University of Glasgow

QUANTUM TECHNOLOGY SCHOOL 2021

ACADEMIC PACK

PART 3: THINKING LIKE A PHYSICIST

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I wonder what it means to "think like a physicist"? Well, "wondering" is in itself the key. Every physicist – well, okay, every scientist, but all science is just branches of physics after all – has wondered about something. Lord Kelvin wondered how you could send electronic signals across the Atlantic; Jocelyn Bell Burnell wondered what the repeating signals in her data meant; Isaac Newton wondered why apples kept falling on his head …

They wondered, wondered, wondered … and one of the interesting things about wondering, is that it very rarely leads to a precise answer. And yet one of the things that often draws people to physics is that there is always a definitive answer to any question. And whilst that is true to a certain extent … well, "a certain extent" contains a whole lot of uncertainty. The reality is that NO question in physics can ever be answered precisely, only to an acceptable level of uncertainty.

Becoming comfortable with that uncertainty is one of the first steps to thinking like a physicist. This Part of the QTS gives you a chance to explore this in both a hands-on way, and a more theoretical manner.

2.1 How many beads?

How many beads are there in the jar? To get a precise, exact answer you would need to count all of those beads. But that would take a considerable amount of time, and indeed patience.

Can you think of a way you could estimate how many beads are in that jar? What would be useful properties to measure to help you with that estimation?

This may seem like a pointless task, but it illustrates how *every* scientific project begins. Once a physicist has started to wonder about something, the first thing they do is work out roughly what the answer may be – they estimate the answer. Then, and only then, can they go about the detailed planning of their experiment that would provide a precise answer (and maybe even a Nobel Prize!). That initial estimation is about determining the order of magnitude of the unknown result – is it 100s, 1000s, millionths …?

If you can look at this jar and go "I don't know how many there are exactly, but here's how we could work it out roughly" then you are thinking like a physicist …

2.2 Glasgow University Estimation Skills Survey – GUESS

In this section, we are going to expand on the idea of finding estimated answers to questions.

Below are a series of questions[1] which cannot be answered precisely with the tools you have immediately to hand, only *estimated.* Each question comes with 5 possible answers – your task is to decide which one you *believe* is correct. You are also then asked to consider how confident you are in that belief.

If you are working in groups in class, try answering the questions individually, then discuss your answers with your classmates. Do you all agree? It is not always the case that there is only one answer to the questions set. How you approach each question depends on your own experience and knowledge; how you apply those could lead to you getting a different result from a classmate, but without either of you being wrong. Remember – all of these questions are uncertain – you are *estimating* an answer.

Something else to consider before you tackle the questions – in this sort of multiple-choice exercise, tackling the questions is as much about ruling out answers that can't be correct, as it is finding the one that could be. Being able to do that with confidence is also part of thinking like a physicist …

[1] Adapted from the work of A.J. MacDonald, S. A. Burke and C. E. Heiner at the University of British Columbia, Vancouver, BC, Canada

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

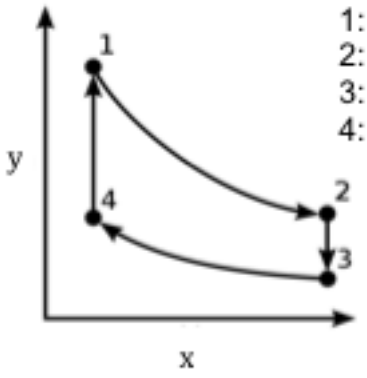
A. 40 °C
B. 55 °C
C. 85 °C
D. 100 °C
E. 110 °C

2. How confident are you in your answer for Question 1?

A. Very confident
B. Somewhat confident
C. Not so confident
D. Not confident
E. Complete guess

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

1: (1.0 m, 1.0 m)
2: (3.0 m, 0.5 m)
3: (3.0 m, 0.2 m)
4: (1.0 m, 0.3 m)



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

4. How confident are you in your answer for Question 3?

A. Very confident
B. Somewhat confident
C. Not so confident
D. Not confident
E. Complete guess

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. $200\ m^3$

6. How confident are you in your answer for Question 5?

A. Very confident
B. Somewhat confident
C. Not so confident
D. Not confident
E. Complete guess

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

8. How confident are you in your answer for Question 7?

A. Very confident
B. Somewhat confident
C. Not so confident
D. Not confident
E. Complete guess

9. Estimate the surface area of the UK.

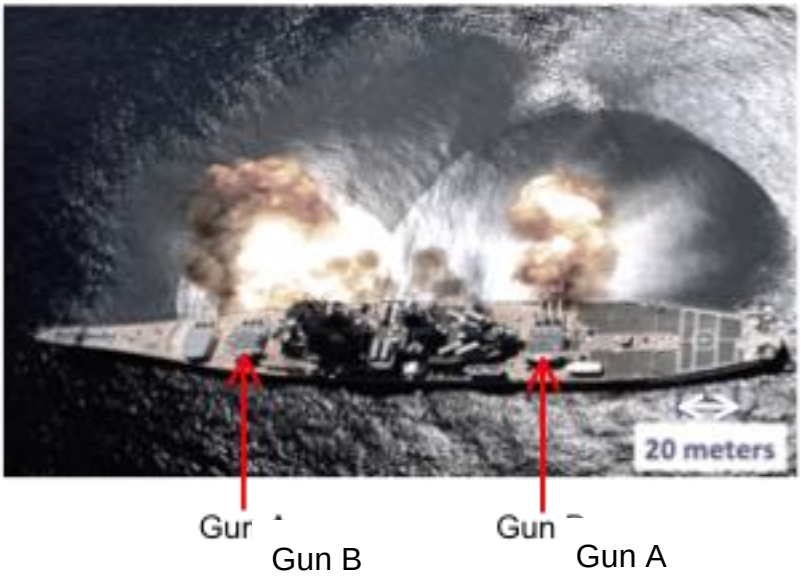
A. 2×10^3 km
B. 2×10^4 km
C. 2×10^5 km
D. 2×10^6 km
E. 2×10^7 km

10. How confident are you in your answer for Question 9?

A. Very confident
B. Somewhat confident
C. Not so confident
D. Not confident
E. Complete guess

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



12. How confident are you in your answer for Question 11?

A. Very confident
B. Somewhat confident
C. Not so confident
D. Not confident
E. Complete guess

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

14. How confident are you in your answer for Question 13?

A. Very confident
B. Somewhat confident
C. Not so confident
D. Not confident
E. Complete guess

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

16. How confident are you in your answer for Question 15?

A. Very confident
B. Somewhat confident
C. Not so confident
D. Not confident
E. Complete guess

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

18. How confident are you in your answer for Question 17?

A. Very confident
B. Somewhat confident
C. Not so confident
D. Not confident
E. Complete guess

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

20. How confident are you in your answer for Question 19?

A. Very confident
B. Somewhat confident
C. Not so confident
D. Not confident
E. Complete guess

And one last one to try …

When you answered the questions above, you had to make one or more assumptions before you could make a final decision. Those assumptions are critical when you are wondering about the answer. A 20th Century Physicist Enrico Fermi was famous for asking these sorts of assumption-based estimation questions. He would pose a question you could not answer precisely, but which you could approximate a solution for, by making and combining a series of numerical assumptions. The most famous one was "How many piano tuners are there in New York?", but I have a different one for you to consider … "How many secondary school physics teachers are there in Scotland?" Google might tell you the answer, but see if you can estimate a sensible answer. We'll come back to this during the Zoom-based QTS sessions … Good luck!