

**Problem Set Courses: Additional Guidance**

2023-24

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# A Problem Set Course

**Including a problem set**

You are reading this guidance because you believe your topic will allow for a **problem set** as part of the baseline and final assignments, in addition to the written aspects. This will be particularly applicable in physics, mathematics and engineering courses but could equally be applied to a creative topic such as poetry or fiction writing. Including a problem set will allow you to include the more skills based elements of your research throughout the course.

If you do include a problem set, then you will need to ensure that when you choose your topic, the problem element is at least 50% of the content, otherwise pupils will not make adequate progress in this part of the course.

Pupils are used to lots of practice to excel in mathematics and will need your support to complete enough practice here.

# Examples

|  |  |  |  |
| --- | --- | --- | --- |
| PhD Research area | Scholars Programme course title | Topics included in the course | Type of Course |
| ‘Molecular Biology of Neurodegenerative Diseases’ | The making and breaking of memories | * Basic brain anatomy * Neuron biology * Neurodegenerative disorders. | Essay based |
| ‘Ultrasound mediated therapies for treatment of biofilms in chronic wounds’ | The bacterial biofilm: Misunderstood microbes or public health hazard? | * Antibiotic resistance * Public health * Microbiology | Essay based |
| ‘Quantum Error Correction’ | Should we build a quantum computer? | * Boolean logic * Quantum computing * Ethics of quantum computing | Problem Set |
| ‘Cellular-resolution volumetric structural and functional imaging of tissue using fiber optic needle probes’ | Seeing the Small With the Small: Designing Miniature Microscopes for Medical Imaging | * Medical Imaging * Microscopy * Endoscopy | Problem Set |
| Finite Group Theory | Are some infinities bigger than others? | * Basic set operations * Functions * Cardinality | Problem Set |
| Particle Physics | Symmetry, Symmetry Breaking and Why the Universe Doesn't Annihilate Itself | * Symmetry * Time dilation * Matter and anti-matter | Problem Set |

## Pitching your course at the right level

**Problem Sets and Pitching for Mathematical Skills**

It can be challenging to pitch a problem set correctly. The problem element of your course should have some questions that will be accessible to all pupils but should also include questions to stretch and challenge your pupils.

To ensure you support pupils to develop their mathematical skills you will need to consider the skills you want pupils to learn throughout the course. Pupils will be used to spending entire weeks learning one key concept in mathematics while you will need to balance developing new mathematical skills with learning to engage in scientific research in a short space of time. When you plan your course, you need to ensure that you do not try to teach too many new concepts. Stick to a clear path of skill development which ensures pupils learn what is needed whilst also including what will interest and excite them, rather than lots of skills that may link to the learning somewhat but pupils won’t be able to grasp in the timeframe.

Pupils will be fascinated to learn how the mathematics they learn in school can link to your research so use that as your starting point before challenging them further.

**Problem Set Mark Scheme**

We do not provide a specific problem set mark scheme, as each problem set will be so unique. As outlined below, you will provide a percentage for each pupil’s problem set mark. We therefore suggest making the total marks available 25 or 50 for the problem set element of the baseline assignment, and 50 for the final assignment, but this is ultimately up to you. When you create the problem set, you should also create a mark scheme to ensure you mark each pupil’s work fairly. This mark scheme will also be used to support the national moderation process.

**What marks should I give for the final assignment and baseline assessment?**

For the baseline and final assignment, you will need to submit a percentage for both the problem set and the written component of the assignment. To mark the written portion, each of the three criteria in the mark scheme must be given a mark out of 100; the average of these three marks will be the final mark for the written component.

The final overall mark the student receives for both assignments will be the average score between their problem set mark and their written mark.

**When including a problem set,** it is very important to ensure that your problem set allows the pupils to perform well, if they have a clear understanding of the key concepts. We encourage you to look carefully at the relevant national curriculum to determine if pupils will have the foundational mathematical skills to carry out any calculations. However, much like university, we do not expect pupils to achieve 100% except in very extreme circumstances.

Please use the same mark scheme and criteria for the baseline assessment and final assignment. You should give students feedback on how they performed in the baseline assessment in line with the mark scheme, with clear instructions for how to improve their work. However, please **do not share** baseline marks with students.

## Creating a final assignment problem set

For many, the concepts for your problem set may come much more easily than designing the written task. It is important to start your course plan by planning what you want pupils to do in the final assignment problem set task to ensure that you can build enough time into each tutorial to develop the pupils’ skills and understanding to successfully answer the problem set work.

You may choose to set a number of problems, increasing in difficulty, as your problem set task. Alternatively, you could set pupils a large task to tackle though, this approach is not as popular. With either method, **it is important to write a mark scheme** with the problem set, to ensure that what you are asking of the pupils is clear, you mark each individual pupil fairly, and that you can easily give the pupils a final mark as a percentage. Pupils will be used to looking at the mark scheme or number of marks awarded for each question and so including this in the handbook will be useful for them.

However you phrase the final assignment sections initially, you may end up rewriting them completely several times before you are happy with it. This is normal and part of the challenge of designing a course.

**Example final assignment:**

**This final assignment consisted of both a problem set and a research question. Below is a section of the problem set and the essay question.**

|  |
| --- |
| **Final assignment problem set (50 Marks)**  Jane wants to design an endoscope that will help her with diagnosing breast cancer. S he knows that she wants a resolution of at least 2 µm (2 µm or less) to be able to accurately determine the boundaries between healthy and cancerous tissue. She plans to start by building her endoscope with bulk lenses. She plans on using an imaging technique called autofluorescence imaging, which is a fluorescence microscopy technique. Autofluorescence relies on substances that naturally exist in the body and fluoresce when exposed to a certain wavelength of light. The substance that Jane wants to excite is sensitive to light of 532nm. The endoscope will be composed of two lenses: L1 will collimate a beam coming from an optical fibre and L2 will focus the beam to the desired spot size when it exits the endoscope.   1. Is 532 nm light visible? If so, what colour is it? What is the frequency of 532nm light? **(3 Marks)** 2. In order to achieve a spot size of 2 µm, what will be the required numerical aperture of L2? You can round your answer to 2 decimal points **(3 Marks)** 3. What will be the depth of field images acquired with this endoscope? **(3 Marks)** 4. Jane would like the beam to have a diameter of 200 µm in the collimated region. What should be the focal length of L2? Note that the beam is focusing in air, and the index of refraction for air is 1. **(4 Marks)** 5. To deliver light to her endoscope, Jane will be using optical fibre. The beam coming out of the fibre has a diameter of 50 µm and a numerical aperture of 0.22. What will be the angle of divergence of the light exciting this fibre? Remember that the index of refraction for air is 1. You may give your answer in radians or degrees. **(3 Marks)** 6. How far should L1 be placed from the end of the fibre to allow the beam to expand to a diameter of 200 µm? You can round your answer to the nearest whole number. What should be the focal length of L2 so that it will collimate the light coming from the fibre? Why? **(5 Marks)** |
| **Final research question (50 Marks)**  Explain how endoscopes can be designed for a specific application and why this is important (1000 words)   * Describe what an endoscope is and discuss the advantages and disadvantages compared with using a table-top microscope * Are endoscopes useful for medical diagnosis? How? * What criteria are important to consider when choosing the right tool for the job? Why? You should discuss the choice of imaging technique, contrast and resolution appropriate for a specific application. You should also mention any trade-offs in design choices; for example: how does numerical aperture link to probe size and resolution?   **Gavrielle Untracht – Seeing the Small with the Small: Designing Miniature Microscopes for Medical Imaging** |

**Example final assignment 2:**

|  |
| --- |
| **Final assignment problem set (50 Marks)**  When attempting the problem set questions you should first establish what basic principle is involved. Write down any equation which you think will be relevant and clearly state the information you have available (which variables in your equation are known and which are unknown?). If you can’t see how you’re going to calculate the final answer, consider what you could calculate which might be a useful intermediate result. You can also start from the answer you want and work backwards. What intermediate result might be useful in helping you get to the final answer? By working forward from the information you have and backwards from the information you want you might be able to meet in the middle.  Be careful with units. It’s always safer to first convert everything into SI units (m, Kg, s, J). This will give you an answer in SI units which you can then convert into a more convenient unit at the end of the question (for example if you’re talking about the lifetime of a star is it more sensible to talk about seconds or years?). Be careful when you consider reference frames. Which is the proper time, and which is the ‘dilated’ time? Remember that marks are awarded for partial solutions so make sure you carefully show your working.   1. Consider the transformation (the transformation on numbers where each number is transformed into its reciprocal e.g. , etc). Which number(s) if any would be unchanged by this transformation? Would you describe this as a continuous or discrete transformation? Is this transformation symmetric under addition? Is it symmetric under multiplication? (You can use examples or better still algebraic proof to justify your answer). 2. A spaceship travels past you at half the speed of light. When a year has passed on your spaceship how much time will you observe having passed on the moving spaceship? 3. A particle has a lifetime of seconds. A physicist is attempting to observe the particle before it decays. The particle detector he is using has a spatial resolution of m. (This means the detector cannot observe any particle which travels less than this distance before decaying). What is the minimum speed the particle must travel in order to be detectable? 4. A particle is observed moving at 99% of the speed of light. It travels 0.1m before decaying. What is its lifetime (in its own reference frame)? 5. Assuming that CPT is an exact symmetry of nature explain why a violation of CP symmetry implies a violation of T symmetry. 6. The particle (a particle similar to the electron and muon but thousands of times heavier) has a mass of Kg. If this particle annihilates with its antiparticle how much energy will be released? 7. During the ‘main sequence’ phase of a star’s lifetime the energy released by the star is due to the nuclear fusion of four hydrogen nuclei into a helium nucleus. The mass of the hydrogen nucleus is Kg and the mass of a helium nucleus is Kg. The power output of the sun is Watts (joules per second). Initially the sun had a mass of around Kg and was composed mainly of hydrogen. Use this information to produce an estimate for how long the main sequence of the sun will last.   **NB: Research question available on next page** |
| **Final research question (50 Marks)**  Symmetry and symmetry breaking have been central to modern physics over the last 150 years and continues to play a pivotal role on the road to probing key unsolved problems at the heart of our understanding of the universe. Produce a 1000-word essay detailing to what extent you agree with this statement.  When writing your essay, you should be careful to introduce the topic and define the terms you use (for example symmetry, discrete, continuous etc). When discussing various symmetries, you should explain how they came to be discovered and distinguish between a symmetry which is assumed to be true, has been proved theoretically to hold or has been experimentally verified. You should also discuss which particular aspects of symmetry and symmetry breaking are important in our current search for ‘new physics’. It is important to reference the source of your information and if you are quoting a source directly you should use quotation marks to make this clear. Your essay should be understandable to an intelligent reader who is unfamiliar with the topic.  **Lauren Martin – Symmetry, Symmetry Breaking and Why the Universe Doesn’t Annihilate Itself** |

## What skills and what knowledge are most important?

When considering a problem set course, it becomes even more important to be clear on what skills pupils will be able to demonstrate by the end of the course.

As you are the subject expert, you know what knowledge is most essential for pupils to know. The mark scheme in the handbook template, will be helpful in thinking about what academic skills you might want pupils to be able to do by the end of the course. You should also think about what mathematical or problem-solving skills pupils will to understand and be able to do. Here’s an example to get you started:

**Example – Final assignment research question**

|  |  |
| --- | --- |
| **Final assignment title:** To what extent do you agree that operational error is more important than design to cipher security?  Consider including the following information in your essay:   * Kerchoff’s Theorem * Numbers of possible combinations * Historical examples of codes being broken * Suggest a design for your own cipher and consider why you have designed it that way and how it could be improved. | |
| **Understand:**   * How ciphers are made more secure and how they are broken * A selection of historical ciphers and their operational flaws * The mathematical theories behind ciphers and how to apply them | **Be able to do:**   * Use of correct mathematical language * Apply mathematical reasoning to support analysis and explain the significance * Assess different points of view and establish a clear point of view |

Use the two sections below to think about what you want pupils to understand and do by the end of the course **in their written work.** For the subject knowledge, these should be 3-4 of the most important points of your course topic. For the academic skills, take a look at the mark scheme and see which 3-4 skills are most central to success in your final assignment question.

|  |  |
| --- | --- |
| **Final assignment title:** | |
| **Understand:** | **Be able to do:** |

Do feel free to revise your final assignment question if you think it does not allow pupils show what they understand and can do as effectively as first thought. It is worth consistently referring to these overall aims of your course as they should inform everything you plan going forward.

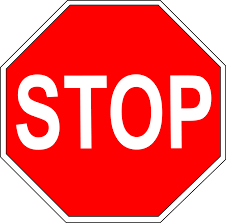
**Example – Final assignment problem set**

You should repeat this activity with your intended **problem set**. There is an example to support with this.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Problem Set (accompanies the written component above)**  Your answer must include   * Working out * Labelled diagrams as necessary * References when used   **Question 1**: ‘E is the most common letter in the English language’ ***(5 marks)***  P(vowel)=  **Question 2:** Use frequency analysis on the above cipher text to find the key of this shift cipher ***(15 marks)***  VULDH FAVZV SCLHU LUJYF WALKT LZZHN LPMDL RUVDP AZSHU NBHNL PZAVM PUKHK PMMLY LUAWS HPUAL EAVMA OLZHT LSHUN BHNLS VUNLU VBNOA VMPSS VULZO LLAVY ZVHUK AOLUD LJVBU AAOLV JJBYY LUJLZ VMLHJ OSLAA LYDLJ HSSAO LTVZA MYLXB LUASF VJJBY YPUNS LAALY AOLMP YZAAO LULEA TVZAV JJBYY PUNSL AALYA OLZLJ VUKAO LMVSS VDPUN TVZAV JJBYY PUNSL AALYA OLAOP YKHUK ZVVUB UAPSD LHJJV BUAMV YHSSA OLKPM MLYLU ASLAA LYZPU AOLWS HPUAL EAZHT WSLAO LUDLS VVRHA AOLJP WOLYA LEADL DHUAA VZVSC LHUKD LHSZV JSHZZ PMFPA ZZFTI VSZDL MPUKA OLTVZ AVJJB YYPUN ZFTIV SHUKJ OHUNL PAAVA OLMVY TVMAO LMPYZ ASLAA LYVMA OLWSH PUALE AZHTW SLAOL ULEAT VZAJV TTVUZ FTIVS PZJOH UNLKA VAOLM VYTVM AOLZL JVUKS LAALY HUKAO LMVSS VDPUN TVZAJ VTTVU ZFTIV SPZJO HUNLK AVAOL MVYTV MAOLA OPYKS LAALY HUKZV VUBUA PSDLH JJVBU AMVYH SSZFT IVSZV MAOLJ YFWAV NYHTD LDHUA AVZVS CL  **Question 3:** A message you have intercepted encrypted using the Vigenère cipher has a repeated pattern 20 letters apart. What are the possible key lengths used? Justify which key lengths are the most likely and how you would test your theory using the intercepted message. ***(6 marks)***  **Question 4:** Write the below permutation in cycle notation ***(4 marks)***  **Question 5:** An adapted Enigma machine has 20 letters with a plug board that chooses 2 letters to exchange. How many possible ways are there to choose these 2 letters? ***(6 marks)***  **Question 6:** The same adapted enigma machine as above has 5 rotors to place in 3 slots. How many possible ground settings are there for this machine? ***(13 marks)***   |  |  |  |  |  | | --- | --- | --- | --- | --- | |  | **Settings** | | | **Total number of Ground settings:** | |  | **Rotor** | **Plugboard setting** | **Initial rotor setting** | |  |  |  |  |  | | |
| **Understand (mathematical skills)**   * How to calculate probabilities * How to calculate permutations * Convert permutations to table notations | **Be able to do:**   * Complete frequency analysis using probabilities * Generate varied expressions of permutations * Clearly display calculations/workings out |

**Use the two sections below to think about what you want pupils to understand and do by the end of the course.** For the subject knowledge, these should be 1-2 of the most important calculation concepts behind the problem set. For the academic skills, take a look at the mark scheme and see which 1-2 skills are most central to success in your final assignment question.

|  |  |
| --- | --- |
| **Problem Set:** | |
| **Understand:** | **Be able to do:** |

****

**and Check**

* Does your final assignment allow pupils to show that **they understand and can do** the points listed above?
* Will the final assignment challenge pupils academically?
* Are both the final assignment and the aims of the course written above in pupil friendly language (i.e. free of complex subject vocabulary) so that they could be shared directly with pupils?
* In your problem set planning,have you determined what operational knowledge pupils need to be successful and does it include a mix of accessible questions and questions that will stretch pupils?
* **Top Tip:** Rope in a family member, flatmate or partner who is not doing a PhD and share the final assignment question and aims with them. If they have a sense of where they might start with the question (even if it’s only what information they may need) then you’re off to a good start!

# Section F: Baseline Assignment

You must include a problem set in the baseline assignment, if you are including one in the final assignment. With the problem set part of the baseline assignment, it is important that the pupils can access part of it. If you give the pupils just one question to answer, that includes the same level of understanding you expect in the final assignment, then pupils will not want to attempt it. Ensure that the problems set will allow you to assess foundational knowledge, including some straightforward questions, as well as some more challenging questions that gives pupils the opportunity to attempt what will be expected of them later in the course.

## Backwards Planning for the baseline assignment

Having designed your final assignment and determined the most vital academic skills and subject knowledge for success in the final assignment, the baseline assignment allows you to assess where pupils are starting from. Therefore, it is important that you continue the backwards planning process to ensure that you are starting from the most useful point to support your pupils towards the final assignment.

**Example – Baseline assignment research question**

|  |  |
| --- | --- |
| **Final assignment title:** To what extent do you agree that operational error is more important than design to cipher security?  Consider including the following information in your essay:   * Kerchoff’s Theorem * Numbers of possible combinations * Historical examples of codes being broken * Suggest a design for your own cipher and consider why you have designed it that way and how it could be improved. | |
| **Understand:**   * **How ciphers are made more secure and how they are broken** * A selection of historical ciphers and their operational flaws * **The mathematical theories behind ciphers and how to apply them** | **Be able to do:**   * **Use of correct mathematical language** * **Apply mathematical reasoning to support analysis and explain the significance** * **Assess different points of view and establish a clear point of view** |
| **Baseline assignment title:** How secure is a Caesar Cipher?  Consider including the following information:   * Why is frequency analysis important? * What can we learn from frequency analysis? * What can we do to stop frequency analysis in breaking codes? | |

**\*Bolded text can be assessed in both the baseline and final assignment**

**Example – Baseline assignment problem set**

|  |  |
| --- | --- |
| **Final assignment problem set:** Please refer to previous section | |
| **Understand (mathematical skills)**   * **How to calculate probabilities** * How to calculate permutations * Convert permutations to table notations | **Be able to do:**   * **Complete frequency analysis using probabilities** * **Clearly display calculations and workings out** * Generate varied expressions of permutations |
| **Baseline assignment problem set:**  **Question 1:** Cipher the below plaintext using the Caesar cipher. ***(4 marks)***  **‘Caesar sent all of his messages in code to keep them secure’**  **Question 2:** Decipher the below ciphertext using the Caesar cipher ***(6 marks)***  **FUBSW RJUDS KBLVW KHVWX GBRIF RGHDQ GFRGH EUHDN LQJ**  **Question 3** The below cipher text has been encrypted using a shift cipher not equal to 3. ***(10 marks)***   1. Use frequency analysis on the below cipher text to find the frequency of G, O and M. 2. Which of these three letters is most likely to be a vowel? Why?   **UWKSQ VOJQZ LALWV BLWWV MBPQV OJCBU ISMUC AQKNW ZCABW MVRWG BPMGL WVBMI BCXXM WXTMA OIZLM VALWV BVMAB QVKWZ VKZQJ ABPMG LWVBL WWVMB PQVOJ CBAQV OBPMQ ZPMIZ BAWCB NWZCA BPIBA EPGQB AIAQV BWSQT TIUWK SQVOJ QZL**  **Question 4:** Design a shift cipher with key>3. Complete the below table for the cipher text. ***(4 marks)***  Key =   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | **Plaintext** | **a** | **b** | **c** | **d** | **e** | **f** | **g** | **h** | **i** | **j** | **k** | **l** | **m** | **n** | **o** | **p** | **q** | **r** | **s** | **t** | **u** | **v** | **w** | **x** | **y** | **z** | | Ciphertext |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |   **Question 5:** Calculate the below equivalences ***(8 marks)***  30 mod 5 ≡  30 mod 12 ≡  30 mod 26 ≡    **Question 6** The below cipher text has been encrypted using a shift cipher not equal to 3. ***(18 Marks)***  CSHDI COMYXNC. DRKDC RYG VYXQ GOBO BOAESBON DY CDKXN YX YEB WODKV MSBMVOC LOPYBO DRO CYEXN YP K QYXQ BOVOKCOC EC. CDOZ YPP LOPYBO DRO WSXEDO SC EZ KXN VKXN WSXOC LVYG IYEB VOQC YPP. CSHDI COMYXNC DY DKUO SX DRO BSXQ YP DBSLEDOC KVV OAESNSCDKXD PBYW DRO MYBXEMYZSK K QSKXD QYVNOX RYBX CRKZON VSUO K MYXO GSDR K MEBFON DKSV DRO WYEDR YP GRSMR SC KD VOKCD DGOXDI POOD RSQR CZSVVSXQ YFOB GSDR DRO DRSXQC DRKD GSVV QSFO EC VSPO ROBO SX DRO KBOXK. PYYN MYXDKSXOBC YP GKDOB GOKZYXC WONSMSXO QKBWOXDC PSBO CDKBDOBC. CDBOGX KBYEXN DRO MYBXEMYZSK KBO YDROB CEZZVSOC DROSB FKVEO NOMBOKCSXQ DRO PKBDROB DROI KBO PBYW DRO RYBX. PYB SXCDKXMO, YXVI K POG CDOZC PBYW WI POOD VSOC K DRBOO-PYYD CAEKBO YP ZVKCDSM. MOBDKSXVI SD MYEVN LO YP CYWO ECO SX K NYGXZYEB. LED DROBO SX DRO WYEDR S MKX COO K DOXD ZKMU DRKD GYEVN ZBYDOMD PBYW KVWYCD KXI CYBD YP GOKDROB. SP S RKN DRO QEDC DY QY SX KXN PSQRD PYB SD KQKSXCD DRO YDROB DGOXDI-DRBOO DBSLEDOC. GRSMR S RKFO LOOX SXCDBEMDON XYD DY NY.  Using frequency analysis and the characteristic of the ciphertext, find which cipher text letter represents ‘e’ and the key. | |

## Examples of problem set baseline assignments

Below are some examples of STEM baseline assignments that work well and allow pupils to access the whole mark scheme, as well as allowing the tutor to understand the student’s prior knowledge. Your baseline assignment should also allow pupils to develop the skills you will be assessing in the final assignment. For the written part of the final assignment, we would recommend for KS4 that this is ~200-250 words. The examples below are the baseline assignments associated with the example final assignments

**Example baseline assignment 1**

|  |
| --- |
| **Baseline assignment problem set (50 Marks)**   1. If light hits a mirror at an angle of 20 degrees, at what angle will it reflect from the mirror? 2. Does absorption depend on the colour of light? If so, how? 3. Does scattering depend on the colour of light? If so, how? 4. Can light focus to an infinitely small spot size? Why or why not? 5. Define the terms **amplitude** and **phase** in terms of how they describe a wave. You may use a drawing to help support your response. 6. Define the terms **resolution** and **contrast**. 7. True or False: Using ray tracing, I can determine the magnification of a lens. Explain your answer. 8. Solve the following equation for x: |
| **Baseline research question (50 Marks)**  **What sources of contrast exist in the body to generate images? (200 words)**   * First, describe in general how contrast is generated in images. You may want to focus on key words discussed in class including **absorption, transmission, reflection, and scattering**. Provide at least one specific example - Don’t be afraid to be creative! Think about how light can interact with different parts of the body. * Second, use your own online research to investigate one imaging technique discussed in class. Describe briefly how it works and what the main source of contrast is. You may use the information on the next few pages to help you.   Don’t forget to include a **bibliography**. A bibliography is a list of any books or websites that you used when writing your response.  **Gavrielle Untracht – Seeing the Small with the Small: Designing Miniature Microscopes for Medical Imaging** |

**Example baseline assignment 2**

|  |
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| **Baseline assignment problem set (50 Marks)**   1. See the diagram of a right angle triangle. Using pythagoras’ theorem calculate the length z in terms of x and y.   z  2x  3y   1. Find x where 2. Find y where 460000000 = 3. Two men are running along a 100m track. Both maintain a steady pace of 5 meters per second. The first travels in a straight line. How long will he take to complete the 100m distance? 4. The second man takes a (symmetrical) diagonal course as shown in the diagram. Calculate how far he needs to travel to complete the race. How long will it take him to complete the race? 5. I’m standing on a platform while a train slowly travels past at 10m/s. A person on the train is walking up the carriage towards the front of the train at 1m/s. How fast is the person moving relative to me? 6. The person now changes direction and walks at the same speed towards the back of the train how fast are they now moving relative to me? 7. The tennis player John Isner holds the world record for the fastest ever serve at 157 miles per hour. For reasons we haven’t been told he is standing on top of a train travelling at 120 miles an hour. He serves a ball from the train. In the opposite direction to the direction of travel of the train. How fast is the ball travelling relative to an observer not on the train? 8. Consider the transformation of numbers . (i.e. each number is transformed into its square). Which number is invariant (doesn’t change) under this transformation? Would this transformation be symmetric under addition? Multiplication?   **NB: Research question available on next page** |
| **Baseline research question (50 Marks)**  Produce a short piece of writing (approximately 150-250 words) formally introducing the concept of symmetry. You should describe what is meant by both continuous and discrete symmetries and give examples (either from the tutorial or if possible further examples which you have researched or thought about yourself) including diagrams where possible. Describe examples of symmetries within physics and give a qualitative description of Noether’s theorem. You might include a brief description of who Emmy Noether was (when she lived and how she came to develop her theorem).  **Lauren Martin – Symmetry, Symmetry Breaking and Why the Universe Doesn’t Annihilate Itself** |

