Higher Applications Task Booklet

APPLYING MATHS

by Bryn Jones, Newbattle High School

TASK 1 - THE SKY DIVE

Task 1

Ethan plans on doing a sky dive for charity later this year. In order to do the skydive, he needs £550. Ethan has received 50 donations, with the average donation amount being £8.50.

(a) How much money does Ethan need to make up the short-fall? (1)

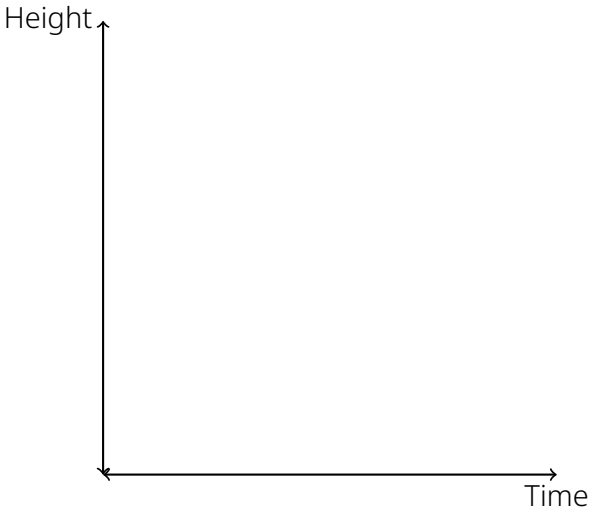
Ethan currently has £125 in his savings account. His account pays 0.3% interest **per month**.

(b) Calculate the balance of the savings account after 5 months. (2)

A parachute jump has two phases: First the jumper will leap from the plane at around 14,000 feet and free fall, then after around 50 seconds the parachute is pulled. The entire jumps takes around 6 minutes.

Task 1 continued on next page…

(c) Sketch a graph showing the height of jumper over time. (3)



Ethan reads the following text from a journal:

"Of 174 patients with injuries of varying severity, 94% were first-time charity-parachutists. The injury rate in charity-parachutists was 11% at an average cost of £3751 per casualty. Sixty-three percent of casualties who were charity-parachutists required hospital admission, representing a serious injury rate of 7%, at an average cost of £5781 per patient." [1]

(d) Create a statistical diagram to represent some of the information above. (3)

END OF QUESTION SET.

[1] https://doi.org/10.1016/s0020-1383(99)00083-2

TASK 2 - SAHIL'S HOLIDAY

Task 2

Sahil is going on holiday. Three years ago Sahil placed £1500 in a three year bond. The bond paid 0.23% interest **per month** for the first 2 years, and then paid 5% interest for the final year.

*(a) How much **interest** did Sahil earn over the three year period? (3)*

Sahil shops around for some travel insurance. Below are the key features of a travel insurance policy:

Key Features

Medical Expenses: Covers emergency medical treatment and hospitalisation abroad.
Trip Cancellation: Reimburses non-refundable trip costs due to unforeseen events.
Baggage and Personal Belongings: Compensation for lost, stolen, or damaged baggage.

Exclusions
Pre-existing Conditions: No coverage for pre-existing medical conditions.
High-Risk Activities: Excludes extreme sports (e.g., skydiving, bungee jumping).

Pricing
£55 for the single trip: Pay upfront for the entire trip duration.

Task 2 continued on next page…

*(b) Give **three** reasons why Sahil might decide to not purchase this policy. (3)*

Sahil researches travel insurance and finds the following information from the ABI [2].

Our data highlights the following trends in 2022:

- The number of claims and payouts rose significantly. Travel insurers handled 362,000 claims, up 148% from 2021. Total claim payouts, at £352 million, leapt by 230% compared to the £107 million paid in 2021.
- The average claim reached a record high of £973, up 33% from the previous year—the highest since data collection began in 2004. Emergency medical treatment claims averaged £1,750, a 26% increase and also a record high.

Emergency medical treatment costs can be astonishingly high. For instance:

- A traveller visiting Thailand suffered a serious blood infection requiring intensive medical treatment and an air ambulance back to the UK. The total bill amounted to £250,000, covered by the travel insurer.
- In Spain, a holidaymaker needed private medical treatment for a kidney infection, incurring costs of £15,000—also covered by travel insurance.

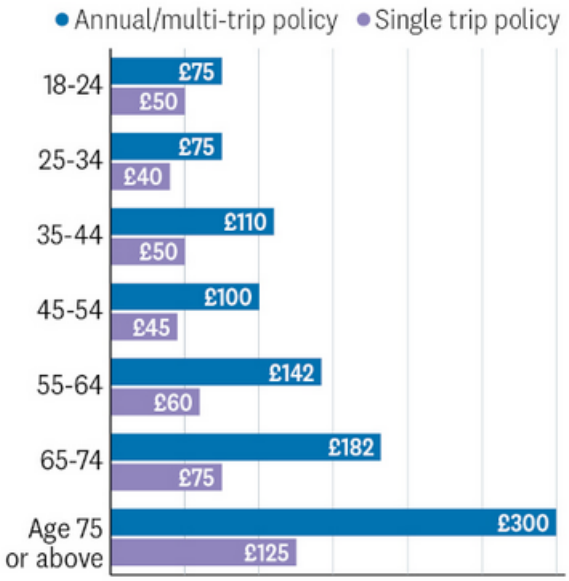
(c) The ABI quote an average of £973. Which average is this- the mean or the median? Show your working. (2)

(d) Which average would be higher- the mean or the median? Explain how you know. (1)

[2] From the ABI- 2022 travel insurance data

Task 2 continued on next page…

Sahil wonders whether the cost of travel insurance changes depending on one's age. He finds the following graph[3].



(e) Interpret the graph: to what extent are age and travel insurance cost related? (1)

Sahil converts £1600 into Euros using an exchange rate of 1.17 €/£. He spends an average of €305 a day for 5 days. He converts his remaining back to pounds with an exchange rate of 1.13 €/£.

(f) How much money will Sahil have remaining? (1)

END OF QUESTION SET.

[3]Source: Restless

TASK 3 - GET BUILDING

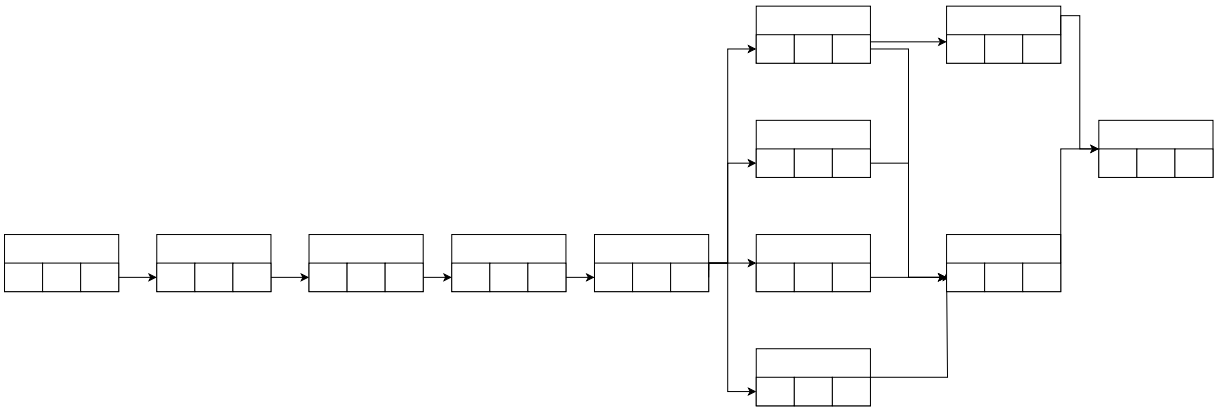
Task 3

A construction company are building a home. Part of their project is represented in the precedence table.

Activity	Description	Predecessor(s)	Duration (days)
A	Site preparation	None	5
B	Order construction materials	A	2
C	Delivery of construction materials	B	3
D	Foundation work	C	10
E	Framing	D	15
F	Roofing	E	5
G	Electrical wiring	E	8
H	Plumbing	E	7
I	HVAC installation	E	12
J	Interior finishing	F, G, H, I	20
K	Exterior finishing	F	10
L	Obtain occupancy permit	J, K	3

Task 3 continued on next page…

(a) Copy and complete the PERT chart. (3)



The delivery of the constructions materials could be delayed. The company estimates there is a 10% probability of delay due to issues with transportation, and a 12% probability of delay due to sourcing the materials. These two events are considered **independent**.

(b) Explain what is meant by the phrase 'independent events'. (1)

(c) Represent this information in a tree diagram, and calculate the overall probability of a delay. (3)

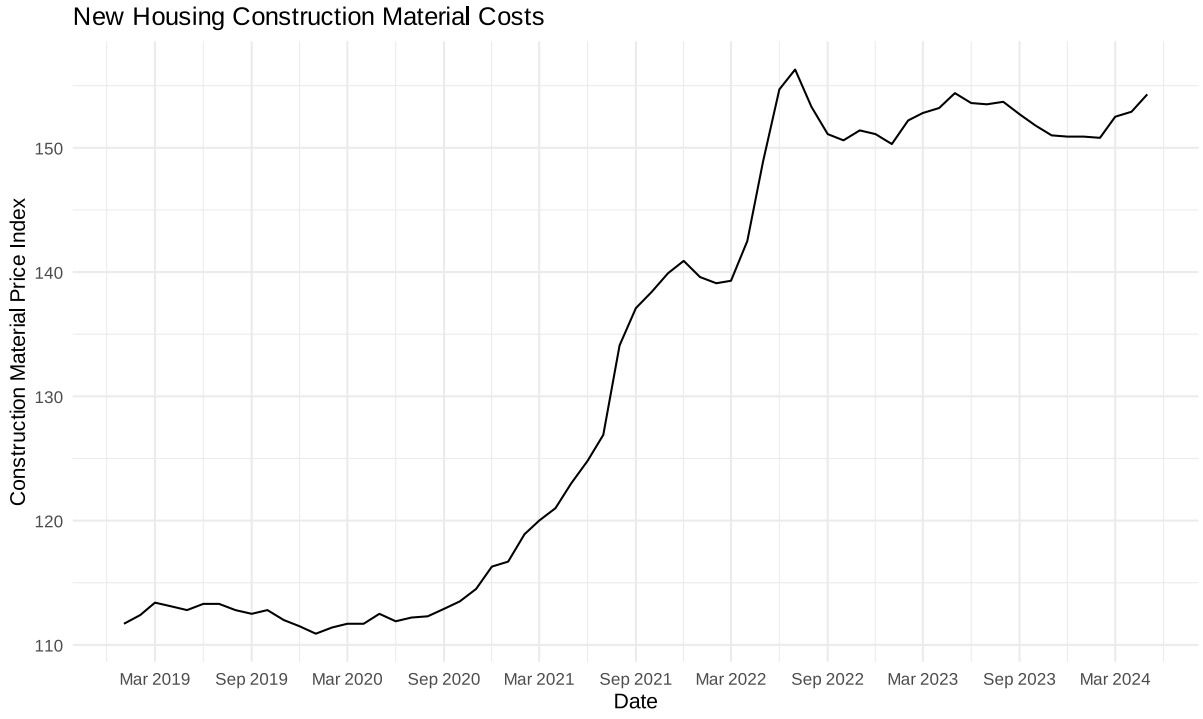
Task 3 continued on next page…

If the delivery is delayed it will cost the company £6000 in wasted wages. The company have two options:

1. Option 1 - Insure themselves against delay. This will cost £1200 but the company will not lose any money if a delay happens.
2. Option 2- Don't take out insurance against delay.

(d) By calculating the expected cost of option 2, explain which option you would recommend the company take. (1)

The cost of construction materials for new housing varies over time. The graph below comes from data from the Department for Business and Trade, a government department.[4] The index uses 2015 as a base year, 2015 = 100.



[4] https://www.data.gov.uk/dataset/75ee36ed-21f7-4d7b-9e7c-f5bf4546145d/building-materials-and-components-statistics

Task 3 continued on next page…

(e) Describe how the cost of new housing construction materials changed between March 2019 and March 2024. (1)

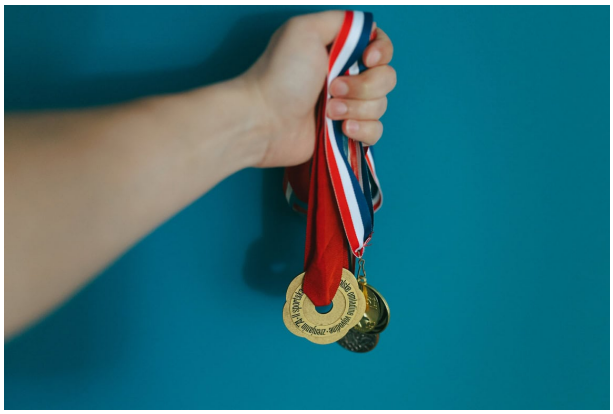
(f) Estimate the rate of inflation between March 2019 and March 2024 for new housing construction materials. (1)

(g) What type of mathematical model is the most appropriate for modelling inflation? Linear or Exponential? Give a reason for your answer. (2)

END OF QUESTION SET.

TASK 4 - SCHOOL SPORTS DAY- AN ERROR SPECIAL

Task 4



It's the school sports day. The high jump pole has been set at $185\,cm$. The error of the height measurement is $2\,cm$.

(a) Calculate the relative error of the height measurement. (1)

One of the events is the discus throw. The discus used for the sports day is circular, and weighs $0.5\,kg$ with a diameter of $18\,cm$.
The error of the mass measurement is 2%.
The error of the diameter measurement is 1%.

(b) Calculate the absolute error of the mass measurement. (1)

(c) Calculate the circumference of the discus. State the maximum and minimum it could be. (2)

Task 4 continued on next page…

The winner of the $1500\,m$ runs the race in 6 minutes and 35 seconds. The distance of the track has a absolute error of $50\,cm$. The time has an absolute error of half a second.

(d) Calculate the relative errors for the distance and the time. (2)

(e) Calculate the average speed of the winning runner. Estimate the relative error of this calculation. (2)

Emily has a method for estimating her heart rate: Count the number of times her heart beats over 6 seconds, and then multiply this number by ten.
Emily uses this method and counts 12 beats in 6 seconds.

(f) Assuming Emily has a half-second error in measuring the time, calculate her heart rate and estimate the relative error. (2)

(g) What's the highest heart rate Emily could have? (1)

END OF QUESTION SET.

TASK 5 - MUSIC CONCERT

Task 5

Taylor Series, a well-known pop musician, is coming to town. Below is a precedence table for setting up a music concert.

Activity	Description	Precedence	Duration
A	Obtain necessary permits and licenses	None	2 days
B	Schedule venue rental and equipment delivery	A	2 days
C	Train staff (security, ushers, etc.)	B	8 days
D	Prepare stage and sound equipment	B	5 days
E	Set up lighting and visuals	D	2 days
F	Install seating or standing areas	C & E	3 days
G	Decorate and brand the venue	F	3 days

(a) Complete a Gantt chart for this table, and state the critical path. (4)

Task 5 continued on next page…

Drinks are regularly sold at music concerts.

(b) Estimate the number of litres of drinks sold at one large venue performance by Taylor Series. (3)

Andrew comes up with a model for predicting the number of Taylor Series tickets that will be sold in a given city:

$$T = U \times P - H$$

where T is tickets sold, U is the percentage of the city that is under 30, P is the population of city, and H is the number of hotels in the city. Using his model, he expects sales of 31,245 tickets.

(c) State the dependent variable is this model. (1)

*(d) Give **two** reasons why you should be sceptical about this prediction. Explain your reasoning clearly. (2)*

Task 5 continued on next page…

Kodi is saving up for Taylor Series tickets. Kodi deposited £100 in a variable rate savings account on 1 January 2023. The effective rates of interest for the savings account are:

Dates	Interest rate
1 January 2023 to 31 March 2023	0.315% per month
1 April 2023 to 31 December 2023	3.7% per year
From 1 January 2024	4.6% per year

(e) Calculate Kodi's balance on 1 July 2023 (2)

On 1 July 2023 Kodi deposits £150.
On 1 January 2024 Kodi deposits £50.

(f) Calculate Kodi's balance on 1 March 2024 (2)

Kodi needs to buy her tickets on 1 September 2024. Concert tickets are £550. Kodi makes a final deposit on 1 March 2024.

(g) Calculate the minimum deposit Kodi needs to make to be able to afford the tickets. (1)

END OF QUESTION SET.

TASK 6 - GALAPAGOS TORTOISES

Task 6

Conservationists are interested in finding out the population of Galapagos tortoises on an island. The island is approximately 52 square kilometres, rounded to the nearest square kilometre.

In one square kilometre off the island, there are 11 Galapagos tortoises. One conservationist estimates there will be around 570 tortoises on the island.

(a) Explain why this figure may not be reasonable. (2)

The conservationists take a random sample of Galapagos tortoises and make a note of their mass, and well as whether they came from the North or South of the island.

(b) What type of data is mass? (1)

Task 6 continued on next page…

The conservationists wish to explore whether there is a difference in the mean mass of tortoises from the north and the south.

(c) State the null and alternative hypothesis, and name the correct hypothesis test to use. (2)

The output from their test is given below:

```
    data:  north and south
t = 1.2898, df = 474.69, p-value = 0.1978
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -2.238492 10.790832
sample estimates:
mean of x mean of y
 230.4204  226.1442
```

*(d) Interpret the p-value **and** confidence interval for this test in context. (3)*

A conservationist says "There is a 3.6% probability that we will make a type II error."

(e) Explain what a type II error would be in this context. (2)

The conservationists estimate the current population of Galapagos tortoises is **250**. Each year, the population decreases by **10%** due to natural causes like predation and old age. However, a successful conservation effort leads to the birth of **30** new tortoises annually.

(f) Complete the spreadsheet 'Galapagos' to find the population after 25 years. Produce a suitable graph to show the change over time, and include labels. (5)

Answer on the spreadsheet.

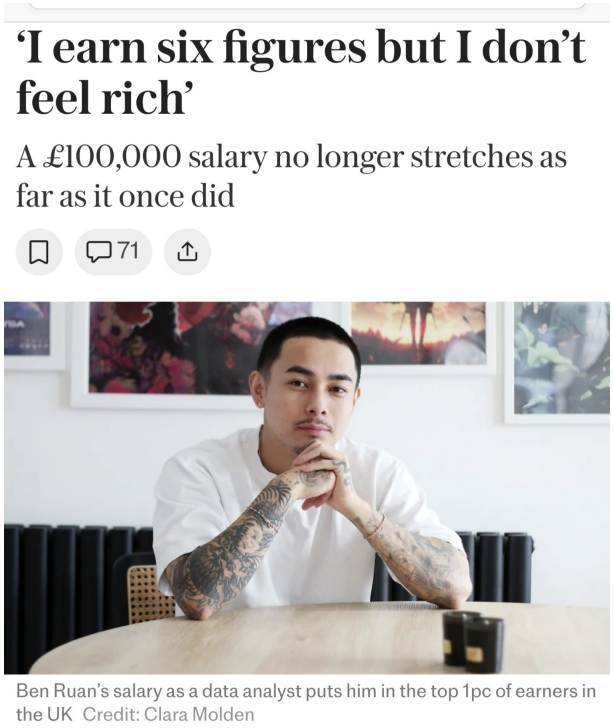
The cost of the project is currently £240,500 per year.

(g) Estimate the cost of the project in its 25th year. State any assumptions you make. (3)

TASK 7 - £100K VERSUS MINIMUM WAGE

Task 7

A recent article in The Telegraph ran with the following headline:



‘I earn six figures but I don’t feel rich’

A £100,000 salary no longer stretches as far as it once did

71

Ben Ruan’s salary as a data analyst puts him in the top 1pc of earners in the UK Credit: Clara Molden

For this task we’ll investigate the net pay for workers earning minimum wage, compared with £100,000.
Current information about income tax and National Insurance can be found in the most recent **Data Booklet**.
The current minimum wage can be found at: https://www.gov.uk/national-minimum-wage-rates

(a) Calculate the annual salary of a person over the age of 21, who works 35 hours a week at minimum wage. (1)

Task 7 continued on next page…

*(b) Assuming the person pays 20% of their **gross pay** into a pension, calculate the income tax for a person earning the minimum wage in Scotland. (3)*

*(c) Hence calculate their monthly **net pay**. (3)*

Now consider an earner with a salary of £100,000.

*(d) Again assuming the person pays 20% of their **gross pay** into a pension, calculate the income tax for a person earning £100,000 in Scotland. (3)*

*(e) Hence calculate their monthly **net pay**. (3)*

Task 7 continued on next page…

You can use online tools to find your expected net pay. For example, The Salary Calculator. These calculators can also take into account things like student loans.

A researcher is interested in the salaries in the UK. She takes a random sample of 1000 people and produces a histogram.

(f) What type of distribution would you expect that data to have? Explain your answer. (3)

A journalist says "The top earning 10% of UK tax payers contribute around £166 billion a year. That's about the same as Finland's national debt."

(g) Explain why this is not a valid comparison. (1)

END OF QUESTION SET.

ANSWERS

Task 1

(a) £125

(b)
- 1.003 as the multiplier.
- £126.89

(c)
- Steep drop, then slower drop.
- Numbers on axis: 14,000 and 50 seconds/360 seconds.
- Curve for first drop, line for second.

(d)
- Categorical data on a pie chart or bar chart. Or otherwise suitable chart choice.
- Axis labels and titles.
- Information does in fact reflect a fact from the journal.

Task 2

(a)
- $£1500 \times 1.0023^2 4 (= 1585.03)$
- $£1585.03 \times 1.05$
- £164.28. Remember to subtract the original £1500 to find the **interest**.

(b) For example: He might prefer multi-trip cover if he is planning to travel again; he might plan on doing some extreme sports, he might have a medical condition.

(c) If it was the mean, then $£973 \times 362000$ (that's the average multiplied by the number of claims) would equal the total paid out (£352 million). It does, so they have used the mean.

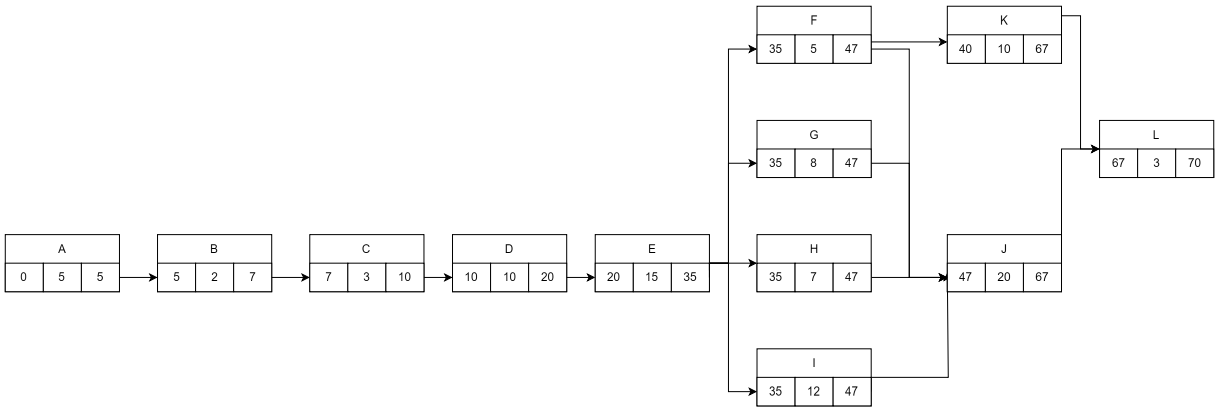
(d) The mean would be the higher average. Because some medical claims can be extremely high, these claims would be outliers skewing the mean.

(e) Generally, as age increases so does the cost of insurance. The exception to this is to 18-24 age group who are considered a higher risk than the 25-34 group.

(f) £307.08

Task 3

(a) See the diagram:



- All the activities and durations correct.
- Forward scan correct.
- Backward scan correct.

(b) Two events are independent if the occurrence of one event does not affect the probability of the occurrence of the other event. In other words, one event happening has no bearing on the probability of the other event happening.

(c)
- Diagram drawn correctly.
- Either: Probability of no delay 79.2%, or the other branches complete (1.2%, 8.8%, 10.8%).
- There is a 20.8% probability of a delay.

(d) $20.8\% \times £6000 = £1248$. Option 1 is slightly cheaper.

(e) The cost has increased over time. Between September 2020 and September 2022 it rose sharply, at other times it seemed more stable.

(f) Estimate March 2024 around 153, and March as around 114. Approximately 34% increase.

(g)
- Exponential.
- Prices do not increase by a fixed amount each month (linear), or prices tend to increase by a percentage amount. It's worth noting the Bank of England target of 2% inflation- if the target was met inflation would be a perfect exponential curve. Also accept: A linear model could imply negative prices if you go back far enough.

Task 4

(a) $\frac{2\,cm}{185\,cm} \approx 1.08\%$

(b) $2\% \times 0.5\,kg = 0.01\,kg = 10\,g$

(c)
- $\pi \times 18\,cm \approx 56.55\,cm$
- Max is approximately $57.11\,cm$ and min is approximately $55.98\,cm$. Remember those units!

(d)
- Distance: 0.033%

- Time: $0.5 \div 395 \approx 0.13\%$

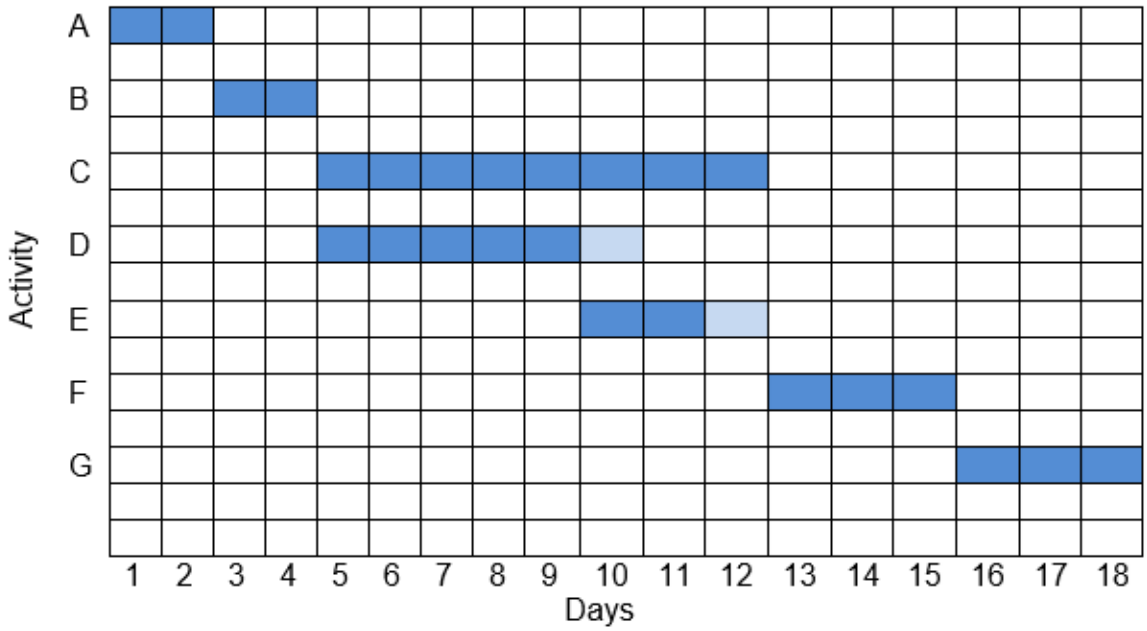
(e)
- Speed: $3.80\,ms^{-}1$
- Relative error: $0.033\% + 0.13\% = 0.163\%$.

(f)
- The heart beat has an absolute error of 0.5, this is a relative error of about 4.17%. The relative error of the time is about 8.33%.
- $12 = 120$ bpm. With a relative error of 12.5 %.

(g) 135 beats per minute using the relative errors from the previous question. Also acceptable: $12.5 \times \frac{60}{5.5} \approx 136$.

Task 5

(a) Gantt:



- Correct labels on axes.
- Activities A, B and C correct.
- Activities E, F and G correct.
- Critical path: ABCFG.

(b)
- Assumption about number of attendees. (e.g. 20000)
- Assumption about drink size. (e.g. $500\,ml$)
- A proportion of the number of attendees, multiplied by the drink size. (e.g. $80\% \times 20000 \times 500\,ml = 8000000\,ml = 8000l$.

(c) T, the number of tickets sold.

(d)
- The answer given is too precise.
- The units of the model are not consistent.

(e)
- Begin calculation: $£100 \times 1.00315^{\cdots} \times 1.037^{\cdots}$
- Complete: $£100 \times 1.00315^{3} \times 1.037^{\frac{3}{12}} = £101.87$

(f)
- 1 Jan 2024: $£251.87 \times 1.037^{\frac{6}{12}} + £50 = £306.49$
- 1 March 2024: $£306.49 \times 1.046^{\frac{2}{12}} = £308.79$

(g)
- $£550 \div 1.046^{\frac{6}{12}} = £537.77$. So £228.98 required.

Task 6

(a) e.g.

- Sampling just one area is too small a sample.
- The density of tortoises might vary across the island.
- They will be error in the calculation.

(b) Continuous Numerical.

(c)
- Null: There is no difference between the mean mass of northern and southern tortoises. Alternative: There is a difference between the mean mass of northern and southern tortoises.
- The correct test is a unpaired t-test.

(d)
- P-value is 0.1978 which is greater than 5%.
- Fail to reject the null hypothesis and conclude there is no significant difference between northern and southern tortoise mass.
- We can be 95% confident that the true difference in the means lies between -2.2 and 10.79. Zero difference is plausible as zero lies within the that range.

(e)
- A false negative, or failing to reject the null hypothesis when the null hypothesis is in fact false.
- Believing there is no difference in mean mass between northern and southern tortoises, when in fact there is a difference.

(f) See the spreadsheet.

- 90%
- Cell C12 contains "`C11*$C$6+$C$7`"
- the INT function is used, "`INT(C11*$C$6+$C$7)`" and the spreadsheet is extended down to year 25.
- Suitable graph.
- Title and axis labels.

(g)
- Assumption about inflation rate: anything suitable. e.g 5%
- Assumption that inflation, costs remain fixed. Or some other assumption about how costs may change.
- New rate found, e.g. $£240500 \times 1.05^{25} = £814418.36$

Task 7

(a) $Rate \times 35 =$ (£20820.80 in 2024)

(b) To check your answers, use the "Higher Applications of Maths Deductions from Salary Calculator." Below are 2024 numbers.

- Remove pension first: £16656.64
- 19% rate: £410.78
- Income tax £795.71

(c)
- Begin finding NI rate: e.g. taxable income £158.40 a week
- Total NI annual: £988.52

- Monthly net pay: £1239.37

(d)
- Remove pension first: £80000
- Begin finding bands: e.g. 410.78
- Income tax £21638.48

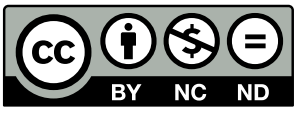
(e)
- Begin finding NI rate: e.g. £87, £19.12
- Total NI annual: £5518.24
- Monthly net pay: £4403.61

(f)
- Skewed
- Right tail or equivalent
- Likely to have outliers at the top end, could make reference to a minimum wage but no "maximum wage".

(g) Units are not consistent: The UK tax payers contribute in "currency per year", whereas debt is measured in "currency."

CREDIT

Images from Unsplash
Questions by Bryn Jones, Newbattle High School.



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