**Q1.**

(a)  In photosynthesis, which chemicals are needed for the light-dependent reaction?

Tick (**✓**) **one** box.

|  |  |
| --- | --- |
| Reduced NADP, ADP, Pi, water and oxygen. |  |
| NADP, ATP and water. |  |
| Reduced NADP, ATP, water and carbon dioxide. |  |
| NADP, ADP, Pi and water. |  |

**(1)**

(b)  Describe what happens during photoionisation in the light-dependent reaction.

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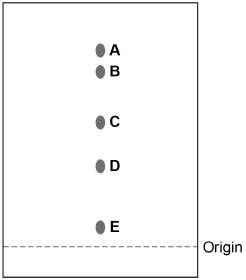
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**(2)**

A student obtained a solution of pigments from the leaves of a plant. Then the student used paper chromatography to separate the pigments.

The diagram shows the chromatogram produced.



(c)  Explain why the student marked the origin using a pencil rather than using ink.

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**(1)**

(d)  Describe the method the student used to separate the pigments after the solution of pigments had been applied to the origin.

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**(2)**

(e)  Calculating the Rf values of the pigments can help to identify each pigment. An Rf value compares the distance the pigment has moved from the origin with the distance the solvent front has moved from the origin.



The distance each pigment has moved is measured from the middle of each spot.

Pigment **A** has an Rf value of 0.95

Use the diagram above to calculate the Rf value of pigment **C**.

Rf value of pigment **C** = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**(1)**

(f)   The pigments in leaves are different colours. Suggest and explain the advantage of having different coloured pigments in leaves.

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**(1)**

**(Total 8 marks)**

**Q2.**

Heat stress is a condition that often occurs in plants exposed to high temperatures for a prolonged period of time. Heat stress is a major factor in limiting the rate of photosynthesis.

(a)     Heat stress decreases the light-dependent reaction of photosynthesis.

Explain why this leads to a decrease in the **light-independent reaction**.

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**(2)**

(b)     Another effect of heat stress is a decrease in the activity of the enzyme rubisco. A decrease in the activity of an enzyme means that the rate of the reaction it catalyses becomes slower.

A decrease in the activity of the enzyme rubisco would limit the rate of photosynthesis.

Explain why.

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**(2)**

(c)     Where precisely is rubisco found in a cell?

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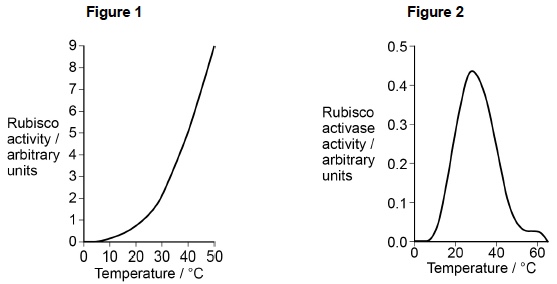
**(1)**

Scientists investigated the effect of temperature on the activity of two enzymes isolated from the leaf cells of cotton plants.

•        Rubisco

•        Rubisco activase – an enzyme that activates rubisco

**Figure 1** and **Figure 2** show their results.



(d)     The scientists concluded that heat stress reduces the activity of rubisco in plant leaves by affecting rubisco activase.

Use all the information to evaluate their conclusion.

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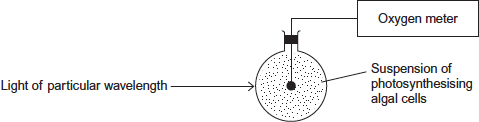
**(4)**

**(Total 9 marks)**

**Q3.**

A student investigated the effect of different wavelengths of light on the rate of photosynthesis. She used the apparatus shown in **Figure 1**.

**Figure 1**

****

(a)     What measurements should the student have taken to determine the rate of photosynthesis?

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**(1)**

(b)     Other than temperature and pH, give **two** factors which should be kept constant during this investigation.

1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

2. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**(2)**

(c)     The student did **not** use a buffer to maintain the pH of the solution.   
Explain what would happen to the pH of the solution during this investigation.

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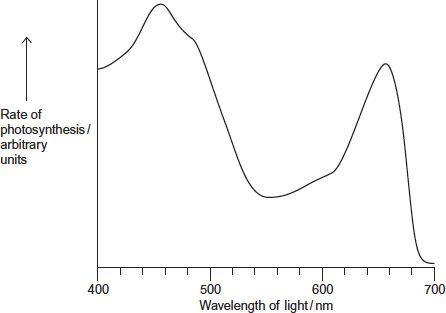
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**(2)**

(d)     **Figure 2** shows the student’s results.

**Figure 2**

****

Suggest and explain why the rate of photosynthesis was low between 525 nm and 575 nm wavelengths of light.

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**(2)**

**(Total 7 marks)**

**Q4.**

Scientists measured the rate of respiration in **three** parts of an ecosystem.

They did this by measuring carbon dioxide released into the air by:

•        leaves of plants

•        stems and roots of plants

•        non-photosynthetic soil organisms.

The table below shows the scientists’ results for these three parts of the ecosystem.

|  |  |  |
| --- | --- | --- |
| **Part of ecosystem** | **Mean rate of carbon dioxide production / cm3 m−2 s−1** | **Percentage of total carbon dioxide production measured by the scientists** |
| Leaves of plants | 0.032 | 25.0 |
| Stems and roots of plants | 0.051 |  |
| Non- photosynthetic soil organisms | 0.045 |  |

(a)     Complete the table to show the percentage of total carbon dioxide production by each part of the ecosystem.

Show your working.

**(2)**

(b)     A student who looked at the data in the table concluded that plants carry out more respiration than non-photosynthetic organisms in the ecosystem.

Use the information provided to suggest why these data may **not** support the student’s conclusion.

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**(2)**

(c)     What measurements would the scientists have made in order to calculate the rate of carbon dioxide production?

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**(2)**

(d)     The scientists calculated the mean rate of carbon dioxide production of the leaves using measurements of carbon dioxide release in the dark.

Explain why they did **not** use measurements taken in the light.

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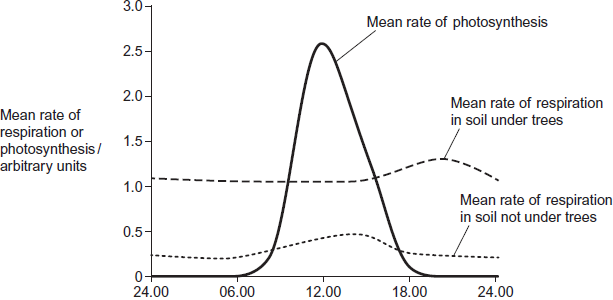
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**(2)**

Another group of scientists measured the mean rate of respiration in soil under trees and soil not under trees in the same wood. They also measured the mean rate of photosynthesis in the trees.

They took measurements at different times of day during the summer.

The figure below shows the scientists’ results.

  
          Time of day

(e)     (i)      Describe **two** ways in which the mean rate of respiration in soil under trees is different from soil not under trees.

1. \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

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**(2)**

(ii)     Suggest **one** explanation for the differences in the mean rate of respiration in soil under trees and soil not under trees between 06.00 and 12.00.

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**(2)**

(f)     The scientists suggested that the rise in the mean rate of photosynthesis was the cause of the rise in the mean rate of respiration in soil under trees.

(i)      Suggest how the rise in the mean rate of photosynthesis could lead to the rise in the mean rate of respiration in soil under trees.

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**(2)**

(ii)     Suggest why there is a delay between the rise in the mean rate of photosynthesis and the rise in the mean rate of respiration.

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**(1)**

**(Total 15 marks)**

**Q5.**

Beech trees have two types of leaves called sun leaves and shade leaves. Sun leaves grow on branches exposed to direct sunlight, shade leaves grow on branches exposed to light that has passed through leaves. An ecologist collected sun leaves and shade leaves from beech trees and determined the mean mass of each photosynthetic pigment in both types of leaf. His results are shown the table below.

|  |  |  |
| --- | --- | --- |
| **Photosynthetic pigment** | **Mean mass of each pigment per m2 of leaf area / μg (± standard deviation)** | |
| **Sun leaves** | **Shade leaves** |
| Chlorophyll a | 299.3 (± 2.1) | 288.9 (± 0.1) |
| Chlorophyll b | 290.7 (± 2.1) | 111.1 (± 0.1) |
| Chlorophyll c | 0.10 (± 0.01) | 0.07 (± 0.01) |

(a)     Describe how you would present the data in the table as a graph.

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**(2)**

(b)     The ecologist collected shade leaves at random from a branch.  
Suggest a method he could have used to collect shade leaves at random from a branch.

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**(2)**

(c)     The ecologist concluded that there is a significant difference between the amounts of chlorophyll b in sun leaves and shade leaves of beech trees.

Do you agree with this conclusion?

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**(2)**

(d)     Each type of chlorophyll is produced by a specific enzyme-controlled pathway.  
Use this information to suggest how the same beech tree can produce more chlorophyll b in some leaf cells than others.

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**(2)**

**(Total 8 marks)**

Mark schemes

**Q1.**

(a)  ☑ NADP, ADP, Pi and water;

**1**

(b)  1.   Chlorophyll absorbs light

**OR**

Light excites/moves electrons in chlorophyll;

*Ignore photosystems.*

2.   Electron/s are lost

**OR**

(Chlorophyll) becomes positively charged;

*Ignore site/molecule from where electrons are lost.*

*Accept electrons go to electron transport/carrier chain for ‘electrons lost’.*

**2**

(c)  Ink and (leaf) pigments would mix

**OR**

(With ink) origin/line in different position

**OR**

(With pencil) origin/line in same position

**OR**

(With pencil) origin/line still visible;

**1**

(d)  1.   Level of solvent below origin/line;

*Reject water or any named aqueous solution.*

*Accept named organic solvent.*

2.   Remove/stop before (solvent) reaches top/end;

**2**

(e)  Accept any answer in range of 0.58 to 0.62;

*Accept 0.58 or 0.62.*

*Ignore any numbers which follow numbers in range.*

**1**

(f)   (Absorb) different/more wavelengths (of light) for photosynthesis;

*Accept wider/larger range of wavelengths.*

*Accept frequency for wavelength.*

*Accept light-dependent reaction /photophosphorylation /photoionisation for photosynthesis.*

**1**

**[8]**

**Q2.**

(a)     1.      (Less/no) ATP;

2.      (Less/no) reduced NADP;

*Accept NADPH, NADPH + H, NADPH2 NADPH + H+*

*Reject reduced NAD, NADH etc,*

**2**

(b)     1.      (Less/no) carbon dioxide (reacts) with RuBP;

2.      (Less/no) GP;

**2**

(c)     1.      Stroma (of/in chloroplast);

*Reject: stoma*

*Reject stroma of cytoplasm/chlorophyll*

*Reject stroma of mitochondrion*

*Ignore references to Calvin cycle or the light-independent reaction*

**1**

(d)     1.      Rubisco activity increases with temperature

**OR**

Rubisco optimum temperature is above (**rubisco activase**);

2.      (Rubisco) **activase** activity decreases at high temperatures (allow any temperature above 25 ºC.)

**OR**

(Rubisco) **activase** optimum (allow in range) 25 to 30 ºC.;

*Accept denatures at high temperature (allow any temperature above 25 ºC)*

3.      (Results/graphs suggest) **activase** cannot/does not affect activity of rubisco;

4.      (Results are) only for cotton;

*Accept may not be the same in other species/types of plant*

*Ignore: only one study*

5.      (Results are) for isolated enzymes;

6.      No stats test;

**4 max**

**[9]**

**Q3.**

(a)     Oxygen production / concentration and time.

*Accept: oxygen volume / concentration*

*Reject: oxygen uptake*

*Neutral: reference to carbon dioxide uptake*

**1**

(b)     1.      Intensity of light;

*Accept: distance from light*

2.      Amount / number / mass / species of algae / photosynthesising cells;

3.      Carbon dioxide (concentration / partial pressure);

4.      Time.

**2 max**

(c)     1.      (pH) increases;

*Neutral: becomes more alkaline / less acidic*

2.      As (more) carbon dioxide removed (for photosynthesis).

**2**

(d)     1.      Less absorption / (more) reflection (of these wavelengths of light);

*Reject: no absorption or cannot absorb unless in context of green light.*

*Note: no green light absorbed or green light reflected = 2 marks.*

2.      (Light required) for light dependent (reaction) / photolysis

*Accept: for excitation / removal of electrons (from chlorophyll)*

3.      (Represents) green light / colour of chlorophyll.

**2 max**

**[7]**

**Q4.**

(a)

|  |  |  |
| --- | --- | --- |
| **Part of ecosystem** | **Mean rate of carbon dioxide production /  cm3 m−2 s−1** | **Percentage of total carbon dioxide production measured by the scientists** |
| Leaves of plants | 0.032 | 25.0 |
| Stems and roots of plants | 0.051 | **39.8** |
| Non- photosynthetic soil organisms | 0.045 | **35.2** |

2 correct = 2 marks;;

Adding rates to get 0.128 = 1;

*If rounded to 40 and 35 in table;*

*•    but working shows decimal points, then award 2 marks   
•    but no working shown, then 1 max*

**2 max**

(b)     1.      Data only include (heterotrophic) soil organisms;

2.      Doesn’t include animals (above ground) / other (non-soil) organisms;

3.      Doesn’t take into account anaerobic respiration;

*Award points in any combination*

*Accept for 1 mark idea that CO2 for leaves doesn’t take into account photosynthesis – not told in dark until part (d)*

**2 max**

(c)     **All three** of following = 2 marks;;

**Two** of them = 1 mark;

Volume of carbon dioxide given off

(From known) area / per m2 / m-2

In a known / set time

*Ignore ‘amount’ / concentration of CO2*

*Accept per second / per unit time*

**2**

(d)     1.      (In the light) photosynthesis / in the dark no photosynthesis;

2.      (In light,) carbon dioxide (from respiration) being used / taken up (by photosynthesis);

**2**

(e)     (i)      (Rate of respiration)

*Assume “it” means soil under trees*

1.      In soil under trees (always) higher;

*Accept converse for soil not under trees*

*Accept ‘in the shade’ means under the trees*

2.      In soil under trees does not rise between 06.00 and 12.00 / in the middle of the day / peaks at 20:00-21.00 / in the evening;

3.      In soil **not** under trees, peaks at about 14:00-15:00 / in middle of day;

*2. and 3. No mm grid, so accept ‘between 18.00 and 24.00’ or ‘between 12.00 and 18.00’*

**2 max**

(ii)     (Between 06.00 and 12.00, (No Mark))

Respiration higher in soil under tree, (No mark)

*Do not mix and match mark points*

*No list rule*

1.      Tree roots carry out (a lot of) respiration;

2.      More / there are roots under tree;

*Accept converse for soil not under trees*

***OR***

3.      More food under trees;

4.      So more active / greater mass of / more organisms (carrying out respiration);

*Accept converse for soil not under trees*

***OR***

Soil not under trees respiration increases (No mark)

5.      Soil in sunlight gets warmer;

6.      Enzymes (of respiration) work faster;

*Accept converse for soil under trees*

**2 max**

(f)      (i)      1.      Photosynthesis produces sugars;

2.      Sugars moved to roots;

*Do not penalise named sugars other than sucrose*

3.      (Sugars) are used / required for respiration;

**2 max**

(ii)     Takes time to move sugars to roots;

*Look for movement idea in (i) – can carry forward to (ii)*

**1**

**[15]**

**Q5.**

(a)     1.      Bar chart;

2.      Error bars to represent standard deviation (of mean);

3.      Photosynthetic pigment on *x* axis and mass of pigment on *y* axis;

*Accept suitable sketch*

**2 max**

(b)     1.      Number leaves on the branch;

2.      Use random number table / calculator / pick numbers from bag to determine which leaf to pick;

*Accept use of random number generator*

***OR***

3.      Collect large number of leaves;

4.      Pick out of bag with some idea of randomness;

**2**

(c)     No (no mark)

1.      No stats test carried out;

2.      Standard error / 95% confidence interval calculation identified;

*If awarded, student scores 2 marks – for points 1 and 2*

Yes (no mark)

3.      No overlap shown by the standard deviations;

4.      Ranges around mean stated;

*88.6-92.8 and 111.0-111.2 (1 × SD) or 86.5-94.9 and 110.9-111.3   
(2 × SD)*

**2 max**

(d)     In shade leaves:

1.      Greater amount of enzyme / enzyme activity (for production of chlorophyll b);

2.      Greater gene expression / transcription of the gene / more mRNA produced / gene switched on;

3.      Greater translation;

4.      Enzyme / substrate is light sensitive – faster rate of reaction with lower light;

**2 max**

**[8]**

Examiner reports

**Q1.**

(a)  Almost 70% of students correctly identified the chemicals needed for the light-dependent reaction.

(b)  Photoionisation in the light-dependent reaction was clearly described by many students, with 44% obtaining both marks and approximately 77% obtaining at least one mark. Some students limited their description to photolysis and gained no marks. Many students referred to chlorophyll absorbing light and/or light exciting the electrons in chlorophyll. Some answers referring only to chloroplasts or photosystems did not obtain this mark point. Many students referred to electrons being lost or being passed to the electron transport chain. Few students referred to chlorophyll molecules becoming positively charged.

(c)  This question was not well answered and was a poor discriminator. Slightly more than 20% of students obtained the mark. Only the minority of students could clearly explain that pencil was used to mark the origin so that the origin/line was still visible after running the chromatogram. The problem of ink dissolving in the solvent was appreciated by many but the consequences of this were not explained; the mixing of the ink and leaf pigments was not appreciated by most students. Answers often only referred to the ink running/smudging/dissolving in the solvent and affecting results. It was not always clear whether students were writing about pencil or ink.

(d)  Considering this required straightforward recall of required practical activity 7, the responses were often quite poor. Approximately 12% of students obtained both marks and around 45% obtained at least one mark. Many answers only mentioned placing the chromatogram in a solvent, adding a lid and running the chromatogram for a set time or until the pigments had separated. More students obtained a mark for the level of the solvent being below the origin than for marking the solvent front or for removing the chromatogram before it reached the top/end. Some students explained the principle of chromatography rather than providing details on the method. A range of inappropriate solvents were referred to including water, glucose and hydrochloric acid.

(e)  Approximately 66% of students used the given formula and correctly calculated the Rf value of pigment **C**.

(f)   Approximately 46% of students obtained this mark, explaining that different wavelengths/frequencies of light could be absorbed for photosynthesis. Students failing to gain credit often omitted to mention photosynthesis or did not refer to wavelength or frequency of light. A few students suggested the different colours of pigments enabled them to be identified during chromatography.

**Q2.**

(a)     Approximately 41% of students obtained both marks by referring to the reduction in ATP and reduced NADP. Students who gained a single mark usually did so by stating that there was less ATP rather than less reduced NADP. Many of these students incorrectly stated that less NADP or less reduced NAD was produced. Some students suggested that heat stress caused stomata to close and this limited carbon dioxide uptake and photosynthesis. Many students used additional pages for this question due to initially describing denaturation of rubisco or ATP synthase before realising that they needed to name specific products of the light-dependent reaction. It was disappointing to note that nearly a third of students scored zero.

(b)     Again, approximately 41% of students obtained both marks by explaining the role of rubisco in photosynthesis. Students gaining a single mark often failed to mention both RuBP and carbon dioxide, or simply referred to a six-carbon product with no mention of GP being formed. A minority of students incorrectly referred to GP as glucose phosphate. One in four students scored zero. Most of these responses were limited to describing how denaturation of rubisco would occur. Some students confused the Calvin cycle with the Krebs cycle.

(c)     Almost two-thirds of students correctly named the stroma as the location of rubisco. The thylakoids, crista and matrix were common incorrect responses.

(d)     The majority of students (56%) obtained two marks, invariably for describing the effects of an increase in temperature on the activity of rubisco and rubisco activase. However, many students then failed to use all the information successfully to evaluate the scientists’ conclusion. Only 25% of students obtained more than two of the four marks available. Relatively few students clearly stated that the results indicate that rubisco activase does not activate rubisco. Similarly, very few students stated that these results were only for cotton plants and were for isolated enzymes. Equally surprising was the scarcity of responses which referred to the lack of a statistical test. Consequently, this question did not discriminate as effectively as had been expected.

**Q3.**

(a)     Fewer than fifty percent of students correctly referred to oxygen production and time. Many simply referred to oxygen production or uptake of carbon dioxide. A number of students mentioned the mass / volume of the algal cells and suggested measuring the rate of oxygen production per unit mass of cells per unit time.

(b)     Two thirds of students were able to suggest two correct factors and almost every student obtained at least one mark usually for light intensity or carbon dioxide concentration. Despite the rubric stating ‘other than temperature’, a significant minority gave temperature as one of the factors. Common incorrect responses included water concentration, humidity and wavelength of light.

(c)     Approximately half the students obtained both marks explaining that the increase in pH was due to carbon dioxide being absorbed and used in photosynthesis. However, other students did not state whether the pH increased or decreased when carbon dioxide was removed from the solution, even though they correctly described the solution becoming more alkaline or less acidic. A decrease in pH sometimes became an increase by the end of an answer. Weaker responses often confused carbon dioxide with oxygen and respiration with photosynthesis. These students often suggested that carbon dioxide or oxygen was alkaline.

(d)     Most students obtained at least one mark usually for outlining the role of light energy in the light-dependent reaction. Fewer students obtained the first mark point as they suggested no light was absorbed rather than less absorption of light. Nevertheless, almost forty percent of students gained both marks by linking less absorption to a decrease in the light-dependent reaction or by suggesting that the wavelengths reflected represented green light. Incorrect responses often referred to limiting factors such as temperature or carbon dioxide.

**Q4.**

(a)    About three quarters of students obtained both marks for the calculation in this part. Some students only scored one mark because of incorrect rounding of numbers in their calculations or answers.

(b)     This part proved far more challenging than intended. It was hoped that students would note that only (plants and) non-photosynthetic soil organisms are mentioned in the study and point out that there are lots of other organisms / animals that are not mentioned. The examiners accepted statements that carbon dioxide from leaves did not take into account effects of photosynthesis, because students were not told until (d) that measurements were taken in the dark. Quite a few students treated the leaves of plants and the stems and roots of plants as separate organisms, rather than different parts of the same organisms. Nearly three quarters of students failed to score any marks.

(c)     To obtain two marks in this part, students had to identify three measurements: volume of carbon dioxide, from a given / known area, in a set time. If they identified two of these, they obtained one mark. A quarter of students obtained two marks and about half failed to score. There were many vague references to *amount* of carbon dioxide and *time* unqualified and many students missed out area altogether.

(d)     This part was done well by many students and three quarters obtained both marks. They were able to state that there is no photosynthesis in the dark and photosynthesis would take up carbon dioxide. Some students were confused about whether it was photosynthesis or respiration that produces carbon dioxide, or uses it.

(e)    (i)       Most students noted that respiration in soil under trees is always higher in this part. Over a third went on to describe a difference in the peak times of respiration in soil under trees and soil not under trees. Although a 2 mm grid was not given on the graph, the examiners expected some attempt to describe time frames, rather than just *earlier* or *later*.

(ii)     Correct answers to this part usually revolved around respiration in soil not under trees increasing because the soil gets warmer in sunshine and this leads to faster enzyme activity. Very few looked back to the table and noted the high rate of respiration in roots of plants, of which there would be a lot under trees. Many students thought that photosynthesis by the trees would make more oxygen available in the soil under the trees. Others thought that photosynthesis by the soil not under the trees would increase during the day.

(f)      As the final interpretive question on the final paper, this part was intended to be challenging and so it proved. Very few students appear to appreciate the relationship between photosynthesis and respiration in plants in terms of respiratory substrate. This was tested last year and proved challenging then. Students should appreciate that plants make their own respiratory substrates via photosynthesis. Those students who did score in this part did understand this. Given that many students treated leaves and roots of plants as separate organisms in (b), it was perhaps not surprising that very few students suggested it takes time for sugars to travel from leaves to roots. Some got ‘close’ by suggesting it took time for oxygen from photosynthesis to travel to the roots.

**Q5.**

(a)     This was generally answered well. Some references to error bars without mention of representing standard deviation were seen, and these answers were not given credit for mark point 2.

(b)     This was generally answered well. There were some inappropriate uses of grids and coordinates and some trees shaken or beaten to remove leaves; neither method was credited.

(c)     The vast majority of students pointed out that there was no overlap of standard deviations (or 2 × the standard deviation) for mark point 3 but did not go any further to gain the second mark. Although the range was calculated correctly by many for mark point 4, very few correctly identified that it was not possible to draw a conclusion without a statistical test result. Many students referred to standard error without appreciating that this had not been given and could not be worked out without knowing the sample size.

(d)     This question provided an opportunity for students to shine and express their understanding correctly in the context of the information provided. Many answers were seen, however, relating to sun leaves being warmer and therefore having more enzyme activity to produce chlorophyll. These were in the wrong context and did not gain the marks.