QUANTUM TECHNOLOGY SCHOOL 2021

ACADEMIC PACK

PART 3: THINKING LIKE A PHYSICIST: TEACHERS PACK

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2.1 How many beads?

The two best ways to estimate the number of beads is by volume or by mass.

You'll need measuring scales, rulers and XXX

By volume:

- Jar is a cylinder, diameter 42.0 mm and height 113 mm. This gives a jar volume of 1.57 x10^5 mm^3.
- Beads are cylinders of diameter 4.5 mm and height 4.5 mm, giving a volume of 7.16 x 10^1 mm^3.
- So the number of marbles estimated this way is …

$$Number_{By\ volume} = \frac{1.57 \times 10^5}{7.16 \times 10^1} = 2.19 \times 10^3$$

So, thousands of beads.

By mass:

- Mass of full jar = 161 g
- Mass of empty jar = 127 g
- So, mass of all beads = 34 g

- Mass of 1 bead (using electronic scales) = too small to measure
- We've given you a small quantity of loose beads – depending on the scales you have they may be enough to give you a mass for each bead. Alternatively, you can take some out of the jar, though be warned – I have learned from bitter experience that THEY GO EVERYWHERE!
- As an example, though, Mass of 100 beads = 4 g, so take mass of 1 bead to be 4 x 10^{-2} g
- So, the number of beads estimated this way is …

$$Number_{By\ mass} = \frac{34}{0.04} = 850$$

- So, here we get hundreds of beads, though we are getting close to thousands again.

By counting:

- A manual count of one of the jars found it to contain 789.
- Mass-based estimation gives a closer result, though in terms of the nearest order of magnitude (1000s) they are in agreement, and that's what is key for these estimations.
- The mass probably works better than volume, as the beads are not in the optimum packing configuration, so there is a lot of wasted volume. Whilst the beads are not solid cylinders, the fraction of their "body" that is empty is relatively low.

2.2 Glasgow University Estimation Skills Survey – GUESS

For each question I have provided what I believe to be the correct answer, along with an explanation of the logic of how I arrived at that answer. Understanding the logic is possibly more important that the answer, as learning to approach this sort of question logically can take a lot of the anxiety of tackling any question, whether it's a research question, or an exam question.

1. What is the temperature of a freshly made cup of tea?

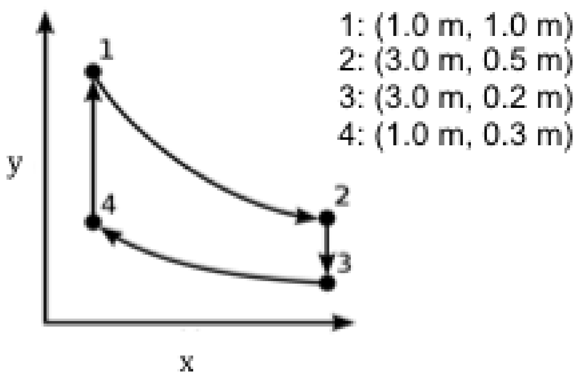
A. 40 °C
B. 55 °C
C. 85 °C
D. 100 °C
E. 110 °C
ANSWER: C

The key here is ruling out the impossible:

- A and B unlikely – “Freshly” made means its just made, and it is unlikely a cuppa would cool down so much so fast – your own experience helps here.
- Real kettles cut out at boiling point of water, so E unlikely.
- The moment the kettle cuts out, the temperature of the water will start dropping. So D is unlikely.

3. Estimate the area inside the shape formed by points 1, 2, 3 and 4 given the following coordinates:

A. 0.05 m^2
B. 0.30 m^2
C. 1.00 m^2
D. 1.50 m^2
E. 3.00 m^2
ANSWER: C



- Roughly rectangular.
- x length is 2.0 m
- Average y length is (0.7+0.3)/2=0.5
- Giving area of roughly 2 x 0.5 = 1 m^2

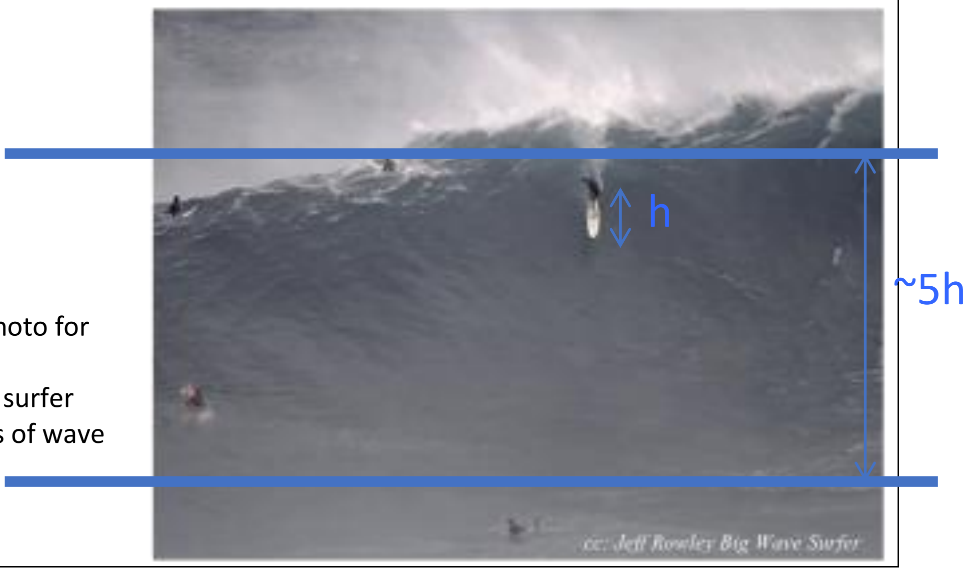
5. What is the volume of a standard city bus?

A. 30 m^3
B. 70 m^3
C. 100 m^3
D. 150 m^3
E. 200 m^3
ANSWER: B

- Roughly cuboid, with a square cross section.
- Height/width around 2.5 m – compare to size of person or width of road lane.
- Estimate length around 10 m
- Gives volume of ~2.5 x 2.5 x 10 ~ 62.5 m^3

7. Estimate the height of the wave in this photo.

A. 2 m
B. 3 m
C. 6 m
D. 10 m
E. 20 m
ANSWER: D



- Use people in photo for scale
- Assume 2 m tall surfer
- Take boundaries of wave to be as shown.

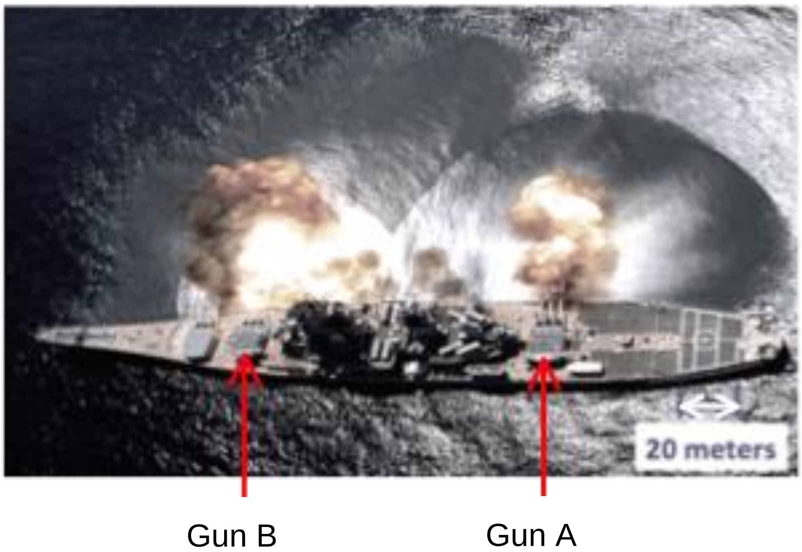
9. Estimate the surface area of the UK.

A. 2×10^3 km
B. 2×10^4 km
C. 2×10^5 km
D. 2×10^6 km
E. 2×10^7 km
ANSWER: C

- Make use of the scale
- Decide on an approximate shape – rectangle or triangle – and then estimate sides. (Really shape is somewhere in between, so the area will fall between the values for each.)
- Whichever shape you take, the "x" and "y" will be the same
- Only difference in the area will be a factor of 2, which doesn't matter given the available answers
- Dimensions: ~ 400 kms by ~ 800 kms gives 1.6×10^5 km^2 or 3.2×10^5 km^2

11. The picture shows a battleship in water firing two test shots. Gun A fires, then Gun B. The snapshot was taken 0.01 s after Gun B was fired. Estimate the time interval between the firing of Gun A and Gun B on the battleship.

A. 0.1 s
B. 0.01 s
C. 0.02 s
D. 0.001 s
E. 0.005 s
ANSWER: B



- The radius of the shockwave from Gun A is roughly twice that of Gun B, suggesting the time since it was fired is twice that since Gun B was.
- Interval is then the same as the time after Gun B fired.

13. What is the approximate height of the Hotel Vancouver?

A. 50 m
B. 100 m
C. 130 m
D. 160 m
E. 200 m
ANSWER: B

- Estimate the *average* height of a floor in the hotel.
    - Lower floors look bigger than a "normal" floor
    - Tall roof space
- Estimate the number of floors
- ~24 floors with average height of ~4 metres gives ~ 100 m

15. What is the thickness of a single sheet of standard photocopy paper?

A. 0.1 mm
B. 0.01 mm
C. 0.001 mm
D. 0.005 mm
E. 0.00025 mm
ANSWER: A

- Measure something bigger and divide down
    - A ream (500 sheets) is 4.5 cm
- Gives ~1×10^{-4} m = 0.1 mm

17. How much time does it take to drive from Glasgow to London on the motorway network? (Assume NO stopping, and no roadworks!)

A. 3 hours
B. 7 hours
C. 10 hours
D. 15 hours
E. 20 hours
ANSWER: B

- Start with scale to approximate distance
  - ~600 km = 375 miles
- *Max* legal limit on motorway = 70 mph
- Gives time of ~5 hours; since can't always drive at 70 mph, 7 hours a better estimate

19. What is the pressure, approximately, inside a typical party balloon?

A. 0.7 atm
B. 3.0 atm
C. 1.0 atm
D. 1.1 atm
E. 10 atm
ANSWER: D

- The key here is ruling out the impossible:
  - Balloon would likely pop if B or E were the answer.
  - If A was the answer, balloon would appear wrinkled.
  - C and D the only reasonable answer; since it takes effort to inflate, likely pressure will be a bit greater than atmospheric.

The "how many teachers" one we'll tackle at the "Thinking Like a Physicist" presentation.