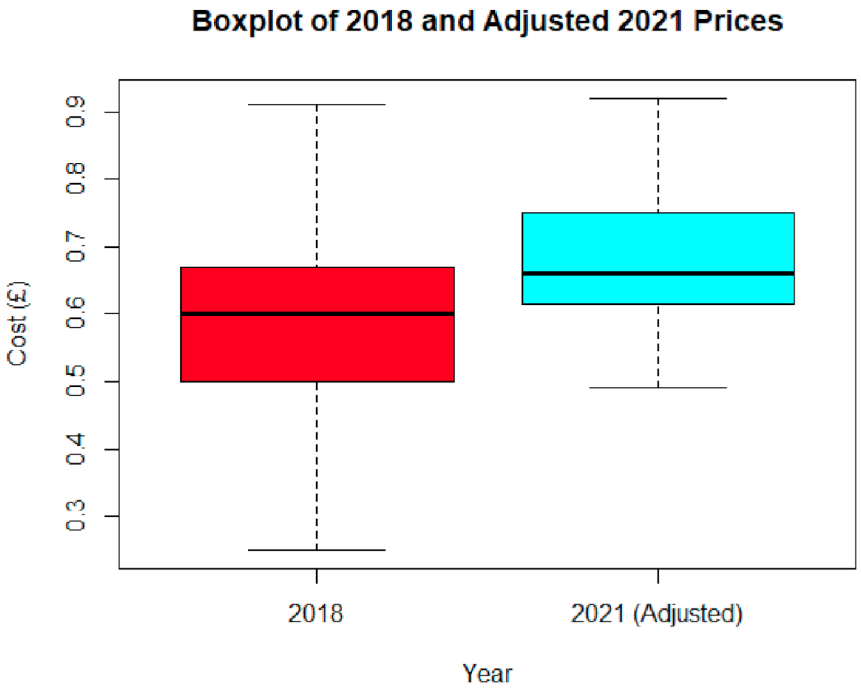
Answers

2.
a. See the csv file "MagicPricesAnswers.csv" for one way to do this.
b. A boxplot would be best.
c.i. Mean and standard deviation as normal data.



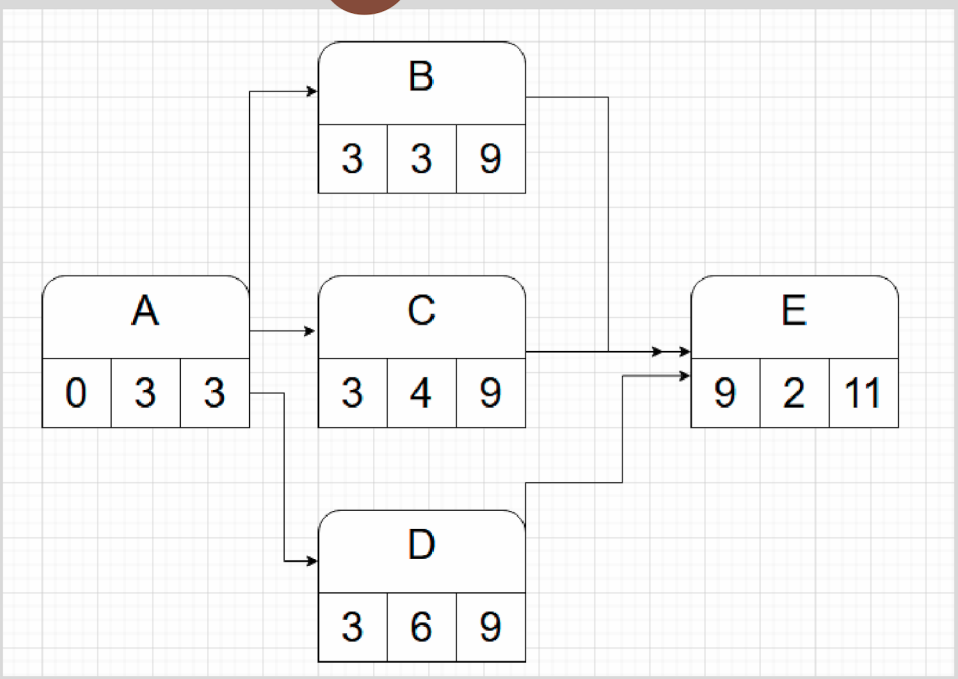

```
> mean(magic$X2018...., na.rm = TRUE)
[1] 0.60175
> mean(magic$X2021.....Adjusted., na.rm = TRUE)
[1] 0.68375
> sd(magic$X2018...., na.rm = TRUE)
[1] 0.1435071
> sd(magic$X2021.....Adjusted., na.rm = TRUE)
[1] 0.09828497
```

ii. Paired t-test. Null- No difference between the means. Alt- There is a difference between the means.
iii. p-value is less than 5% so reject the null hypothesis. The prices have risen a statistically significant amount, even allowing for inflation.

Answers

3.

a.



app.diagrams.net

b. ADE

c. Slack or float time - the time an activity can be delayed without delaying the project as a whole. e.g. Activity B has 3 hours of slack time.

d. e.g.

	Hours										
Activity	1	2	3	4	5	6	7	8	9	10	11
A											
B											
C											
D											
E											