# 2004 Physics Pilot GA 3: Written examination 2

## GENERAL COMMENTS

The number of students who sat for the examination in 2004 was 671. With a mean score of 63%, students generally found it to be quite a reasonable paper. Those who had thoroughly prepared themselves were well rewarded for their efforts. The variety in the styles of questions appeared to be well received. As with the June exam, those areas of the course which were new caused more difficulty for students than the familiar topics. This can be at least partly attributed to the fact that revision material for these areas was rather limited. Despite this, one student achieved the maximum score.

The following concerns became evident while marking the student scripts.

- Students are to attempt questions from **only one** of the detailed studies. There were still some who attempted two or three detailed studies, although it was mainly the weaker students who did this.
- Students need to be more careful with their writing. If the assessor could not decipher the answer, no marks were awarded. This applied particularly to multiple-choice questions where one answer was written over another.
- Written explanations must address the specifics of the question asked. Simply copying generic answers from their pre-written notes will not enable students to gain full marks. They should be encouraged to reread their explanations to ensure that they have answered the question asked and that what they have written makes sense. Diagrams can be a valuable aid in answering these questions, but must be drawn with reasonable care. The key features of the diagrams must be clear and labelled correctly.
- In questions that require an explanation, generally one mark was awarded for each point made. In a two mark question, students could not expect to obtain full marks for a single phrase. Although the answer may have contained the key point, some expansion on it was generally expected to obtain the second mark.
- Generalised written explanations without the key points of relevant physics did not receive full marks.
- There appeared to be some improvement in students' ability to perform numerical calculations. However, there were still examples of students who identified the correct equation and substituted properly, but were then unable to determine the final answer. This was either because of an inability to transpose the formula or a problem with using the calculator properly.
- It was clear that some students had trouble with unit conversions.
- Students should be aware that if their answer looks to be a ridiculous number, then it needs to be checked. For example, objects moving at a speed greater than the speed of light or interference path differences of the order of $10^{30}$ m.
- It is important for students to ensure that their calculators are in degree mode.
- A continuing concern is the relatively poor understanding by some students of current and voltage in parallel and series circuits.
- If a unit is required in the answer, students must make sure that they give the unit.

## SPECIFIC INFORMATION

## Section A - Core

## Area of Study 1 – Interactions of light and matter

**Questions 1-3**

| Marks | 0 | 1 | 2 | 3 | 4 | 5 | 6 | Average |
|---|---|---|---|---|---|---|---|---|
| % | 10 | 1 | 19 | 2 | 26 | 1 | 41 | **4.0** |

**Question 1**

The work function was 2.1 eV, which could be obtained by using $E_k(\text{max}) = hf - W$ and substituting the data from the table for either blue or UV.

Some students tried to estimate the threshold frequency from the available data and used it to calculate the work function.

**Question 2**
A value of 2.2 eV was obtained by substituting the appropriate values into $E = hf$. A common error was to substitute 5.4 for the frequency instead of $5.4 \times 10^{14}$.

**Question 3**
The current depended on the number of photons, so the answer was A.

**Questions 4-6**

| Marks | 0 | 1 | 2 | 3 | 4 | 5 | 6 | Average |
|---|---|---|---|---|---|---|---|---|
| % | 3 | 9 | 10 | 15 | 19 | 28 | 17 | 3.9 |

**Question 4**
The graph was a straight line commencing at about $5.2 \times 10^{14}$ on the frequency axis. A common mistake was to continue the graph below the frequency axis.

Red light did not emit any electrons. From the graph it could be seen that UV2 emitted electrons of about 2.9 eV.

**Question 5**
The possible transitions of those listed were from second excited state to first and from first to ground. So the answer was B and D.

**Question 6**
The energy difference between the second and third excited states was 2.1 eV, so the answer was C.

**Questions 7-8**

| Marks | 0 | 1 | 2 | 3 | 4 | 5 | Average |
|---|---|---|---|---|---|---|---|
| % | 9 | 4 | 19 | 16 | 14 | 39 | 3.4 |

**Question 7**
The diffraction patterns for the electrons and x-rays were very similar, therefore they had the same wavelength and the answer was A.

**Question 8**
Momentum $= \frac{h}{\lambda}$. The wavelength of the electrons was the same as the x-rays (35 pm), so the momentum was $1.9 \times 10^{-23}$ kg m s$^{-1}$.

One common mistake was to apply formulae which involved the speed of light. Another was to mistake the prefix pico for nano or micro. Some students forgot to include the unit for momentum.

**Questions 9-10**

| Marks | 0 | 1 | 2 | 3 | 4 | 5 | 6 | Average |
|---|---|---|---|---|---|---|---|---|
| % | 11 | 5 | 6 | 23 | 8 | 6 | 39 | 3.9 |

**Question 9**
To obtain full marks students had to indicate that it was an interference pattern where the bright bands resulted from constructive interference (or path difference 0λ, λ, 2λ, etc.) and the dark bands from destructive interference (or path difference ½ λ, 1 ½ λ, etc.).

**Question 10**
The path difference was six wavelengths = $6 \times 632 \times 10^{-9} = 3.79 \times 10^{-6}$.

Some students misunderstood the prefix nano in the unit for wavelength. Others were confused about whether it was a node or antinode and whether the path difference was 5λ, 6λ, 7λ, 5 ½ λ or 6 ½ λ.

**Question 11**

| Marks | 0 | 1 | 2 | Average |
|---|---|---|---|---|
| % | 18 | 0 | 82 | **1.7** |

This was a straightforward question with four wavelengths, so the answer was C.

## Area of study 2 – Electric power

**Question 1**

| Marks | 0 | 1 | 2 | 3 | Average |
|---|---|---|---|---|---|
| % | 6 | 4 | 20 | 70 | **2.6** |

The correct responses were **perpendicular, magnetic** and **increases**.

This relatively straightforward question also provided a lead in to the next couple of questions. It was surprising that a number of students did not attempt this question.

**Questions 2-3**

| Marks | 0 | 1 | 2 | 3 | 4 | Average |
|---|---|---|---|---|---|---|
| % | 12 | 4 | 19 | 6 | 58 | **2.9** |

**Question 2**

A simple application of the right hand rule showed that the force was down, so the answer was B.

**Question 3**

The magnitude of the magnetic field was calculated by applying the formula $F = I\, l\, B$, which resulted in a magnetic field of 1.0 T.

It was disappointing how many students were unable to convert 10 mm to metres. The simple transposition required to obtain B also caused difficulty for a surprising number of students.

**Question 4**

| Marks | 0 | 1 | 2 | Average |
|---|---|---|---|---|
| % | 27 | 16 | 57 | **1.3** |

With an AC power source, the force alternates up/down causing the wire to oscillate with a frequency of 100 Hz.

**Questions 5-6**

| Marks | 0 | 1 | 2 | 3 | 4 | Average |
|---|---|---|---|---|---|---|
| % | 15 | 3 | 25 | 15 | 42 | **2.7** |

**Question 5**

Closing the switch caused an increasing current which led to an increasing magnetic field. The resultant change in flux produced a current in the secondary. Once the supply current reached a constant value, the magnetic field was constant and thus there was no change in flux. Therefore, there was no more current induced in the secondary and the meter returned to zero.

Students were awarded marks for the key points, not every detail was required.

**Question 6**

The correct answer was C. The reasoning is similar to that given for Question 5.

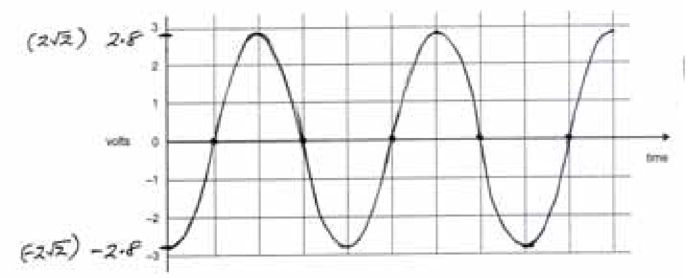
**Questions 7-8**

| Marks | 0 | 1 | 2 | 3 | 4 | 5 | 6 | Average |
|---|---|---|---|---|---|---|---|---|
| % | 10 | 7 | 10 | 14 | 10 | 19 | 29 | **3.8** |

**Question 7**

The period of the flux graph $T = \frac{1}{f} = \frac{1}{10} = 0.1$ s. From P to Q was half a period so the answer was 0.05 s.

**Question 8**




It would also be acceptable if the graph was inverted as no positive direction had been specified. One common error was to label the peak value of the output voltage with the RMS value.

**Question 9**

| Marks | 0 | 1 | 2 | Average |
|---|---|---|---|---|
| % | 32 | 0 | 68 | **1.4** |

As the shaft gradually slows, the rate of change of flux is reduced and so the voltage output is reduced. As it slows, the period of rotation increases and so the period of the output voltage is increased. So the answer was D.

**Questions 10-11**

| Marks | 0 | 1 | 2 | 3 | 4 | Average |
|---|---|---|---|---|---|---|
| % | 7 | 14 | 32 | 30 | 18 | **2.4** |

**Question 10**
Increasing the number of turns was the only possible method of those listed which would increase the generator voltage, so the answer was A.

**Question 11**
The commutator reversed the direction of flow of the **output** every half rotation, thus converting AC to pulsed DC.

Some students sketched a graph of the output, for which they received one mark. However, most students discussed the operation of the commutator in a motor instead of a generator.

**Questions 12-13**

| Marks | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Average |
|---|---|---|---|---|---|---|---|---|---|
| % | 13 | 20 | 14 | 13 | 6 | 5 | 10 | 20 | **3.4** |

**Question 12**
While the voltage drop across lamp one was 12 V, that across lamp two was reduced because of the voltage drop across the resistance of the extension lead. Alternatively, it could have been explained in terms of the power loss in the extension lead. Some of the explanations that students wrote were rather vague.

**Question 13**
Using Ohm's Law, the voltage loss in the extension lead was 4 V. So the voltage across lamp two was 12 – 4 = 8 V. Therefore the power dissipated in lamp two was P = V I = 8 x 4 = 32 W.

Many students evaluated the voltage drop (or power loss) in the lead but were unable to relate it to the lamp. It was apparent from this question that many students did not properly understand current flow and voltage drop in series and parallel circuits.

**Questions 14-16**

| Marks | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Average |
|---|---|---|---|---|---|---|---|---|---|---|
| % | 13 | 5 | 14 | 8 | 11 | 12 | 21 | 5 | 11 | **4.1** |

**Question 14**
The resistance in the branch with lamp one is less than that in the branch with lamp two. Therefore the current through lamp one is greater than 4 A. Accordingly the combined current is greater than 8 A, so the answer was D.

This question also demonstrated that students have trouble with current in parallel circuits.

**Question 15**
To obtain full marks the diagram had to show a core, indicate more turns on the primary side and give an appropriate turns ratio.

**Question 16**
The larger voltage meant a smaller current was required for the same power ($P = VI$). The smaller current meant less power loss in the lead ($P = I^2R$).

Students generally either received full marks or gave very muddled answers.

## Section B – Detailed studies

## Detailed study 1 – Synchrotron and applications

**Questions 1-2**

| Marks | 0 | 1 | 2 | 3 | 4 | Average |
|---|---|---|---|---|---|---|
| % | 40 | 8 | 34 | 5 | 12 | **1.4** |

**Question 1**
Compton Scattering (B).

It was surprising how many students were unable to distinguish between Compton and Thomson scattering.

**Question 2**
71 pm.

Some students did not give the unit as requested.

**Question 3**

| Marks | 0 | 1 | 2 | 3 | 4 | Average |
|---|---|---|---|---|---|---|
| % | 35 | 7 | 19 | 13 | 26 | **1.8** |

There was a range of acceptable characteristics; high intensity, tuneable, small beam divergence, coherent and can be polarised. Some students had difficulty explaining their answers clearly.

**Questions 4-5**

| Marks | 0 | 1 | 2 | 3 | 4 | Average |
|---|---|---|---|---|---|---|
| % | 37 | 4 | 39 | 7 | 12 | **1.5** |

**Question 4**
As the electrons accelerated they travelled increasing distances in the same time.

Students found it difficult to explain the reason for the longer accelerating stages in terms of the distances travelled in a set time.

**Question 5**
Use of the right hand rule for the electromagnetic force on a charged particle shows that it deflected to the right, so the answer was B.

A common mistake was to neglect the negative charge on the electron and thus have it deflected left.

**Questions 6-7**

| Marks | 0 | 1 | 2 | 3 | 4 | 5 | 6 | Average |
|---|---|---|---|---|---|---|---|---|
| % | 25 | 12 | 5 | 9 | 2 | 6 | 40 | **3.2** |

**Question 6**
By substituting in the formula for kinetic energy, the speed of the electron can be calculated. A common problem was to neglect to convert the energy to joules. Some students who attempted the conversion were unable to cope with the fact that it was in keV. Some students obtained an answer greater than the speed of light and did not appear to realise this was a problem.

**Question 7**

By applying the formula $r = \frac{p}{qB} = \frac{mv}{qB}$ the radius was found to be $1.7 \times 10^{-4}$.

**Question 8**

| Marks | 0 | 1 | 2 | Average |
|---|---|---|---|---|
| % | 31 | 0 | 69 | **1.4** |

The answer was $\overline{BC} + \overline{CD}$ (C). This question was done well.

**Questions 9-10**

| Marks | 0 | 1 | 2 | 3 | 4 | 5 | Average |
|---|---|---|---|---|---|---|---|
| % | 21 | 4 | 19 | 18 | 3 | 35 | **2.7** |

**Question 9**
Application of the formula $n\lambda = 2d\sin\theta$ and use of $n = 1$ when $\theta = 10^0$ gives the wavelength as $6.9 \times 10^{-11}$. It was also possible to use $n = 2$ and $\theta = 20^0$ or $n = 3$ and $\theta \approx 31^0$.

This question required calculators to be in degree mode; however, students who had them in radian mode received credit for what they had done. Teachers are advised to ensure that students are aware of the necessity of having their calculators in degree mode for Physics.

**Question 10**
The formula from Question 9 shows that increasing the wavelength slightly will increase the angle, so the answer was A. Students who were unable to start Question 9 were generally unable to answer this question.

## Detailed study 2 – Photonics

**Question 1**

| Marks | 0 | 1 | 2 | 3 | Average |
|---|---|---|---|---|---|
| % | 45 | 36 | 11 | 7 | **0.8** |

Source one was sunlight, source two was an incandescent globe and source three was a candle.

Many students included a laser and/or a mercury vapour lamp. This was disappointing considering that each source showed a continuous distribution of frequencies.

**Questions 2-4**

| Marks | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | Average |
|---|---|---|---|---|---|---|---|---|---|---|
| % | 7 | 5 | 8 | 5 | 11 | 10 | 23 | 11 | 20 | **5.0** |

**Question 2**
Students were generally able to explain that the atoms first had to be excited and that they were then stimulated to emit photons to form coherent light.

**Question 3**

Using the formula for the energy of a photon $E = \frac{hc}{\lambda}$ and the energy 1.9 eV, the wavelength is shown to be $6.5 \times 10^{-7}$ m.

**Question 4**
The correct answers were C and D.

The most commonly selected incorrect response was B. Presumably it was thought that increasing the voltage also increased the energy of the individual photons and therefore decreased the wavelength.

**Question 5**

| Marks | 0 | 1 | 2 | 3 | Average |
|---|---|---|---|---|---|
| % | 35 | 18 | 20 | 27 | **1.4** |

The output decreased.

The refractive index of the fluid was greater than that of the plastic and total internal reflection would no longer occur, therefore light would refract into the liquid. While many students stated that $n_{fluid} > n_{plastic}$ few were able to explain the significance of this.

**Questions 6-8**

| Marks | 0 | 1 | 2 | 3 | 4 | 5 | 6 | Average |
|---|---|---|---|---|---|---|---|---|
| % | 10 | 6 | 17 | 16 | 19 | 15 | 17 | **3.4** |

**Question 6**
The largest angle at which the beam would still experience total internal reflection was somewhere between $\beta$ and $\gamma$ so the answer was C. The most common incorrect response was B.

**Question 7**
Single mode does not suffer from modal dispersion over long distances. In multimode, the signals take different paths and the arrival times will vary.

The mere mention of modal dispersion without some explanation was insufficient for full marks.

**Question 8**
With a wavelength of 1.1 µm, the graph showed a loss of 1 dB/km. Since the maximum signal loss allowed was 30 dB, the maximum distance between repeater stations was 30 km, so the answer was C.

**Questions 9-10**

| Marks | 0 | 1 | 2 | 3 | 4 | 5 | Average |
|---|---|---|---|---|---|---|---|
| % | 18 | 9 | 20 | 24 | 21 | 9 | **2.5** |

**Question 9**
Light is focused onto the imaging bundle by the lens. It is then transmitted by total internal reflection along the fibres. The fibres maintain their relative positions so an accurate image is formed at the camera.

Students tended to give generalised explanations without referring to the physics involved.

**Question 10**
The fibre bundle formed an image 100 by 100 pixels, so the number of fibres was 10 000, option D. The most common incorrect response was C.

## Detailed study 3 – Recording and reproducing sound

**Questions 1-2**

| Marks | 0 | 1 | 2 | 3 | 4 | 5 | Average |
|---|---|---|---|---|---|---|---|
| % | 4 | 5 | 7 | 17 | 18 | 49 | **3.9** |

**Question 1**
- dynamic (moving coil)
- velocity (ribbon)
- electret-condensor (capacitor).

Students were generally able to identify the types from the descriptions provided.

**Question 2**
Most students were able to identify that 120 dB was equivalent to 1 W $m^{-2}$ (B).

**Question 3**

| Marks | 0 | 1 | 2 | Average |
|---|---|---|---|---|
| % | 16 | 0 | 84 | **1.7** |

Halving the sound intensity reduced the sound level by 3 dB, so the answer was B.

**Questions 4-6**

| Marks | 0 | 1 | 2 | 3 | 4 | 5 | 6 | Average |
|---|---|---|---|---|---|---|---|---|
| % | 2 | 0 | 15 | 3 | 52 | 13 | 13 | **3.9** |

**Question 4**
Speaker two provided the loudest response from 100 Hz – 1000 Hz, so the answer was B.

**Question 5**
The best response for 500 Hz – 10 000 Hz was speaker four, so the answer was D.

**Question 6**
Sound from the back and front of the speaker is out of phase. The board prevents sound diffracting around the speaker and interfering destructively.

Some students thought the boards increased the area of vibration to give more sound, like the sounding box of a guitar. Others knew that sound diffracting around the speaker had something to do with it but did not relate it to the interference of waves out of phase.

**Questions 7-8**

| Marks | 0 | 1 | 2 | 3 | 4 | 5 | 6 | Average |
|---|---|---|---|---|---|---|---|---|
| % | 4 | 5 | 8 | 12 | 18 | 15 | 37 | **4.3** |

**Question 7**
Speakers three and four were the most appropriate choices. The high frequency cut off of speaker three matched the low frequency cut off of speaker four and the output of both speakers was about the same.

Options selected by students were many and varied. It was common for students to talk about the amount of diffraction caused by the various speakers.

**Question 8**
Use of the wave equation shows that a frequency of 80 Hz equates to a wavelength of 4.25 m. For a tube closed at one end, the length of the tube is a quarter of the wavelength – 1.1 m.

Some students assumed the length of the tube was half the wavelength, presumably confusing it with one open at both ends. Others made mistakes with calculations.

**Questions 9-10**

| Marks | 0 | 1 | 2 | 3 | 4 | 5 | 6 | Average |
|---|---|---|---|---|---|---|---|---|
| % | 6 | 2 | 11 | 19 | 17 | 15 | 30 | **4.0** |

**Question 9**
For a tube opened at one end the resonant frequencies are odd multiples of the fundamental. So the possibilities were 80, 240, 400, 560, 720, and 880. The only one listed was 560 Hz, so the answer was D.

Once again some students treated it as a tube open at both ends so also included 320 and 800.

**Question 10**
Use of the wave equation shows that the wavelength was 3.4 m.

The high frequencies have a wavelength much less than the width of the TV (for example 1000Hz = 0.34 m), so the sound does not diffract around and cannot be heard. However, the low frequencies have wavelengths which are greater than the width of the TV (>3.4 m), therefore they diffract around the TV and can be heard.

Students did not have to include actual values for the wavelengths, but they did have to make a statement about the relative sizes of the wavelength and the TV.