Vertex Academy

NCEA Level 2 Science workbook

45 worksheets · answers at the back

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Year 12 Science: Biology investigation: catalase and temperature, start to finish

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. A student investigates how sugar concentration (0, 2, 4, 6 and 8%) affects how fast yeast respires, by counting carbon dioxide bubbles per minute. Name the independent and dependent variables.

2. Three catalase discs rise in 20 s, 22 s and 21 s. Find the mean time and the rate.

3. Write a hypothesis for the yeast investigation in question 1, with a biological reason.

4. At one temperature the discs take 20 s, 22 s and 45 s, and the student noted the third disc stuck to the tube. What should the mean be, and why?

5. A group's three repeats at every temperature were within 2 s of each other. Is that evidence of reliability or of validity?

6. In a field study comparing leaf size in sun and shade, why should leaves be picked at random?

Fix the mistake

7. Correct this statement: "My hypothesis is that temperature will affect catalase."

8. Correct this statement: "I graphed the time taken, so the graph shows the rate."

9. Correct this statement: "The high temperatures killed the enzyme."

10. Correct this statement: "My repeats were close, so my method was valid."

Year 12 Science: Biological validity: judging the science in public claims

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. A social media post says: 'Antibiotics will help you get over the flu faster.' Label the claim and correct it.

2. A dairy company's website says milk contains calcium, which is needed to build strong bones. Label the claim, and say who produced it and a likely audience.

3. A supplement's website says: 'In our study of 15 people, 12 felt less tired after two weeks.' Give two weaknesses in this evidence.

4. A student writes: 'The Wakefield paper was peer reviewed, so its findings were valid.' What is wrong with this?

5. An article contains three claims: a true one about vitamin C, an untrue one saying its product cures colds, and a vague quote from 'scientists'. Which should rank first for Excellence, and why?

6. Why does a vested interest not automatically make a claim inaccurate?

Fix the mistake

7. Correct this statement: "The intended audience is the general public."

8. Correct this statement: "The company wants to sell it, so everything it says is inaccurate."

9. Correct this statement: "It was in a peer-reviewed journal, so it must be true."

10. Correct this statement: "For Excellence I summarised every claim again at the end."

Year 12 Science: Adaptation: how New Zealand plants and animals fit their way of life

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. Classify each as structural, physiological or behavioural: (a) tuatara basking near their burrows, (b) woolly alpine leaves, (c) antifreeze sugars in alpine plant cells.

2. Which life process do mangrove pneumatophores help, and how?

3. Explain how nostrils at the tip of the bill help a kiwi's nutrition.

4. Give one limitation of pneumatophores.

5. Why does gas exchange through tracheae limit how big an insect like a wētā can grow?

6. Most of New Zealand's alpine plants have white flowers. Which life process does this help, and why?

Fix the mistake

7. Correct this statement: "Kiwi grew nostrils at the end of their bills because they needed to smell worms."

8. Correct this statement: "The mangrove has pneumatophores. (and nothing more)"

9. Correct this statement: "Feeding at night is a physiological adaptation of kiwi."

10. Correct this statement: "For Option 1 I compared a mangrove, a kiwi and a tuatara."

Year 12 Science: Cells, organelles and membrane transport

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. A cube-shaped cell has sides of 3 µm. What is its SA:V?

2. A potato cylinder goes from 4.00 g to 3.70 g in a salt solution. What is its percentage change in mass?

3. Glucose enters a cell down its concentration gradient through a carrier protein, without ATP. Which transport method is this?

4. A red blood cell is put into pure water. What happens to it, and why?

5. Sperm cells swim using a tail that needs a lot of ATP. Which organelle would you expect to find in large numbers near the tail?

Exam-style question: seawater on a paddock

A storm surge floods a coastal paddock with seawater. A day later the ryegrass is wilting, even though the soil is soaking wet. Seawater is a much more concentrated salt solution than the sap inside the grass's root hair cells.

6. Describe osmosis.

7. Explain why the grass wilts after the seawater flood.

8. Before the flood, the root hair cells took in nitrate ions by active transport. Explain why this process needs mitochondria.

9. Discuss how the structure of a root hair cell suits it to taking in both water and mineral ions, and compare how the two cross the membrane.

Fix the mistake

10. Correct this statement: "In osmosis, the salt moves out of the cell into the water."

11. Correct this statement: "Water moves from a high concentration of solute to a low concentration of solute."

12. Correct this statement: "Facilitated diffusion uses energy because it uses a protein."

13. Correct this statement: "A bigger cell has a bigger SA:V because it has more surface area."

Year 12 Science: Enzymes and the factors that affect them

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. An enzyme reaction gives off 30 cm³ of oxygen in 2 minutes. What is the average rate?

2. An enzyme is kept at 5 °C for an hour, then warmed to 37 °C. What happens to its activity, and why?

3. The rate has levelled off at a high substrate concentration. What happens to the rate if you double the substrate concentration again?

4. Which kind of inhibitor can be overcome by adding more substrate?

5. In the class's catalase results, how many times faster was the rate at 30 °C than at 10 °C?

Exam-style question: kiwifruit in jelly

Mere makes two jellies with gelatine, which is a protein. She stirs fresh kiwifruit into the first and canned kiwifruit into the second. Canning heats the fruit to a high temperature. The jelly with canned fruit sets, but the jelly with fresh fruit stays runny.

6. Describe what an enzyme is.

7. Explain why the jelly with fresh kiwifruit does not set, using the idea of the active site.

8. Explain why the jelly with canned kiwifruit does set.

9. Mere keeps fresh kiwifruit in the fridge at 4 °C for a week, then puts it in a jelly. Discuss whether this jelly will set, comparing the effects of low and high temperature on the enzyme.

Fix the mistake

10. Correct this statement: "At low temperatures the enzyme is denatured, so it stops working."

11. Correct this statement: "The enzyme dies at high temperatures."

12. Correct this statement: "The enzyme is used up in the reaction, so the rate slows down."

13. Correct this statement: "The active site and the substrate are the same shape."

Year 12 Science: Photosynthesis and respiration in the cell

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. Where in the chloroplast are water molecules split?

2. A cell breaks down 5 glucose molecules. How many ATP can it make at most aerobically (38 per glucose), and how many anaerobically?

3. Besides ATP, what does anaerobic respiration make in yeast?

4. Doubling the light makes no difference to a plant's rate of photosynthesis, but adding carbon dioxide raises it. What was limiting?

5. A pondweed shoot gives off 72 bubbles in 4 minutes. What is the rate?

Exam-style question: tomatoes in a glasshouse

A grower in Pukekohe raises tomatoes in a glasshouse. On sunny days she pumps in extra carbon dioxide, raising it to 1000 parts per million; outside air has about 424 parts per million.

6. Write the word equation for photosynthesis and name the organelle where it happens.

7. Calculate how many times higher the carbon dioxide concentration is inside the glasshouse than outside.

8. Explain why the tomato plants photosynthesise faster at midday than at sunrise.

9. Discuss why the extra carbon dioxide raises the rate of photosynthesis on a bright summer day but makes little difference on a dull winter morning, and why letting the glasshouse overheat would lower the rate.

Fix the mistake

10. Correct this statement: "Plants photosynthesise, and animals respire."

11. Correct this statement: "Respiration makes energy."

12. Correct this statement: "The light-independent stage happens in the dark."

13. Correct this statement: "Anaerobic respiration happens in the mitochondria without oxygen."

Year 12 Science: DNA replication, mitosis and the cell cycle

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. At what point in the cell cycle is DNA copied?

2. A cell has 8 chromosomes. How many DNA molecules does it contain at metaphase, and how many chromosomes does each daughter cell get?

3. One DNA strand reads 5' ATGCCTA 3'. Write the new strand built on it during replication, with its ends labelled.

4. In a root tip squash, 45 of the 300 cells counted are in mitosis. Calculate the mitotic index.

5. Explain why a growing root makes more cells rather than making its cells bigger.

Exam-style question: a copper skink

Copper skinks are small lizards common in Auckland gardens. Like most New Zealand skinks, they give birth to live young, and a newborn is only a fraction of its adult size. When a bird grabs its tail, the skink can drop the tail and escape, then slowly grow a new one.

6. Describe when DNA replication happens in the cell cycle, and how the DNA is copied.

7. Explain why DNA replication must happen before mitosis.

8. Explain why the young skink grows by making more cells rather than by its cells getting larger.

9. Discuss why mitosis is needed throughout the skink's life, linking the survival of its cells to the survival of the whole skink.

Fix the mistake

10. Correct this statement: "DNA replication happens during prophase, when the chromosomes appear."

11. Correct this statement: "Interphase is when the cell rests between divisions."

12. Correct this statement: "Mitosis makes four cells that are all genetically different."

13. Correct this statement: "Each daughter cell gets half of the parent cell's DNA."

Year 12 Science: Meiosis, mutation and inheritance

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. A human skin cell has 46 chromosomes. How many does a human sperm cell have?

2. In guinea pigs, black (B) is dominant to brown (b). What percentage of the offspring of Bb × bb would you expect to be brown?

3. A pink snapdragon (C^RC^W) is crossed with a white snapdragon (C^WC^W). Give the phenotype ratio.

4. Two yellow mice (A^ya) are crossed and 12 pups survive. How many would you expect to be yellow, and how many non-yellow (agouti)?

5. Genes A and B are on different chromosomes. What percentage of the offspring of AaBb × aabb would be aabb?

6. Two parents are both carriers (Aa) of a recessive condition. What is the chance their next child is affected?

Exam-style question: Shorthorn cattle

A Waikato farmer breeds Shorthorn cattle. Coat colour shows codominance: RR is red, WW is white and RW is roan, with red and white hairs mixed. Polled (no horns, P) is dominant to horned (p). The two genes are on different chromosomes.

7. Describe codominance, using roan cattle as the example.

8. Two roan cattle are mated many times. Give the expected ratio of coat colours in their calves, using a Punnett square.

9. The farmer's new bull is polled. Explain how a test cross would show whether he is PP or Pp.

10. The bull is mated with three horned cows and all three calves are polled. Discuss whether the farmer can now be sure the bull is PP, using probabilities.

Fix the mistake

11. Correct this statement: "Crossing over happens between sister chromatids."

12. Correct this statement: "A 3 : 1 ratio means a family with four children will have exactly three with the dominant trait."

13. Correct this statement: "Codominance and incomplete dominance are the same, because the heterozygote looks different from both parents."

14. Correct this statement: "Independent assortment creates new alleles."

Year 12 Science: Gene pools and how they change

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. A population of 50 snails has 18 AA, 24 Aa and 8 aa. Find the frequency of A and of a.

2. The frequency of allele B in a population is 0.35. What is the frequency of its only other allele, b?

3. A storm kills most of a small island population of skinks, and which ones die is down to luck. Which process has changed the gene pool?

4. Six birds are blown to a new island and start a population there. What is this called?

5. In 1989, 18 of 35 black robin females laid rim eggs. What percentage is that, to one decimal place?

6. Which process adds alleles to a gene pool from another population of the same species?

Exam-style question: the black robin

In 1980 only five black robins survived, with one breeding pair. Some females lay eggs on the rim of the nest, a trait that fits a single dominant allele (R). Rim eggs never hatch unless people move them into the nest. Staff did this until 1990: in 1989, 51.4% of females were rim layers, and in 2007 to 2011, after it stopped, 9% were.

7. Describe what is meant by a gene pool and allele frequency.

8. Explain why the 1980 bottleneck reduced the genetic diversity of the black robin.

9. Suppose a sample of 40 robins contained 2 RR, 12 Rr and 26 rr birds (practice numbers, not real counts). Calculate the frequency of R and of r.

10. Discuss how human management and natural selection changed the frequency of the rim-laying allele between 1980 and 2011.

Fix the mistake

11. Correct this statement: "Individuals evolve when they adapt to their environment."

12. Correct this statement: "After a bottleneck, once the population grows back, its genetic diversity comes back too."

13. Correct this statement: "Genetic drift means the best adapted alleles become more common."

14. Correct this statement: "With 98 BB, 84 Bb and 18 bb, the frequency of b is 18 ÷ 200."

Year 12 Science: Zonation on a rocky shore: investigating a community pattern

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. Three transects gave 3, 6 and 3 lined whelks in their Q5 quadrats. Find the mean per quadrat.

2. Turn that mean into a density per m², using 0.25 m² quadrats.

3. Using the class's table, describe where Neptune's necklace is found and where it is most abundant.

4. What kind of factor most likely sets the lower limit of the barnacle band?

5. Periwinkles crowd into crevices at low tide. Is that a structural, behavioural or physiological adaptation?

6. Write an Achieved sentence describing the periwinkle pattern, quoting data.

7. Give one reason, using an adaptation, why periwinkles can live at Q1 where barnacles cannot.

8. Lined whelks were absent from Q1 to Q3. Explain why, for a Merit answer.

Fix the mistake

9. Correct this statement: "The barnacles live in the mid shore because they like it there."

10. Correct this statement: "Periwinkles have adapted to the high shore so they can survive there."

11. Correct this statement: "There were 42 periwinkles at Q1, so the density is 42 per m²."

12. Correct this statement: "I chose where to put my transect so it went through the best rock pools."

Year 12 Science: DNA, transcription and translation

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. Write the complementary strand of 5' ATGCCA 3', with its ends labelled.

2. A DNA template triplet is TTC. What is the mRNA codon?

3. What anticodon pairs with the mRNA codon GGU?

4. Which amino acid does AUG code for, and what else does AUG do?

5. Of the 64 codons, how many code for amino acids?

6. A DNA sample is 30% adenine. What percentage is guanine?

Exam-style question: a section of a keratin gene

Keratin is the structural protein in hair and nails. A short, made-up section of the template strand of a keratin gene, written 3' to 5', reads TAC AAA CGT GGC ATT.

7. Give the mRNA codons and the amino acid sequence this section codes for.

8. Give the anticodons of the tRNAs that bring the first four amino acids.

9. Explain why changing the codon GCA to GCC would not change the keratin.

10. Discuss how the base sequence of the gene decides the shape and function of keratin, and why the ribosome reads mRNA rather than the DNA itself.

Fix the mistake

11. Correct this statement: "The template triplet TAC gives the mRNA codon ATG."

12. Correct this statement: "The codon AUG has the anticodon AUG."

13. Correct this statement: "Given the coding strand ATG, I complemented it to get the mRNA UAC."

14. Correct this statement: "Translation happens in the nucleus, where the DNA is."

Year 12 Science: Mutations, metabolic pathways and the environment

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. The mRNA codon UAC changes to UAA. Name the type of mutation.

2. The mRNA codon GGU changes to GGC. What happens to the amino acid?

3. Which shifts the reading frame: deleting 1 base or deleting 3 bases?

4. In the pathway A → B → C, enzyme 2 (B to C) does not work. Which substance builds up, and which is missing?

5. Name two mutagens.

6. What environmental factor makes a Siamese cat's ears dark?

Exam-style question: melanin and mutations

Gene 2 codes for tyrosinase, the enzyme that turns tyrosine into melanin. A short, made-up section of its template strand, 3' to 5', reads TAC AAG CTT GTA ACC. Mutation 1 reads TAC AAG CTC GTA ACC, and mutation 2 reads TAC AAG CTT GTA ACT.

7. Give the amino acid sequence for the normal gene and for each mutation.

8. Name the type of each mutation.

9. Explain which mutation is more likely to cause albinism.

10. Discuss how a mutation in gene 1 would show differently from one in gene 2, and how the environment can change melanin production without changing the genes.

Fix the mistake

11. Correct this statement: "A substitution always changes the protein."

12. Correct this statement: "A deletion removes one amino acid, so it is mild."

13. Correct this statement: "The Siamese cat's cold ears changed its genes for dark fur."

14. Correct this statement: "If enzyme 2 is blocked, the substrate of enzyme 1 builds up."

Year 12 Science: Investigating cells under the light microscope

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. What is the total magnification with a ×10 eyepiece and a ×10 objective?

2. The field of view at ×100 is 1.8 mm. What is it at ×400, in µm?

3. Six cells fit across a 1.8 mm field of view. How long is one cell, in µm?

4. A 50 µm guard cell is drawn 75 mm long. What is the magnification of the drawing?

5. A drawing at ×2000 needs a 10 µm scale bar. How long should the bar be, in mm?

6. Name the convention error: the student labelled each organelle with an arrow drawn freehand that crossed another label line.

7. Your onion epidermis slide shows no chloroplasts. Write an Achieved annotation linking this to where the tissue grows.

8. Write a Merit annotation explaining how the contractile vacuoles help Paramecium survive in pond water.

9. A drawing of Elodea cells has gaps between the cells and no chloroplasts drawn. Is each a convention error or a representation error?

Fix the mistake

10. Correct this statement: "I shaded the chloroplasts in green so they stand out."

11. Correct this statement: "I focused at ×400 using the coarse focus knob."

12. Correct this statement: "The field of view is 4.0 mm at ×40, so it is 40 mm at ×400."

13. Correct this statement: "I drew the cell with mitochondria and ribosomes because textbook cells have them."

Year 12 Science: The chemistry behind the lithium-ion battery

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. Write the oxidation half equation at the graphite electrode during discharge.

2. Give the oxidation number of cobalt in CoO_2 and in $LiCoO_2$, and say whether cobalt is oxidised or reduced on discharge.

3. Explain why water cannot be used as the solvent in the electrolyte.

4. Explain why Yoshino's carbon electrode made the battery safer than Whittingham's.

5. A laptop battery is labelled 11.1 V and 4.0 Ah. How many 3.7 V cells are in series, and how much energy does it store in Wh?

Fix the mistake

6. Correct this statement: "Electrons travel through the electrolyte from one electrode to the other."

7. Correct this statement: "The lithium-ion battery runs out because the lithium gets used up."

8. Correct this statement: "My report lists the history and the equations in separate sections."

9. Correct this statement: "$CoO_2 + e^- \rightarrow LiCoO_2$ is the reduction half equation."

Year 12 Science: Lewis structures, shapes and polarity

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. How many valence electrons are shown in the Lewis structure of HCN?

2. Give the shape and bond angle of methanal, H2CO (C in the middle, double bonded to O).

3. What is the bond angle in silane, SiH4?

4. Name the shape of oxygen difluoride, OF2.

5. Is dichloromethane, CH2Cl2, polar or non-polar?

Exam-style question: BCl3 and PCl3

Boron trichloride, BCl3, and phosphorus trichloride, PCl3, are both used to make other chemicals in industry. Each has three Cl atoms bonded to a central atom.

6. Give the total number of valence electrons in the Lewis structure of each molecule.

7. Name the shape of each molecule and give its bond angle.

8. Explain why the two molecules have different shapes.

9. Both molecules contain polar bonds. Discuss why BCl3 is non-polar but PCl3 is polar.

Fix the mistake

10. Correct this statement: "CO2 is bent like water, because it has three atoms."

11. Correct this statement: "A double bond counts as two regions of electron density."

12. Correct this statement: "CCl4 has polar bonds, so it must be a polar molecule."

13. Correct this statement: "In a Lewis structure of PCl3 only the bonds and the P lone pair need drawing."

Year 12 Science: Structure and properties of solids

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. What type of solid is magnesium, Mg?

2. What type of solid is silicon dioxide, SiO_2?

3. What type of solid is dry ice, solid CO_2?

4. Does solid potassium bromide, KBr, conduct electricity?

5. Will iodine, I_2, dissolve in hexane?

Exam-style question: copper, magnesium chloride and iodine

Copper, Cu, is used for electrical wiring; magnesium chloride, $MgCl_2$, is a salt found in seawater; and iodine, I_2, is a dark grey solid.

6. Give the type of solid and the particles in each of copper, magnesium chloride and iodine.

7. Explain why copper conducts electricity as a solid, but magnesium chloride conducts only when molten or dissolved.

8. Explain why iodine has a much lower melting point than magnesium chloride.

9. Predict and explain whether magnesium chloride and iodine will dissolve in hexane, a non-polar solvent.

Fix the mistake

10. Correct this statement: "When iodine melts, the covalent bonds between the iodine atoms break."

11. Correct this statement: "Solid sodium chloride conducts because it is made of ions."

12. Correct this statement: "Metals conduct because their positive ions move through the metal."

13. Correct this statement: "Graphite conducts because its layers can slide over each other."

Year 12 Science: Energy changes in reactions

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. Is ice melting endothermic or exothermic?

2. $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$, $\Delta rH = -890$ kJ mol^{-1}. How much energy is released by burning 4.00 g of methane? $M(CH_4) = 16.0$ g mol^{-1}.

3. Using the same equation, what mass of methane must burn to release 1780 kJ?

4. Use the bond enthalpy table to calculate ΔrH for $H_2(g) + Br_2(g) \rightarrow 2HBr(g)$.

5. $N_2 + 3H_2 \rightarrow 2NH_3$ has $\Delta rH = -92$ kJ mol^{-1}. What is ΔrH for $2NH_3 \rightarrow N_2 + 3H_2$?

Exam-style question: hydrogen as a fuel

Hydrogen can power vehicles, either burned in an engine or in a fuel cell, and the only product is water. $2H_2(g) + O_2(g) \rightarrow 2H_2O(l)$, $\Delta rH = -572$ kJ mol^{-1}. $M(H_2) = 2.0$ g mol^{-1}.

6. State whether the reaction is exothermic or endothermic, and explain your choice in terms of bonds.

7. Calculate the energy released when 1.00 kg of hydrogen reacts.

8. Calculate the mass of hydrogen that must react to release 2000 kJ.

9. When the water forms as a gas, $\Delta rH = -484$ kJ mol^{-1}. Use this and H–H = 436 and O=O = 498 kJ mol^{-1} to calculate the average O–H bond enthalpy.

10. Explain why ΔrH is more negative when liquid water forms than when water vapour forms.

Fix the mistake

11. Correct this statement: "Breaking bonds releases energy, which is why fuels give out heat."

12. Correct this statement: "ΔrH = bonds formed − bonds broken."

13. Correct this statement: "For $N_2 + 3H_2 \rightarrow 2NH_3$, bonds formed = 3 × N–H."

14. Correct this statement: "An endothermic reaction feels hot, because it takes in heat."

Year 12 Science: Naming and drawing organic compounds

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. Name $CH_3CH_2CH_2CH_2OH$.

2. Name $CH_3CH(CH_3)CH_2CH_2CH_3$.

3. Name $CH_3CH_2CH{=}CHCH_3$.

4. Name $CH_3CH_2CH_2COOH$.

5. Is $CH_3CBr(CH_3)CH_3$ primary, secondary or tertiary, and what is its name?

Exam-style question: three bottles of $C_4H_{10}O$

A technician finds three unlabelled bottles, each holding a compound with the formula $C_4H_{10}O$: butan-1-ol, butan-2-ol and 2-methylpropan-2-ol.

6. Draw the structural formula of butan-2-ol and classify it as primary, secondary or tertiary.

7. Name a constitutional isomer of butan-1-ol, also an alcohol, that is not in the bottles.

8. The technician also has but-1-ene and but-2-ene. Explain which of the two forms geometric isomers.

9. Butan-1-ol dissolves only partly in water, but ethanol mixes completely. Discuss why, using the structure of each molecule.

Fix the mistake

10. Correct this statement: "$CH_3CH_2CH_2CH(CH_3)CH_3$ is 4-methylpentane."

11. Correct this statement: "$CH_3CH_2CH(CH_2CH_3)CH_3$ is 2-ethylbutane."

12. Correct this statement: "But-1-ene has cis and trans isomers because it has a C=C double bond."

13. Correct this statement: "Butan-1-ol boils higher than butane because its O–H bond takes more energy to break."

Year 12 Science: Reactions of organic compounds

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. Ethene with H_2 and a Pt catalyst: give the type of reaction and the organic product.

2. Chloroethane heated with KOH(aq): type and product?

3. Propan-2-ol heated with concentrated H_2SO_4: type and product?

4. Butan-1-ol heated with $Cr_2O_7^{2-}/H^+$: type and product?

5. Propene with HCl: type and major product?

Exam-style question: starting from 2-bromobutane

A chemist starts with 2-bromobutane, $CH_3CHBrCH_2CH_3$.

6. Classify 2-bromobutane as primary, secondary or tertiary, and give the reason.

7. Give the reagent and conditions that turn it into butan-2-ol, and the reaction type.

8. Heated with KOH(alc), 2-bromobutane gives two alkenes. Name both, say which is major, and justify your choice.

9. Describe how bromine water could tell the alkene products apart from 2-bromobutane.

Fix the mistake

10. Correct this statement: "1-Bromopropane heated with KOH gives propene."

11. Correct this statement: "In the major product, the Br adds to the carbon with more H atoms."

12. Correct this statement: "2-Methylpropan-2-ol turns acidified dichromate green."

13. Correct this statement: "Polypropene is drawn with a double bond in each repeating unit."

Year 12 Science: Rates of reaction and collision theory

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. 40 mL of hydrogen is made in the first 20 s of a reaction. What is the average rate?

2. A flask loses 0.66 g of CO_2 in 3.0 minutes. What is the average rate in g min^{-1}?

3. Which two factors increase the fraction of collisions that have enough energy to react?

4. Why does a graph of gas volume against time level off?

5. A catalyst lowers Ea from 80 kJ mol^{-1} to 50 kJ mol^{-1} for a reaction with $\Delta H = -30$ kJ mol^{-1}. What is ΔH with the catalyst?

Exam-style question: decomposing hydrogen peroxide

Hydrogen peroxide slowly breaks down: $2H_2O_2(aq) \rightarrow 2H_2O(l) + O_2(g)$. A student adds manganese dioxide powder, a catalyst, to 50 mL of the solution and records the oxygen collected every 20 s: 0, 24, 40, 50, 55, 57 and 57 mL at 0 to 120 s.

6. Calculate the average rate of oxygen production over the first 40 s.

7. Describe how the rate changes over the 120 s, and explain the change using collision theory.

8. Explain how manganese dioxide speeds up the reaction, and state what it does to the final volume of oxygen.

9. Discuss how running the same reaction at a higher temperature would change the graph of volume against time.

Fix the mistake

10. Correct this statement: "A catalyst gives the particles more energy."

11. Correct this statement: "A higher concentration makes the particles move faster."

12. Correct this statement: "Powdered marble makes more gas than chips."

13. Correct this statement: "The rate is the number of collisions."

Year 12 Science: Equilibrium, acids, bases and pH

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. Write the Kc expression for $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$.

2. What is the pH of 0.0050 mol L^{-1} HCl?

3. What is the pH of 0.10 mol L^{-1} KOH?

4. Find $[H_3O^+]$ in a solution of pH 9.20.

5. For $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$, which way does the equilibrium shift when the pressure is increased?

Exam-style question: making methanol

Methanol, a fuel and solvent, is made industrially from carbon monoxide and hydrogen: $CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$. The forward reaction is exothermic.

6. Write the Kc expression for this equilibrium.

7. In a test vessel at equilibrium, [CO] = 0.20, $[H_2]$ = 0.30 and $[CH_3OH]$ = 0.045 mol L^{-1}. Calculate Kc and say what it shows.

8. Explain why the process is run at high pressure.

9. Discuss how raising the temperature affects the amount of methanol at equilibrium, the value of Kc, and the rate.

10. Equipment is rinsed with 0.010 mol L^{-1} NaOH. Calculate its pH.

Fix the mistake

11. Correct this statement: "At equilibrium the concentrations of reactants and products are equal."

12. Correct this statement: "Adding more reactant increases Kc."

13. Correct this statement: "The pH of 0.020 mol L^{-1} NaOH is –log(0.020) = 1.70."

14. Correct this statement: "A weak acid is the same as a dilute acid."

Year 12 Science: Oxidation and reduction: electrons, colours and equations

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. Find the oxidation number of Cr in $Cr_2O_7^{2-}$.

2. Find the oxidation number of N in NO_3^- and in NO_2, and say whether N is oxidised or reduced when NO_3^- becomes NO_2.

3. Balance the half equation for hydrogen peroxide acting as a reductant: $H_2O_2 \rightarrow O_2$.

4. Acidified hydrogen peroxide is added to colourless potassium iodide solution. Write the overall equation and describe what you see.

5. A copper wire is put in colourless silver nitrate solution. Write the overall equation, name the oxidant, and describe two observations.

Fix the mistake

6. Correct this statement: "The oxidant is the substance that gets oxidised."

7. Correct this statement: "$MnO_4^- + 8H^+ + 5Fe^{2+} + 5e^- \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O + 5e^-$"

8. Correct this statement: "Observation: Mn^{2+} ions are formed."

9. Correct this statement: "Mn has an oxidation number of 7+ in MnO_4^-."

Year 12 Science: Titration: how much acid is really in the vinegar?

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. 2.650 g of anhydrous sodium carbonate (M = 105.99 g mol^{-1}) is made up to 250.0 mL. Find its concentration.

2. A student's titres are 22.60 (rough), 22.15, 22.40, 22.20 and 22.10 mL. Which are concordant, and what is the mean titre?

3. $Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$. 20.00 mL of 0.1000 mol L^{-1} Na_2CO_3 needs 22.15 mL of HCl. Find c(HCl).

4. A cleaner is diluted 25.00 mL to 250.0 mL, and the diluted solution is 0.0850 mol L^{-1}. What is the concentration in the bottle?

5. Explain why the student standardised the sodium hydroxide instead of weighing out the pellets.

Fix the mistake

6. Correct this statement: "I averaged all four titres, including the rough one."

7. Correct this statement: "n(NaOH) = n($H_2C_2O_4$), so c(NaOH) = 0.04870 mol L^{-1}."

8. Correct this statement: "The vinegar's concentration is 0.07013 mol L^{-1}."

9. Correct this statement: "I rinsed the burette with distilled water before filling it with NaOH."

Year 12 Science: Qualitative analysis: which ions are in the sample?

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. A solution gives a white precipitate with NaOH that dissolves in excess, and a white precipitate with NH_3 that also dissolves in excess. Which cation is present?

2. Write the ionic equation for a few drops of NaOH added to a solution of Cu^{2+} ions.

3. Excess ammonia then turns that precipitate into a deep blue solution. Write the equation.

4. A white precipitate with NaOH dissolves in excess. With NH_3 the white precipitate stays, and with KI a bright yellow precipitate forms. Name the cation and write the equation for the yellow precipitate.

5. Why is the sample acidified with dilute nitric acid before silver nitrate is added?

6. Tank water from an old house contains 3 mg/L of copper. Is it within the drinking water standard?

Fix the mistake

7. Correct this statement: "White precipitate with NaOH, so it is Zn^{2+}."

8. Correct this statement: "$2NaOH + CuSO_4 \rightarrow Cu(OH)_2 + Na_2SO_4$ is my ionic equation."

9. Correct this statement: "I tipped in lots of NaOH at once and saw a clear solution, so there was no precipitate."

10. Correct this statement: "The green precipitate went brown on top, so the ion is Fe^{3+}."

Year 12 Science: Carrying out an Earth and Space Science investigation

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. Three repeats give crater diameters of 8.2 cm, 8.6 cm and 8.4 cm. Find the mean.

2. Purpose: to find out how the slope angle of a sand tray affects the mass of sand washed off by 500 mL of water. Name the independent and the dependent variable.

3. Repeats at 80 cm are 7.0 cm, 7.2 cm and 9.6 cm, and the third marble hit an old crater. Find the mean you should report.

4. A 20 g marble is dropped from 0.50 m. Calculate its gravitational potential energy (g = 9.8 N/kg).

5. Which change to a method makes the data more reliable?

6. Explain why the crater widths rise by less with each extra 20 cm of drop height.

Fix the mistake

7. Correct this statement: "My results are reliable because I was careful."

8. Correct this statement: "I put every result in the mean, even the one that bounced."

9. Correct this statement: "I joined my points dot to dot and drew the line through zero."

10. Correct this statement: "My science section explains what a crater is."

Year 12 Science: Sea-level rise in Aotearoa: an issue and its sources

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. Auckland's sea level rose 2.54 mm a year from 1961 to 2020. How much is that over the 60 years, in centimetres?

2. Dunedin's rate rose from 0.69 to 1.76 mm a year. How many times faster is the later rate, to one decimal place?

3. The ocean near a town rises 3 mm a year, and the land there is being pushed up by 1 mm a year. What relative rise does the town's tide gauge record?

4. Which is more valid evidence of the national trend: 120 years of tide-gauge records, or a homeowner's two photos of a beach 30 years apart?

5. Give one Earth and Space Science point against a nationwide ban on new coastal homes.

6. What lifts a Merit position to Excellence?

Fix the mistake

7. Correct this statement: "Stats NZ is valid because it is a government website."

8. Correct this statement: "Melting sea ice is a main cause of sea-level rise."

9. Correct this statement: "I only included evidence for my side so my position looks stronger."

10. Correct this statement: "The sea is rising the same amount everywhere in New Zealand."

Year 12 Science: Geological processes at Franz Josef and the Southern Alps

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. In the cross-section, which of layers A, B and C is the oldest?

2. Is fault F older or younger than layer C?

3. Put A, B, C, D, E and F in order from oldest to youngest.

4. What rock type is schist, and which process made it at Franz Josef?

5. Why are most boulders in West Coast rivers greywacke, with less schist?

6. Write one sentence linking uplift and erosion in the Southern Alps, as an Excellence answer would.

Fix the mistake

7. Correct this statement: "Schist is igneous because it formed with heat."

8. Correct this statement: "The Alps are tall because plates push them up, and that is the whole story."

9. Correct this statement: "My report explains how schist forms anywhere in the world."

10. Correct this statement: "The top layer is the oldest because it has been there longest."

Year 12 Science: Surviving extreme environments: hot springs, ice and alpine cold

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. Venenivibrio grows from 45 to 75 °C. Could it grow in water at 37 °C?

2. Antarctic seawater is –1.9 °C, and fish body fluids freeze at about –1 °C. By how many degrees is the sea colder than that freezing point?

3. Why would a human enzyme stop working in 75 °C water?

4. Which organism avoids freezing and which tolerates it: the toothfish or the alpine wētā?

5. Why does growing best at 4 to 8% oxygen help Venenivibrio in a hot spring?

6. Write one condition, problem, adaptation chain for the toothfish, as an Excellence answer would.

Fix the mistake

7. Correct this statement: "The environment is extreme because it is really hot."

8. Correct this statement: "The toothfish's antifreeze works by adding salt to its blood."

9. Correct this statement: "The bacterium adapted to the heat because it wanted to survive."

10. Correct this statement: "I listed five adaptations with a sentence on each."

Year 12 Science: Earthquakes and volcanoes in Aotearoa

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. Which plate subducts under the North Island, and what type of crust is it?

2. What lowers the melting point of the mantle above a subducting plate?

3. A magnitude 6.2 and a magnitude 7.2 earthquake: roughly how many times more energy does the bigger one release?

4. What is the epicentre of an earthquake?

5. Which magma has the most silica, and what kind of volcano does it build?

Exam-style question: Ruapehu

Ruapehu is an andesitic stratovolcano in the central North Island, inland from the Hikurangi subduction zone. Its eruptions alternate between ash eruptions and short lava flows.

6. Name the two plates involved and the type of crust each is made of.

7. Explain how tectonic processes form the magma that feeds Ruapehu.

8. Explain how andesitic magma produces a steep, layered cone.

9. A shallow magnitude 6 earthquake and a deep magnitude 6 earthquake happen under the central North Island. Explain which one is more likely to damage buildings near the epicentre.

Fix the mistake

10. Correct this statement: "The Pacific Plate melts because of friction as it rubs against the Australian Plate."

11. Correct this statement: "The epicentre is where the earthquake happens underground."

12. Correct this statement: "A magnitude 7 is a bit bigger than a magnitude 6."

13. Correct this statement: "Andesite volcanoes are steep because the lava is hot and flows fast."

Year 12 Science: Tsunami, landslides and linked hazards

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. What makes a tsunami different from a wind wave?

2. Find the speed of a tsunami where the ocean is 1000 m deep, in m/s.

3. What happens to a tsunami's wavelength as it moves into shallow water?

4. Why do strike-slip earthquakes seldom cause large tsunami?

5. Give two ways heavy rain makes a landslide more likely.

Exam-style question: a Kermadec tsunami

A magnitude 8.1 megathrust earthquake ruptures the Kermadec subduction zone, north-east of New Zealand, and tsunami warnings are issued around the Pacific.

6. Describe a tsunami wave, referring to the water column.

7. Explain how this earthquake generates a tsunami, including the energy changes.

8. Suppose the ocean between the source and a coast 1000 km away is 4000 m deep on average. Calculate how long the tsunami takes to arrive, in hours.

9. Explain the changes in speed, wavelength and amplitude as the tsunami approaches New Zealand's coast.

Fix the mistake

10. Correct this statement: "A tsunami is a giant wind wave that is tall out at sea."

11. Correct this statement: "The tsunami speeds up as it reaches the shore, which is why it is so powerful."

12. Correct this statement: "Every big earthquake under the sea makes a big tsunami."

13. Correct this statement: "Rain causes landslides by washing the soil away."

Year 12 Science: Stars: fusion, the HR diagram and life cycles

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. What stops a main sequence star from collapsing under gravity?

2. Where on the HR diagram are white dwarfs, and why are they dim?

3. If a star were moved to 3 times its distance from us, what fraction of its brightness would we see?

4. What does a star of 30 Sun masses become at the end of its life?

5. How far is 4.24 light-years in km, using 1 light-year = 9.5×10^{12} km?

Exam-style question: two stars near the Southern Cross

Alpha Centauri A is a yellow, Sun-like main sequence star 4.37 light-years away. Gamma Crucis, at the top of the Southern Cross, is a red giant much further away, yet both are easy to see.

6. Compare the colour, surface temperature and position on the HR diagram of the two stars.

7. Explain how Gamma Crucis can be cooler than Alpha Centauri A but far more luminous.

8. Explain how a Sun-like star changes from the main sequence into a red giant, referring to gravity, fuel use and energy.

9. Explain why a star of 15 Sun masses ends very differently from Alpha Centauri A.

Fix the mistake

10. Correct this statement: "A red star is cool, so it must be dim and low on the HR diagram."

11. Correct this statement: "Massive stars live longest because they have the most fuel."

12. Correct this statement: "The Sun will explode as a supernova."

13. Correct this statement: "The temperature axis on an HR diagram increases to the right."

Year 12 Science: Planetary systems: formation, orbits and exoplanets

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. Why did the solar nebula flatten into a disc as it collapsed?

2. Why could water ice exist as a solid beyond the frost line but not close to the Sun?

3. Jupiter is 5.204 AU from the Sun. Use $T^2 = a^3$ to find its period in years.

4. A star dims by 1% during a transit. What is the planet's radius as a fraction of the star's?

5. Give two pieces of evidence that Phobos may be a captured asteroid.

Exam-style question: TRAPPIST-1

TRAPPIST-1 is a small, cool red dwarf about 40 light-years away with seven Earth-sized planets. They were found by the transit method.

6. Describe a protoplanetary disc.

7. Explain how rocky planets like these form from the disc, referring to changes in temperature.

8. Explain how the transit method detected these planets.

9. Explain why the habitable zone of TRAPPIST-1 is much closer to its star than the Sun's habitable zone is to the Sun.

10. Earth's Moon has rock very like Earth's mantle but a tiny iron core. Explain how this evidence supports the collision theory and rules out capture.

Fix the mistake

11. Correct this statement: "There is no gravity in space, so planets just keep moving."

12. Correct this statement: "The gas giants are big because they are further from the Sun's gravity."

13. Correct this statement: "Earth's Moon was captured as it flew past."

14. Correct this statement: "The habitable zone is the same distance from every star."

Year 12 Science: Density, pressure and convection in the Earth system

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. A 54 g rock has a volume of 20 cm^3. Find its density.

2. Find the pressure from seawater ($\rho = 1025\ kg\ m^{-3}$) 200 m below the surface, ignoring the air. Use $g = 9.8\ N\ kg^{-1}$.

3. Explain why water under forming sea ice sinks.

4. Which kind of heat transfer carries most heat through the outer core, and which through the crust?

5. Does rising air or sinking air bring cloud, and why?

Exam-style question: hot pools in the Taupō Volcanic Zone

Hot pools in the Taupō Volcanic Zone are fed by rainwater that soaks down through cracks in the rock, is heated deep underground, and returns to the surface.

6. Describe two sources of the heat inside the Earth.

7. Explain how heat is carried from the outer core up through the mantle.

8. Discuss how the rainwater is heated and why it returns to the surface, linking heat transfer, density and pressure.

Fix the mistake

9. Correct this statement: "Hot air rises because heating makes its particles lighter."

10. Correct this statement: "The mantle is a sea of liquid magma, so it convects like water in a pot."

11. Correct this statement: "Heat rises."

12. Correct this statement: "The core stays hot because the Sun's heat soaks down into the Earth."

Year 12 Science: Heat transfer in the Earth system

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. How much energy warms 2.0 kg of water by 3.0 °C? Use $c = 4200$ J kg^{-1} °C^{-1}.

2. 8400 J is absorbed by 0.50 kg of dry sand ($c = 800$ J kg^{-1} °C^{-1}). Find its temperature rise.

3. Using NIWA's table, how much bigger is Alexandra's July daily range than Dunedin's?

4. Explain why a cloudy winter night is usually warmer than a clear one.

5. Explain why the sky is blue.

6. Which way does the breeze blow on a beach on a clear night, and why?

Exam-style question: the Canterbury nor'wester

Moist westerly air from the Tasman Sea is forced up over the Southern Alps. The West Coast gets heavy rain, while the Canterbury Plains, on the other side, get a hot, dry nor'wester.

7. Describe what latent heat is.

8. Explain why the air cools as it rises over the Alps, and why rain falls on the West Coast.

9. Discuss why the air reaching the Canterbury Plains is warmer and drier than it was at the same height over the Tasman Sea.

Fix the mistake

10. Correct this statement: "Water has a high heat capacity, so it heats up quickly."

11. Correct this statement: "Greenhouse gases reflect heat back down to Earth."

12. Correct this statement: "The sky is blue because it reflects the colour of the sea."

13. Correct this statement: "Sunsets are red because the Sun cools down in the evening."

Year 12 Science: A physics investigation with a non-linear relationship

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. Theory says the height h a ball falls is proportional to t^2, where t is the time. What should you plot to get a straight line?

2. At a fixed voltage, current I is proportional to 1/R. What should you plot to get a straight line?

3. A pendulum's period is 1.40 s. Find T^2.

4. A graph of I against 1/R has a line of best fit through the origin and (0.10 Ω^{-1}, 0.60 A). Find the gradient and write the equation.

5. Explain why timing 10 swings gives a more accurate period than timing one.

Your turn: a marble on a ramp

Another Year 12 class let a marble roll from rest down a ramp and measured the time t to roll each distance d, three times each.

Distance d (m)	Mean time t (s)
0.20	0.89
0.40	1.26
0.60	1.55
0.80	1.79
1.00	2.00

6. Their graph of d against t curves upward, steeper and steeper. What should they plot to get a straight line?

7. Find t^2 for d = 0.40 m.

8. The straight-line graph has its line of best fit through the origin and (4.00 s^2, 1.00 m). Find the gradient and write the equation.

9. Name a controlled variable that would change the results if it changed, and say why.

Fix the mistake

10. Correct this statement: "The relationship is $T^2 = 4.02\,L$, so I wrote $y = 4.02x$."

11. Correct this statement: "I worked out the gradient from my first and last data points."

12. Correct this statement: "I kept the mass of the bob the same, so that is my controlled variable."

13. Correct this statement: "My graph of T against L is a curve, so there is no relationship."

Year 12 Science: Physics in a selected context: the bungy jump

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. A 60 kg jumper falls freely for 15 m. Find their speed. Use $g = 9.8\ N\ kg^{-1}$.

2. A cord with $k = 80\ N\ m^{-1}$ is stretched by 20 m. Find its tension.

3. How much elastic potential energy does that cord store?

4. A 70 kg jumper moving at $14\ m\ s^{-1}$ is brought to rest in 2.0 s. Find the average net force.

5. Explain, using impulse, why a stiffer cord would hurt the jumper more.

Fix the mistake

6. Correct this statement: "The jumper is fastest at the lowest point because they have fallen furthest."

7. Correct this statement: "In $E_p = \frac{1}{2}kx^2$, I used $x = 40$ m, the whole fall."

8. Correct this statement: "The stretchy cord makes the change in momentum smaller."

9. Correct this statement: "I copied a good paragraph from a website and referenced it."

Year 12 Science: Light: mirrors, refraction, total internal reflection and lenses

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. Light goes from air into glass (n = 1.50) at an angle of incidence of 35°. Find the angle of refraction.

2. Use the table: what is the speed of light in diamond (n = 2.4)?

3. Find the critical angle for light going from water (n = 1.33) into air.

4. A converging lens has f = 20 cm, and an object is 60 cm away. Find the image distance and the magnification.

5. A concave make-up mirror has f = 30 cm, and a face is 10 cm in front of it. Find the image distance and describe the image.

Exam-style question: the magnifying glass

Hemi reads the small print on a museum label with a glass magnifying lens. The lens is converging, with a focal length of 8.0 cm. The letters are 2.0 mm tall, and he holds the lens 6.0 cm from the label.

6. Describe the nature of the image Hemi sees.

7. Calculate the image distance and the height of the image of a letter.

8. Hemi lifts the lens until it is 12 cm from the label. Explain what happens to the image, with a calculation.

9. Explain, in terms of the speed of light, why the glass lens changes the direction of the light.

Fix the mistake

10. Correct this statement: "The ray hits the surface at 30°, so I put 30° into Snell's law."

11. Correct this statement: "For the diverging lens I used f = +12 cm and got a real image."

12. Correct this statement: "Light changes frequency when it goes into glass, which is why its wavelength changes."

13. Correct this statement: "Total internal reflection happens when light goes from air into glass at a big angle."

Year 12 Science: Wave behaviour: reflection, refraction, diffraction and interference

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. A wave has a frequency of 4.0 Hz and a wavelength of 0.60 m. Find its speed.

2. Find the period of that wave.

3. Find the wavelength of a 2.4 GHz Wi-Fi signal.

4. Water waves travel at 0.30 m s^{-1} in deep water and 0.20 m s^{-1} in shallow water. They meet the boundary at 30° to the normal. Find the angle in the shallow water.

5. Two dippers in phase make waves with λ = 2.0 cm. A point is 9.0 cm from one dipper and 12.0 cm from the other. Is it on a nodal or an antinodal line?

Exam-style question: swell at a marina

Ocean swell with a period of 8.0 s and a wavelength of 100 m rolls towards a marina. The breakwater has a 12 m wide entrance, and the water inside gets shallower towards the boat ramp.

6. Calculate the speed of the swell.

7. Describe what happens to the waves as they pass through the entrance, and why.

8. Inside, the water gets shallower. Explain what happens to the speed, frequency, wavelength and amplitude of the waves.

9. A second entrance is opened further along the breakwater. Explain why boats at some moorings now rock a lot while boats at others hardly move.

Fix the mistake

10. Correct this statement: "The waves slow down in shallow water, so their frequency goes down."

11. Correct this statement: "Diffraction through the gap makes the wavelength longer."

12. Correct this statement: "A nodal line is where the crests from both sources meet."

13. Correct this statement: "12 waves in 4.0 s, 2.5 cm apart: $v = 3.0 \times 2.5 = 7.5\ m\ s^{-1}$."

Year 12 Science: Motion, vectors and projectiles

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. A cyclist speeds up uniformly from 2.0 m s^{-1} to 8.0 m s^{-1} in 4.0 s. What is her acceleration?

2. How far does she travel in those 4.0 s?

3. A ball is thrown straight up at 14.7 m s^{-1}. How high does it rise?

4. A rock rolls horizontally off a cliff 44.1 m high at 5.00 m s^{-1}. How far from the foot of the cliff does it land?

5. A plane heads north at 70.0 m s^{-1} through air that is moving east at 24.0 m s^{-1}. What is its velocity over the ground?

Exam-style question: the driving range

At a golf driving range, Tama hits a ball from the ground at 30.0 m s^{-1} at 25.0° above the horizontal. A safety fence 3.00 m high stands 60.0 m away on level ground. Ignore air resistance and use g = 9.8 m s^{-2}.

6. Describe the force on the ball during its flight and what it does to the horizontal and vertical parts of its velocity.

7. Calculate the horizontal and vertical components of the ball's initial velocity.

8. By calculating, decide whether the ball clears the fence.

9. Explain why the ball's speed is smallest at the top of its path, but not zero.

Fix the mistake

10. Correct this statement: "At the top of its path the ball has stopped, so its acceleration is zero there."

11. Correct this statement: "Time to reach the posts = 45.0 m ÷ 25.0 m s^{-1}, using the launch speed."

12. Correct this statement: "A ball thrown up at 14.7 m s^{-1}: $v_f^2 = 14.7^2 + 2 \times 9.8 \times d$, so d comes out negative."

13. Correct this statement: "The heavier ball has more weight, so it falls faster and lands sooner."

Year 12 Science: Forces, torque and circular motion

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. What net force gives a 1500 kg car an acceleration of 2.4 m s^{-2}?

2. A box is pushed with 30.0 N east and 40.0 N north at the same time. What is the resultant force?

3. A 40.0 N force pushes at right angles on the end of a spanner 0.250 m long. What torque does it make?

4. A 30.0 kg child sits 1.50 m from the pivot of a seesaw. How far from the pivot, on the other side, must a 45.0 kg child sit to balance it?

5. A 0.200 kg puck on a string moves in a horizontal circle of radius 0.800 m at 3.00 m s^{-1} on a frictionless table. What is the tension in the string?

Exam-style question: the diving board

At the pools, a uniform diving board is 3.00 m long and weighs 300 N. Its left end, A, is bolted to the ground, and it rests on a support B, 1.00 m from A. A diver weighing 600 N stands at the far right end. Use g = 9.8 m s^{-2}.

6. State the two conditions for the board to be in equilibrium.

7. By taking torques about B, calculate the size and direction of the force the bolt at A exerts on the board.

8. Calculate the force from support B.

9. The diver walks slowly from above B to the far end. Discuss how the forces at A and B change, and why.

Fix the mistake

10. Correct this statement: "Drawing friction, then a separate centripetal force arrow, on a car going round a corner."

11. Correct this statement: "Torque of the plank's weight = 200 N × 4.00 m, using the plank's length."

12. Correct this statement: "The table pushes up on the book and the book pushes down on the table, so those balance and the book stays still."

13. Correct this statement: "In a circle, the object flies outwards when the string breaks."

Year 12 Science: Momentum, energy and springs

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. What is the momentum of a 1200 kg car travelling at 15.0 m s^{-1}?

2. A 0.0600 kg tennis ball hits a wall at 20.0 m s^{-1} and bounces straight back at 15.0 m s^{-1}. What is its change in momentum?

3. A 60.0 kg skater and a 40.0 kg skater stand still on ice and push each other apart. The 60.0 kg skater moves off at 2.00 m s^{-1}. What is the other skater's velocity?

4. A 60.0 kg student runs up stairs 3.50 m high in 4.00 s. What power does she develop lifting herself?

5. A spring with k = 50.0 N m^{-1} is stretched by 0.120 m. How much elastic potential energy does it store?

Exam-style question: coupling rail wagons

In a rail yard, a 1500 kg wagon rolls at 2.00 m s^{-1} towards a stationary 1000 kg wagon on a level track. They couple together and move off as one. Ignore friction.

6. Calculate the momentum of the moving wagon, with its unit.

7. Calculate the speed of the coupled wagons.

8. Show that kinetic energy is not conserved in the coupling, and say where it goes.

9. The coupled wagons then run into a spring buffer with k = 2.40 × 10^{5} N m^{-1}. Calculate how far the buffer compresses as it stops them.

10. Discuss whether a stiffer buffer (bigger k) would be better for the wagons and their load.

Fix the mistake

11. Correct this statement: "A ball hits the wall at 20 m s^{-1} and bounces back at 15 m s^{-1}, so Δv = 20 − 15 = 5 m s^{-1}."

12. Correct this statement: "Momentum was conserved in the collision, so the kinetic energy must have been conserved too."

13. Correct this statement: "Doubling the compression of a spring doubles the energy it stores."

14. Correct this statement: "Work to climb stairs = 60 kg × 3.5 m = 210 J."

Year 12 Science: Atomic and nuclear physics: the nucleus, radiation and $E = mc^2$

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. How many protons and how many neutrons are in $^{239}_{94}\text{Pu}$?

2. Complete the alpha decay: $^{241}_{95}\text{Am} \rightarrow ? + {}^{4}_{2}\text{He}$.

3. Iodine-131 ($Z = 53$) is a beta emitter. Write the product.

4. What fraction of a radioactive sample is left after 4 half-lives?

5. Which radiation is stopped by a sheet of paper, and why does it travel so short a distance?

Task: answering like an Excellence report

Write a short answer to each question, then compare it with the model answers.

6. A uranium-235 nucleus absorbs a neutron and splits into barium-141 ($Z = 56$), krypton-92 and some neutrons. How many neutrons are released?

7. Explain where the energy released in this fission comes from, and how a reactor keeps the rate of fission steady.

Fix the mistake

8. Correct this statement: "In beta decay, one of the atom's orbiting electrons is thrown out."

9. Correct this statement: "After two half-lives, all of the sample has decayed."

10. Correct this statement: "Gamma rays are the most ionising because they go through everything."

11. Correct this statement: "In fission the mass number is lost and turned into energy."

Year 12 Science: Electric fields and charges between parallel plates

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. Plates 4.0 cm apart have 200 V across them. What is the field strength?

2. What force does a proton feel in that field?

3. A dust grain carries a charge of 4.8×10^{-18} C. How many extra electrons does it have?

4. An electron crosses from the negative to the positive plate of a pair 3.0 mm apart with 1500 V across them. How much energy does it gain?

5. A field of 2.0×10^{4} V m^{-1} pushes a charged drop with a force of 6.4×10^{-14} N. What is the drop's charge?

Exam-style question: a model smoke filter

Mere's class builds a model chimney filter: smoke rises between two vertical metal plates 4.0 cm apart, connected to a 3000 V supply. One smoke particle picks up 120 extra electrons. Ignore gravity.

6. Describe the electric field between the plates.

7. Calculate the electric field strength between the plates.

8. Calculate the size of the electric force on the smoke particle, and state its direction.

9. The particle starts next to the negative plate. Calculate the energy the field gives it by the time it reaches the positive plate.

10. The supply is turned down to 1500 V. Discuss how this changes the force on the particle and the energy it gains crossing the gap.

Fix the mistake

11. Correct this statement: "E = 5.0×10^{4} V m^{-1}, so the electron gains 5.0×10^{4} J of energy."

12. Correct this statement: "Field lines go from the negative plate to the positive plate, the way the electrons move."

13. Correct this statement: "With the plates 5.0 mm apart, E = 250 ÷ 5.0 = 50 V m^{-1}."

14. Correct this statement: "A drop with 4 extra electrons has a charge of 4 C."

Year 12 Science: DC circuits: series, parallel and combined

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. Find the total resistance of a 4.0 Ω and a 12 Ω resistor in parallel.

2. A 9.0 V battery drives 0.30 A round a circuit. How much charge flows in 2.0 minutes?

3. A lamp has 6.0 V across it and a resistance of 4.0 Ω. What is its power?

4. A 5.0 Ω resistor in series with two 10 Ω resistors in parallel is connected to 20 V. What is the total current?

5. In question 4, what is the current in each 10 Ω resistor?

Exam-style question: a campervan's lights

A campervan's 12 V battery runs two lamps in parallel: a reading lamp of 12 Ω and a ceiling lamp of 4.0 Ω. A dimmer, a rheostat set to 1.0 Ω, is in series with the battery.

6. Show that the two lamps together have a resistance of 3.0 Ω.

7. Calculate the current in the ceiling lamp.

8. Explain why the reading lamp carries a third of the ceiling lamp's current.

9. Calculate the energy the reading lamp transfers in 2.0 hours.

10. The ceiling lamp burns out. Discuss what happens to the brightness of the reading lamp.

Fix the mistake

11. Correct this statement: "Current gets used up as it goes through each lamp, so less comes back to the battery."

12. Correct this statement: "$1/R_t = 1/6.0 + 1/12 = 0.25$, so $R_t = 0.25$ Ω."

13. Correct this statement: "When one branch breaks, the other lamp keeps the same voltage, so nothing else changes."

14. Correct this statement: "The current splits in parallel, so each branch gets half."

Year 12 Science: Magnetic forces and induced voltage

Name: _____ Date: _____

Try these without your notes first, then check the answer key.

Practice

1. What force acts on 0.50 m of wire carrying 4.0 A at right angles to a 0.20 T field?

2. The same wire is turned to lie along the field lines. What is the force now?

3. A proton moves at 3.0×10^{5} m s^{-1} at right angles to a 0.80 T field. What force acts on it?

4. A 2.0 m rod moves at 5.0 m s^{-1} across a 0.10 T field. What voltage is induced between its ends?

5. At what speed would the same rod need to move to induce 0.25 V?

Exam-style question: a model motor

A model motor has a rectangular coil of 25 turns between a north pole on the left and a south pole on the right, where the field is 0.30 T. Each long side has 4.0 cm of wire in the field and the coil carries 1.2 A. Seen end-on, side P carries current out of the page and side Q carries it into the page.

6. State the direction of the force on side P, and the rule you used.

7. Calculate the size of the force on side P.

8. In the position shown, the short ends of the coil run along the field. Explain why they feel no force.

9. The battery is removed and the coil is spun so each long side moves at 0.50 m s^{-1}. Calculate the biggest voltage the whole coil can produce.

10. Explain where the coil must be in its turn to give that biggest voltage, and where it gives none.

Fix the mistake

11. Correct this statement: "In V = BvL the two V's are the same thing, so a 12 V generator means v = 12."

12. Correct this statement: "For an electron moving right, point your thumb right and read the force off your palm."

13. Correct this statement: "The side of the coil that lies along the field feels the same force as the other sides."

14. Correct this statement: "The positive pole of the magnet is on the left."

Answer key (for parents and tutors)

1. A student investigates how sugar concentration (0, 2, 4, 6 and 8%) affects how fast yeast respires, by counting carbon dioxide bubbles per minute. Name the independent and dependent variables.
   Independent: sugar concentration; dependent: bubbles of carbon dioxide per minute.
2. Three catalase discs rise in 20 s, 22 s and 21 s. Find the mean time and the rate.
   Mean = (20 + 22 + 21) ÷ 3 = 21 s; rate = 1 ÷ 21 = 0.048 s^{-1}.
3. Write a hypothesis for the yeast investigation in question 1, with a biological reason.
   For example: as sugar concentration increases from 0% to 8%, the number of bubbles per minute will increase, because glucose is the substrate for respiration, so more is available to the yeast's enzymes each second.
4. At one temperature the discs take 20 s, 22 s and 45 s, and the student noted the third disc stuck to the tube. What should the mean be, and why?
   (20 + 22) ÷ 2 = 21 s, leaving out the 45 s disc and recording why: it stuck, so its time did not measure the reaction.
5. A group's three repeats at every temperature were within 2 s of each other. Is that evidence of reliability or of validity?
   Reliability: close repeats show the data can be repeated; they do not show the method measured the right thing.
6. In a field study comparing leaf size in sun and shade, why should leaves be picked at random?
   To avoid sampling bias: if you choose the leaves yourself you may pick big or unusual ones, so the sample would not represent the plants.
7. Correct this statement: "My hypothesis is that temperature will affect catalase."
   A hypothesis predicts the direction of the change and gives a biological reason for it, such as collisions and denaturing.
8. Correct this statement: "I graphed the time taken, so the graph shows the rate."
   Time goes down as the reaction speeds up; convert to a rate (1 ÷ time) so the graph rises when the enzyme works faster.
9. Correct this statement: "The high temperatures killed the enzyme."
   Enzymes are not alive; heat denatures them by changing the shape of the active site so the substrate no longer fits.
10. Correct this statement: "My repeats were close, so my method was valid."
    Close repeats show reliability; validity comes from measuring the right thing and controlling every other variable.

Answer key (for parents and tutors)

1. A social media post says: 'Antibiotics will help you get over the flu faster.' Label the claim and correct it.
   Inaccurate: flu is caused by a virus, and antibiotics only work against bacteria, so they will not shorten the flu.
2. A dairy company's website says milk contains calcium, which is needed to build strong bones. Label the claim, and say who produced it and a likely audience.
   Accurate, but from a company with a vested interest in selling milk; a likely audience is parents buying food for their children.
3. A supplement's website says: 'In our study of 15 people, 12 felt less tired after two weeks.' Give two weaknesses in this evidence.
   For example: the sample is small (15 people), and there is no control group, so the 12 who felt less tired might have improved anyway or expected to; the study was also run by the seller, not peer reviewed.
4. A student writes: 'The Wakefield paper was peer reviewed, so its findings were valid.' What is wrong with this?
   Peer review does not guarantee validity: the paper used only 12 children with no control group, involved misconduct and was retracted in 2010.
5. An article contains three claims: a true one about vitamin C, an untrue one saying its product cures colds, and a vague quote from 'scientists'. Which should rank first for Excellence, and why?
   The claim that the product cures colds: it is the main selling point and it is inaccurate, so it is the one most likely to mislead readers.
6. Why does a vested interest not automatically make a claim inaccurate?
   A claim is judged on its biology; a producer with something to gain may still state an accurate fact, so you check the science and note what has been left out.
7. Correct this statement: "The intended audience is the general public."
   Name a specific group, such as parents of young children or adults who go to the gym, and say what in the article tells you.
8. Correct this statement: "The company wants to sell it, so everything it says is inaccurate."
   Vested interest makes bias likely, but each claim must still be checked against the biology; some will be accurate.
9. Correct this statement: "It was in a peer-reviewed journal, so it must be true."
   Peer review lowers the risk but does not remove it; check sample size, controls and whether other studies agree.
10. Correct this statement: "For Excellence I summarised every claim again at the end."
    Excellence ranks the claims by significance with reasons, then judges the overall effect on the audience.

Answer key (for parents and tutors)

1. Classify each as structural, physiological or behavioural: (a) tuatara basking near their burrows, (b) woolly alpine leaves, (c) antifreeze sugars in alpine plant cells.
   (a) behavioural, (b) structural, (c) physiological.

2. Which life process do mangrove pneumatophores help, and how?
   Gas exchange: at low tide air enters through lenticels and oxygen diffuses down through air spaces to roots buried in oxygen-poor mud, so they can respire.

3. Explain how nostrils at the tip of the bill help a kiwi's nutrition.
   The kiwi can smell worms and other prey while its bill is pushed into the soil, so it finds food it cannot see, even at night.

4. Give one limitation of pneumatophores.
   They only work when the tide is out, so mangroves need the mud uncovered for at least half of each tide and cannot grow lower on the shore.

5. Why does gas exchange through tracheae limit how big an insect like a wētā can grow?
   Oxygen moves along the tracheae mainly by diffusion, which is fast only over short distances, so cells deep inside a large body would not get enough oxygen.

6. Most of New Zealand's alpine plants have white flowers. Which life process does this help, and why?
   Reproduction: white flowers attract the flies and short-tongued bees that pollinate most alpine plants, without spending resources on coloured pigment.

7. Correct this statement: "Kiwi grew nostrils at the end of their bills because they needed to smell worms."
   Kiwi with nostrils nearer the tip found more food and bred more, so over many generations natural selection made the feature common.

8. Correct this statement: "The mangrove has pneumatophores. (and nothing more)"
   Name the life process and explain how the feature helps it, for example getting oxygen to roots in waterlogged mud.

9. Correct this statement: "Feeding at night is a physiological adaptation of kiwi."
   It is behavioural, something the kiwi does; physiological means an internal or chemical process, such as the wētā's freeze tolerance.

10. Correct this statement: "For Option 1 I compared a mangrove, a kiwi and a tuatara."
    Keep to all plants or all animals; compare one life process across three groups within that one kingdom.

Answer key (for parents and tutors)

1. A cube-shaped cell has sides of 3 µm. What is its SA:V?
   SA = 6 × 3 × 3 = 54 µm², V = 3 × 3 × 3 = 27 µm³, so SA:V = 54 ÷ 27 = 2:1 (2 µm⁻¹).
2. A potato cylinder goes from 4.00 g to 3.70 g in a salt solution. What is its percentage change in mass?
   (3.70 − 4.00) ÷ 4.00 × 100 = −7.5%, a 7.5% decrease.
3. Glucose enters a cell down its concentration gradient through a carrier protein, without ATP. Which transport method is this?
   Facilitated diffusion.
4. A red blood cell is put into pure water. What happens to it, and why?
   It swells and bursts, because water moves in by osmosis from the more dilute water and it has no cell wall to stop it.
5. Sperm cells swim using a tail that needs a lot of ATP. Which organelle would you expect to find in large numbers near the tail?
   Mitochondria, which make ATP in aerobic respiration.
6. Describe osmosis.
   Osmosis is the net movement of water across a partially permeable membrane from a dilute solution to a more concentrated one; it is passive (Achieved).
7. Explain why the grass wilts after the seawater flood.
   The soil water is now more concentrated than the cell sap, so water leaves the root hair cells by osmosis instead of entering; the cells lose turgor, water is no longer supplied to the leaves, and the grass wilts (Merit, because it gives the reason using the gradient).
8. Before the flood, the root hair cells took in nitrate ions by active transport. Explain why this process needs mitochondria.
   Nitrate is pumped in against its concentration gradient by carrier proteins, which change shape using ATP; ATP comes from aerobic respiration in mitochondria, so the cell needs many of them (Merit).
9. Discuss how the structure of a root hair cell suits it to taking in both water and mineral ions, and compare how the two cross the membrane.
   Excellence links the ideas: the long thin hair gives a large surface area to volume ratio, so more water and ions cross the membrane each second; water enters passively by osmosis while the sap is more concentrated than the soil water, so it needs no ATP, while nitrate is taken in against its gradient by active transport, which needs carrier proteins and ATP from the many mitochondria; the ions pumped in keep the sap concentrated, which keeps water flowing in, so the seawater flood reverses the gradient and both processes suffer.
10. Correct this statement: "In osmosis, the salt moves out of the cell into the water."
    In osmosis only water moves across the membrane; the dissolved particles cannot cross it.
11. Correct this statement: "Water moves from a high concentration of solute to a low concentration of solute."
    Water moves towards the more concentrated solution, from where there is more free water to where there is less.
12. Correct this statement: "Facilitated diffusion uses energy because it uses a protein."
    Facilitated diffusion is passive: it goes down the gradient and needs no ATP; only active transport pumps against the gradient.
13. Correct this statement: "A bigger cell has a bigger SA:V because it has more surface area."
    A bigger cell has more surface area, but its volume grows faster, so its SA:V is smaller.

Answer key (for parents and tutors)

1. An enzyme reaction gives off 30 cm^3 of oxygen in 2 minutes. What is the average rate?
   Rate = 30 cm^3 ÷ 2 min = 15 cm^3/min.
2. An enzyme is kept at 5 °C for an hour, then warmed to 37 °C. What happens to its activity, and why?
   Its activity returns: low temperature only slowed the molecules down and did not change the active site's shape.
3. The rate has levelled off at a high substrate concentration. What happens to the rate if you double the substrate concentration again?
   No change, because every active site is already occupied, so the enzyme concentration is limiting.
4. Which kind of inhibitor can be overcome by adding more substrate?
   A competitive inhibitor, because more substrate molecules win more of the collisions with the active site.
5. In the class's catalase results, how many times faster was the rate at 30 °C than at 10 °C?
   14 ÷ 4 = 3.5 times faster.
6. Describe what an enzyme is.
   An enzyme is a protein that acts as a biological catalyst, speeding up a reaction by lowering its activation energy without being used up (Achieved).
7. Explain why the jelly with fresh kiwifruit does not set, using the idea of the active site.
   Fresh kiwifruit contains actinidin, an enzyme whose active site fits the gelatine protein; the gelatine binds to form an enzyme–substrate complex and is broken into smaller pieces that cannot form the network that sets the jelly (Merit).
8. Explain why the jelly with canned kiwifruit does set.
   The high temperature of canning broke the bonds holding actinidin's shape, so its active site changed shape and the gelatine can no longer fit; the enzyme is denatured, so the gelatine stays whole and sets (Merit).
9. Mere keeps fresh kiwifruit in the fridge at 4 °C for a week, then puts it in a jelly. Discuss whether this jelly will set, comparing the effects of low and high temperature on the enzyme.
   The jelly will not set (Excellence for linking the ideas). At 4 °C the enzyme molecules moved slowly and collided with substrate less often, but their shape was not changed, so actinidin was not denatured; once the fruit is in the warm jelly mixture, the molecules collide more often and the active site still fits the gelatine, so the gelatine is broken down. The canned fruit's enzyme is different: denaturing changed its active site permanently, so it cannot recover even when cooled.
10. Correct this statement: "At low temperatures the enzyme is denatured, so it stops working."
    Low temperature only slows the enzyme by reducing collisions; it is not denatured and works again once warmed.
11. Correct this statement: "The enzyme dies at high temperatures."
    Enzymes are proteins, not living things: they are denatured, meaning the active site changes shape so the substrate cannot fit.
12. Correct this statement: "The enzyme is used up in the reaction, so the rate slows down."
    The enzyme is unchanged and reused; the rate slows because the substrate is being used up.
13. Correct this statement: "The active site and the substrate are the same shape."
    They are complementary shapes that fit together, like a key and its lock, not identical ones.

Answer key (for parents and tutors)

1. Where in the chloroplast are water molecules split?
   On the thylakoid membranes (the grana), in the light-dependent stage.
2. A cell breaks down 5 glucose molecules. How many ATP can it make at most aerobically (38 per glucose), and how many anaerobically?
   Aerobically 5 × 38 = 190 ATP; anaerobically 5 × 2 = 10 ATP.
3. Besides ATP, what does anaerobic respiration make in yeast?
   Ethanol and carbon dioxide.
4. Doubling the light makes no difference to a plant's rate of photosynthesis, but adding carbon dioxide raises it. What was limiting?
   Carbon dioxide concentration.
5. A pondweed shoot gives off 72 bubbles in 4 minutes. What is the rate?
   72 bubbles ÷ 4 min = 18 bubbles/min.
6. Write the word equation for photosynthesis and name the organelle where it happens.
   Carbon dioxide + water → glucose + oxygen, using light energy, in the chloroplasts (Achieved).
7. Calculate how many times higher the carbon dioxide concentration is inside the glasshouse than outside.
   1000 ppm ÷ 424 ppm = 2.36, about 2.4 times higher.
8. Explain why the tomato plants photosynthesise faster at midday than at sunrise.
   At sunrise the light is dim, so the light-dependent stage makes little ATP and hydrogen, and the cool air slows the enzymes; by midday the light is far stronger and it is warmer, so chlorophyll absorbs more energy and the enzymes work faster (Merit).
9. Discuss why the extra carbon dioxide raises the rate of photosynthesis on a bright summer day but makes little difference on a dull winter morning, and why letting the glasshouse overheat would lower the rate.
   Excellence links the factors: on a bright, warm day light is not limiting, so carbon dioxide is in shortest supply; adding more lets the stroma's enzymes fix more carbon dioxide into glucose, so the rate rises. On a dull winter morning light is the limiting factor, so the light-dependent stage cannot supply enough ATP and hydrogen to use the extra carbon dioxide, and the cold also slows the enzymes, so adding carbon dioxide is wasted. If the glasshouse overheats, the enzymes pass their optimum and begin to denature, so the active sites no longer fit their substrates, and the plants may close their stomata to save water, so less carbon dioxide gets in and the rate falls even with plenty of light and carbon dioxide.
10. Correct this statement: "Plants photosynthesise, and animals respire."
    Plant cells respire all the time too; they also photosynthesise when there is light.
11. Correct this statement: "Respiration makes energy."
    Energy cannot be made; respiration releases the chemical energy stored in glucose and transfers it to ATP.
12. Correct this statement: "The light-independent stage happens in the dark."
    It does not need light directly, but it runs in the light, because it uses the ATP and hydrogen the light-dependent stage makes.
13. Correct this statement: "Anaerobic respiration happens in the mitochondria without oxygen."
    Anaerobic respiration happens only in the cytoplasm; the mitochondria need oxygen to do their part.

Answer key (for parents and tutors)

1. At what point in the cell cycle is DNA copied?
   In the S phase of interphase, before mitosis begins.
2. A cell has 8 chromosomes. How many DNA molecules does it contain at metaphase, and how many chromosomes does each daughter cell get?
   16 DNA molecules at metaphase (8 chromosomes, each two chromatids); each daughter cell gets 8 chromosomes.
3. One DNA strand reads 5' ATGCCTA 3'. Write the new strand built on it during replication, with its ends labelled.
   3' TACGGAT 5': A pairs with T and C with G, and the new strand runs antiparallel to the template.
4. In a root tip squash, 45 of the 300 cells counted are in mitosis. Calculate the mitotic index.
   45 ÷ 300 × 100 = 15%.
5. Explain why a growing root makes more cells rather than making its cells bigger.
   A bigger cell has a lower surface area to volume ratio, so substances could not diffuse in and out fast enough; dividing keeps each cell small with a high ratio.
6. Describe when DNA replication happens in the cell cycle, and how the DNA is copied.
   DNA is copied in the S phase of interphase, before mitosis (Achieved). Helicase unzips the double helix by breaking the hydrogen bonds between bases; each strand is a template, and DNA polymerase joins free nucleotides to it by complementary pairing, A with T and C with G, building each new strand antiparallel to its template. Each new molecule has one old and one new strand, so replication is semi-conservative (Merit for template, base pairing and enzymes together).
7. Explain why DNA replication must happen before mitosis.
   Mitosis shares one chromatid of every chromosome between the two daughter cells, so the DNA must be doubled first; otherwise each new cell would get only half the genes and could not make all the proteins and enzymes it needs to work (Merit).
8. Explain why the young skink grows by making more cells rather than by its cells getting larger.
   As a cell grows, its volume increases faster than its surface area, so its surface area to volume ratio falls. Oxygen and glucose could not diffuse in, or carbon dioxide out, fast enough for a large cell, so the skink makes more small cells, each with a high ratio (Merit).
9. Discuss why mitosis is needed throughout the skink's life, linking the survival of its cells to the survival of the whole skink.
   Mitosis is needed at every stage, at different rates (Excellence for linking the ideas). While the young skink grows, mitosis is fast, making many new small cells whose high surface area to volume ratio keeps diffusion fast enough to supply them. When the tail is lost, mitosis at the wound makes new cells to close it and rebuild the tail, and in the adult it keeps replacing worn-out skin and gut cells after growth slows. Because the DNA was copied exactly, every new cell has the full instructions to make the proteins its job needs. Cells that were too large or missing DNA would die, and if enough cells failed, tissues and organs would fail and the skink could not survive.
10. Correct this statement: "DNA replication happens during prophase, when the chromosomes appear."
    DNA is copied in the S phase of interphase, before mitosis starts; in prophase the already-copied chromosomes only coil up and become visible.
11. Correct this statement: "Interphase is when the cell rests between divisions."
    Interphase is the busiest part of the cycle: the cell grows, makes organelles and proteins, and copies all its DNA.
12. Correct this statement: "Mitosis makes four cells that are all genetically different."
    That is meiosis, which makes gametes; mitosis makes two cells identical to the parent, for growth and repair.
13. Correct this statement: "Each daughter cell gets half of the parent cell's DNA."
    The DNA was doubled first, so each daughter cell gets a complete copy, with the same number of chromosomes as the parent.

Answer key (for parents and tutors)

1. A human skin cell has 46 chromosomes. How many does a human sperm cell have?
   23 (gametes are haploid: one chromosome from each pair).
2. In guinea pigs, black (B) is dominant to brown (b). What percentage of the offspring of Bb × bb would you expect to be brown?
   Bb × bb gives 1 Bb : 1 bb, so 50% brown.
3. A pink snapdragon (C^RC^W) is crossed with a white snapdragon (C^WC^W). Give the phenotype ratio.
   Gametes C^R or C^W, and C^W: offspring 1 C^RC^W : 1 C^WC^W, so 1 pink : 1 white.
4. Two yellow mice (A^ya) are crossed and 12 pups survive. How many would you expect to be yellow, and how many non-yellow (agouti)?
   1 A^yA^y (dies) : 2 A^ya : 1 aa, so the survivors are 2 yellow : 1 agouti; 2/3 of 12 is 8 yellow and 4 agouti.
5. Genes A and B are on different chromosomes. What percentage of the offspring of AaBb × aabb would be aabb?
   The AaBb parent makes AB, Ab, aB and ab equally; only ab gives aabb, so 1 in 4 = 25%.
6. Two parents are both carriers (Aa) of a recessive condition. What is the chance their next child is affected?
   Aa × Aa gives 1 AA : 2 Aa : 1 aa, so 1 in 4 = 25% for each child.
7. Describe codominance, using roan cattle as the example.
   In codominance both alleles are fully expressed in the heterozygote: a roan (RW) animal grows red hairs (from R) and white hairs (from W) side by side, rather than one blended colour (Achieved).
8. Two roan cattle are mated many times. Give the expected ratio of coat colours in their calves, using a Punnett square.
   RW × RW: gametes R or W from each parent; offspring RR, RW, RW, WW, so 1 red : 2 roan : 1 white, or 25% red, 50% roan, 25% white (Achieved for the ratio with phenotypes).
9. The farmer's new bull is polled. Explain how a test cross would show whether he is PP or Pp.
   Mate him with horned (pp) cows, which can only give p gametes. If he is PP, every calf gets P and is polled. If he is Pp, each calf has a 1 in 2 chance of getting his p and being horned (pp). So any horned calf proves he is Pp (Merit: uses the gametes from both parents).
10. The bull is mated with three horned cows and all three calves are polled. Discuss whether the farmer can now be sure the bull is PP, using probabilities.
    No. If he were Pp, each calf would still have a 1/2 chance of being polled, so three polled calves in a row happens with probability $(1/2)^3 = 1/8 = 12.5\%$. That is unlikely but far from impossible, so three calves cannot prove he is PP. Each calf is a separate random event, because segregation at meiosis puts P or p into each sperm by chance. With more calves the evidence gets stronger: seven polled calves from a Pp bull would happen only $(1/2)^7 = 1/128$, about 0.8% of the time, but a single horned calf at any point would prove Pp (Excellence: links segregation, gametes from both parents and probability to why the result is not guaranteed).
11. Correct this statement: "Crossing over happens between sister chromatids."
    It happens between non-sister chromatids of a homologous pair; sister chromatids are identical, so swapping between them would change nothing.
12. Correct this statement: "A 3 : 1 ratio means a family with four children will have exactly three with the dominant trait."
    Each child has a 3 in 4 chance; ratios only show up reliably in large numbers of offspring.
13. Correct this statement: "Codominance and incomplete dominance are the same, because the heterozygote looks different from both parents."
    Incomplete dominance blends to an in-between phenotype (pink); codominance shows both phenotypes fully at once (red and white hairs).
14. Correct this statement: "Independent assortment creates new alleles."
    Only mutation makes new alleles; meiosis and fertilisation reshuffle existing alleles into new combinations.

Answer key (for parents and tutors)

1. A population of 50 snails has 18 AA, 24 Aa and 8 aa. Find the frequency of A and of a.
   Total alleles = 50 × 2 = 100. A = (2 × 18) + 24 = 60, so f(A) = 0.60; a = (2 × 8) + 24 = 40, so f(a) = 0.40.
2. The frequency of allele B in a population is 0.35. What is the frequency of its only other allele, b?
   1 – 0.35 = 0.65.
3. A storm kills most of a small island population of skinks, and which ones die is down to luck. Which process has changed the gene pool?
   Genetic drift, as a bottleneck: survival was by chance, not by phenotype.
4. Six birds are blown to a new island and start a population there. What is this called?
   The founder effect, a kind of genetic drift: the new gene pool holds only the six founders' alleles.
5. In 1989, 18 of 35 black robin females laid rim eggs. What percentage is that, to one decimal place?
   18 ÷ 35 × 100 = 51.4%.
6. Which process adds alleles to a gene pool from another population of the same species?
   Migration (immigration), also called gene flow.
7. Describe what is meant by a gene pool and allele frequency.
   A gene pool is all the alleles of all the individuals in a population; allele frequency is the proportion of the copies of one gene that are a particular allele (Achieved).
8. Explain why the 1980 bottleneck reduced the genetic diversity of the black robin.
   Only the five survivors' alleles could be passed on, so all other alleles were lost; with so few birds, which alleles survived and how common they became was down to chance (drift), so some alleles were fixed and diversity fell (Merit).
9. Suppose a sample of 40 robins contained 2 RR, 12 Rr and 26 rr birds (practice numbers, not real counts). Calculate the frequency of R and of r.
   Total alleles = 40 × 2 = 80; R = (2 × 2) + 12 = 16, so f(R) = 16 ÷ 80 = 0.20; f(r) = 1 – 0.20 = 0.80 (check: (2 × 26) + 12 = 64, and 64 ÷ 80 = 0.80) (Achieved for the method, Merit with full working).
10. Discuss how human management and natural selection changed the frequency of the rim-laying allele between 1980 and 2011.
    Normally the R allele is selected against, because rim eggs fail and rim-laying females leave fewer offspring. Moving the eggs removed that selection pressure, so R-carrying females raised as many chicks as others; in a population descended from so few founders, chance (drift) let R spread until over half the females (51.4%) laid rim eggs by 1989. Once staff stopped in 1990, rim eggs failed again: rim layers laid smaller clutches and raised fewer chicks, so fewer copies of R were passed on each generation and natural selection cut the share of rim layers to 9% by 2007 to 2011. R is dominant, so every carrier shows the trait and is exposed to selection, which is why it fell quickly, though in a small population drift can keep it from being lost entirely (Excellence: links the removal and return of the selection pressure, drift in the small population, and the data).
11. Correct this statement: "Individuals evolve when they adapt to their environment."
    Populations evolve: allele frequencies in the gene pool change over generations, while each individual keeps the alleles it was born with.
12. Correct this statement: "After a bottleneck, once the population grows back, its genetic diversity comes back too."
    The alleles lost in the bottleneck are gone; growth only makes more copies of the survivors' alleles, unless mutation or migration adds new ones.
13. Correct this statement: "Genetic drift means the best adapted alleles become more common."
    That is natural selection; drift is a change by chance, and it can even fix a harmful allele in a small population.
14. Correct this statement: "With 98 BB, 84 Bb and 18 bb, the frequency of b is 18 ÷ 200."
    Count alleles, not individuals: b = (2 × 18) + 84 = 120 out of 400, so f(b) = 0.30.

Answer key (for parents and tutors)

1. Three transects gave 3, 6 and 3 lined whelks in their Q5 quadrats. Find the mean per quadrat.
   (3 + 6 + 3) ÷ 3 = 12 ÷ 3 = 4 whelks per quadrat.
2. Turn that mean into a density per m², using 0.25 m² quadrats.
   4 × 4 = 16 whelks per m².
3. Using the class's table, describe where Neptune's necklace is found and where it is most abundant.
   From Q3 down to Q6, most abundant at Q5 (70% cover): a band in the mid to low shore.
4. What kind of factor most likely sets the lower limit of the barnacle band?
   Biotic factors: competition for space with Neptune's necklace and predation by lined whelks.
5. Periwinkles crowd into crevices at low tide. Is that a structural, behavioural or physiological adaptation?
   Behavioural, because it is something the snail does; the crevice keeps it cooler and damper.
6. Write an Achieved sentence describing the periwinkle pattern, quoting data.
   Periwinkles are most abundant at the top of the shore (42 per quadrat at Q1) and decrease down the shore until none are found at Q5 and Q6.
7. Give one reason, using an adaptation, why periwinkles can live at Q1 where barnacles cannot.
   Periwinkles can survive losing a lot of body water and seal themselves in with an operculum, and they graze the film of algae on damp rock, while barnacles can only filter-feed under water.
8. Lined whelks were absent from Q1 to Q3. Explain why, for a Merit answer.
   Whelks hunt only when covered by the tide and cannot tolerate long spells in air, so the high quadrats, out of the water for most of the tide, give them too little feeding time and dry them out.
9. Correct this statement: "The barnacles live in the mid shore because they like it there."
   Name the factor and the mechanism: at the top they dry out and cannot feed; lower down they lose space to seaweed and are eaten by whelks.
10. Correct this statement: "Periwinkles have adapted to the high shore so they can survive there."
    Adaptations evolved over generations by natural selection; an individual snail does not adapt on purpose, it already has the features.
11. Correct this statement: "There were 42 periwinkles at Q1, so the density is 42 per m²."
    That count is per 0.25 m² quadrat, so the density is 42 × 4 = 168 per m².
12. Correct this statement: "I chose where to put my transect so it went through the best rock pools."
    Choose the starting point at random so the sample represents the shore and is not biased by what looks interesting.

Answer key (for parents and tutors)

1. Write the complementary strand of 5' ATGCCA 3', with its ends labelled.
   3' TACGGT 5' (complementary and antiparallel).
2. A DNA template triplet is TTC. What is the mRNA codon?
   AAG (T→A, T→A, C→G).
3. What anticodon pairs with the mRNA codon GGU?
   CCA (G→C, G→C, U→A).
4. Which amino acid does AUG code for, and what else does AUG do?
   Methionine (Met); it is also the start codon.
5. Of the 64 codons, how many code for amino acids?
   61; the other 3 are stop codons.
6. A DNA sample is 30% adenine. What percentage is guanine?
   A = T = 30%, so G + C = 100 − 60 = 40%, and G = 20%.
7. Give the mRNA codons and the amino acid sequence this section codes for.
   mRNA AUG UUU GCA CCG UAA; Met–Phe–Ala–Pro, then stop (Achieved for the correct row).
8. Give the anticodons of the tRNAs that bring the first four amino acids.
   UAC AAA CGU GGC; UAA is a stop codon, so no tRNA matches it (Achieved).
9. Explain why changing the codon GCA to GCC would not change the keratin.
   The code is degenerate: GCA and GCC both code for alanine, so the same amino acid is added and the polypeptide is unchanged (Merit, because it gives the reason).
10. Discuss how the base sequence of the gene decides the shape and function of keratin, and why the ribosome reads mRNA rather than the DNA itself.
    Achieved: the gene is transcribed into mRNA and translated into a chain of amino acids. Merit: each mRNA codon pairs with a complementary tRNA anticodon carrying one specific amino acid, so the base order sets the amino acid order. Excellence: the amino acid order decides how the chain folds, so keratin gets the strong, fibrous shape it needs for hair and nails; the DNA is copied into single-stranded mRNA because DNA stays protected in the nucleus while ribosomes work in the cytoplasm, and many mRNA copies let many ribosomes make keratin at once.
11. Correct this statement: "The template triplet TAC gives the mRNA codon ATG."
    RNA has uracil, not thymine, so the codon is AUG.
12. Correct this statement: "The codon AUG has the anticodon AUG."
    The anticodon is complementary to the codon, so AUG pairs with UAC.
13. Correct this statement: "Given the coding strand ATG, I complemented it to get the mRNA UAC."
    The mRNA copies the coding strand (with U for T), so it is AUG; only the template strand is complemented.
14. Correct this statement: "Translation happens in the nucleus, where the DNA is."
    Transcription is in the nucleus; translation is at ribosomes in the cytoplasm.

Answer key (for parents and tutors)

1. The mRNA codon UAC changes to UAA. Name the type of mutation.
   Nonsense: UAC codes for Tyr, but UAA is a stop codon, so the polypeptide ends early.
2. The mRNA codon GGU changes to GGC. What happens to the amino acid?
   Nothing: GGU and GGC both code for glycine, a silent mutation.
3. Which shifts the reading frame: deleting 1 base or deleting 3 bases?
   Deleting 1 base; deleting 3 removes one codon without a frameshift.
4. In the pathway A → B → C, enzyme 2 (B to C) does not work. Which substance builds up, and which is missing?
   B builds up and C is missing.
5. Name two mutagens.
   Any two of: UV light, X-rays, gamma rays, chemicals in tobacco smoke, some viruses.
6. What environmental factor makes a Siamese cat's ears dark?
   The lower temperature of the ears lets the temperature-sensitive tyrosinase work there and make melanin.
7. Give the amino acid sequence for the normal gene and for each mutation.
   Normal mRNA AUG UUC GAA CAU UGG: Met-Phe-Glu-His-Trp. Mutation 1 mRNA AUG UUC GAG CAU UGG: Met-Phe-Glu-His-Trp. Mutation 2 mRNA AUG UUC GAA CAU UGA: Met-Phe-Glu-His, then stop (Achieved for a correct sequence).
8. Name the type of each mutation.
   Both are substitutions; mutation 1 is silent and mutation 2 is nonsense (Achieved).
9. Explain which mutation is more likely to cause albinism.
   Mutation 2, because the stop codon ends translation early, so the tyrosinase is too short to fold into its working shape and no melanin is made; mutation 1 still gives Glu (GAA and GAG both code for it) so the enzyme is unchanged (Merit). A person needs two faulty copies of the gene to have albinism.
10. Discuss how a mutation in gene 1 would show differently from one in gene 2, and how the environment can change melanin production without changing the genes.
    Excellence: a block at gene 1 stops phenylalanine becoming tyrosine, so phenylalanine builds up (PKU), but melanin can still be made from tyrosine in food; a block at gene 2 leaves tyrosine unused, so there is no melanin and the phenotype is albinism. The environment changes the phenotype without changing the genotype: a temperature-sensitive tyrosinase makes melanin only in a Siamese cat's cool ears, paws and tail, and a low-phenylalanine diet prevents the brain damage of PKU.
11. Correct this statement: "A substitution always changes the protein."
    Because the code is degenerate, a substitution can give a codon for the same amino acid: a silent mutation.
12. Correct this statement: "A deletion removes one amino acid, so it is mild."
    Deleting one base shifts the reading frame, so every codon after it changes; only deleting three bases removes a single amino acid.
13. Correct this statement: "The Siamese cat's cold ears changed its genes for dark fur."
    The genotype is the same everywhere; the cool temperature only lets the existing enzyme work there.
14. Correct this statement: "If enzyme 2 is blocked, the substrate of enzyme 1 builds up."
    The substance just before the block builds up: the substrate of enzyme 2, which is the product of enzyme 1.

Answer key (for parents and tutors)

1. What is the total magnification with a ×10 eyepiece and a ×10 objective?
   10 × 10 = ×100.
2. The field of view at ×100 is 1.8 mm. What is it at ×400, in µm?
   ×400 is 4 times ×100, so 1.8 ÷ 4 = 0.45 mm = 450 µm.
3. Six cells fit across a 1.8 mm field of view. How long is one cell, in µm?
   1.8 mm = 1800 µm; 1800 ÷ 6 = 300 µm.
4. A 50 µm guard cell is drawn 75 mm long. What is the magnification of the drawing?
   75 mm = 75 000 µm; 75 000 ÷ 50 = ×1500.
5. A drawing at ×2000 needs a 10 µm scale bar. How long should the bar be, in mm?
   10 µm × 2000 = 20 000 µm = 20 mm.
6. Name the convention error: the student labelled each organelle with an arrow drawn freehand that crossed another label line.
   Label lines must be ruled lines (not arrows), must not cross each other, and should end exactly on the part.
7. Your onion epidermis slide shows no chloroplasts. Write an Achieved annotation linking this to where the tissue grows.
   Onion bulb epidermis cells have no chloroplasts because the bulb grows underground, where there is no light for photosynthesis.
8. Write a Merit annotation explaining how the contractile vacuoles help Paramecium survive in pond water.
   Pond water is more dilute than the Paramecium's cytoplasm, so water keeps moving into the cell by osmosis. The contractile vacuoles collect this extra water and squeeze it out through the membrane, so the cell does not swell and burst, and its cytoplasm stays at the right concentration for its reactions.
9. A drawing of Elodea cells has gaps between the cells and no chloroplasts drawn. Is each a convention error or a representation error?
   The gaps are a convention error: cells in a tissue are drawn touching, sharing their walls. Leaving out the chloroplasts is a representation error: they are typical organelles of Elodea cells and show clearly at ×400, so the drawing is no longer an accurate record.
10. Correct this statement: "I shaded the chloroplasts in green so they stand out."
    Biological drawings use pencil outlines only; shading or colouring is a convention error.
11. Correct this statement: "I focused at ×400 using the coarse focus knob."
    At high power use only the fine focus; the coarse focus can push the objective into the slide and crack it.
12. Correct this statement: "The field of view is 4.0 mm at ×40, so it is 40 mm at ×400."
    More magnification shows a smaller area: ×400 is ten times ×40, so the field is 4.0 ÷ 10 = 0.40 mm.
13. Correct this statement: "I drew the cell with mitochondria and ribosomes because textbook cells have them."
    Draw only what your own slide shows at that magnification; electron microscope detail is a representation error.

Answer key (for parents and tutors)

1. Write the oxidation half equation at the graphite electrode during discharge.
   $LiC_6 \rightarrow C_6 + Li^+ + e^-$.
2. Give the oxidation number of cobalt in CoO_2 and in $LiCoO_2$, and say whether cobalt is oxidised or reduced on discharge.
   +4 in CoO_2 and +3 in $LiCoO_2$; cobalt gains an electron, so it is reduced.
3. Explain why water cannot be used as the solvent in the electrolyte.
   The cell runs at about 4 V, far above the 1.23 V that splits water, and lithium reacts with water to make hydrogen: $2Li + 2H_2O \rightarrow 2LiOH + H_2$.
4. Explain why Yoshino's carbon electrode made the battery safer than Whittingham's.
   Carbon holds lithium as ions between its layers, so no lithium metal is deposited on charging and no dendrites grow to short-circuit the cell.
5. A laptop battery is labelled 11.1 V and 4.0 Ah. How many 3.7 V cells are in series, and how much energy does it store in Wh?
   11.1 ÷ 3.7 = 3 cells; energy = 11.1 V × 4.0 Ah = 44.4 Wh.
6. Correct this statement: "Electrons travel through the electrolyte from one electrode to the other."
   Electrons go through the external circuit; only ions, Li^+, move through the electrolyte and separator.
7. Correct this statement: "The lithium-ion battery runs out because the lithium gets used up."
   The lithium ions just move to the other electrode; recharging moves them back. Cells wear out slowly through side reactions.
8. Correct this statement: "My report lists the history and the equations in separate sections."
   Merit and Excellence need links: say which chemical property caused each design change, and evaluate the trade-off.
9. Correct this statement: "$CoO_2 + e^- \rightarrow LiCoO_2$ is the reduction half equation."
   The lithium has to appear on both sides: $CoO_2 + Li^+ + e^- \rightarrow LiCoO_2$, balanced for atoms and charge.

Answer key (for parents and tutors)

1. How many valence electrons are shown in the Lewis structure of HCN?
   1 + 4 + 5 = 10 electrons (5 pairs: H–C≡N with one lone pair on N).
2. Give the shape and bond angle of methanal, H2CO (C in the middle, double bonded to O).
   C has three regions (two C–H and one C=O) and no lone pairs, so it is trigonal planar with angles of 120°.
3. What is the bond angle in silane, SiH4?
   Si has four bonding regions and no lone pairs, so it is tetrahedral, 109.5°.
4. Name the shape of oxygen difluoride, OF2.
   O has 2 bonds and 2 lone pairs (20 electrons in all), so four regions give a bent shape.
5. Is dichloromethane, CH2Cl2, polar or non-polar?
   Polar: it is tetrahedral, but the C–Cl dipoles are bigger than the C–H dipoles, so they do not cancel.
6. Give the total number of valence electrons in the Lewis structure of each molecule.
   BCl3: 3 + (3 × 7) = 24 electrons, 12 pairs: three B–Cl bonds and three lone pairs on each Cl; B has only 6 electrons.
   PCl3: 5 + (3 × 7) = 26 electrons, 13 pairs: three P–Cl bonds, three lone pairs on each Cl and one lone pair on P (Achieved for a correct Lewis structure).
7. Name the shape of each molecule and give its bond angle.
   BCl3 is trigonal planar, 120°; PCl3 is a trigonal pyramid, about 109.5° (Achieved for both).
8. Explain why the two molecules have different shapes.
   Merit: B has three regions of electron density, all bonded, which repel to maximum separation in a flat triangle at 120°. P has four regions (three bonds and a lone pair), which repel into a tetrahedral arrangement at 109.5°; only three are bonded, so the shape is a trigonal pyramid. Excellence links the lone pair on P to both the different arrangement and the different shape.
9. Both molecules contain polar bonds. Discuss why BCl3 is non-polar but PCl3 is polar.
   Excellence: B–Cl (3.16 – 2.04) and P–Cl (3.16 – 2.19) are both polar, with Cl δ–. In BCl3 the three equal dipoles are arranged symmetrically in a plane, so they cancel and the molecule is non-polar. In PCl3 the lone pair makes the shape a pyramid, which is not symmetrical, so the three dipoles do not cancel and the molecule is polar.
10. Correct this statement: "CO2 is bent like water, because it has three atoms."
    C in CO2 has two double-bond regions and no lone pairs, so the regions sit 180° apart and the molecule is linear.
11. Correct this statement: "A double bond counts as two regions of electron density."
    A double or triple bond is one region, because all its electrons sit between the same two atoms.
12. Correct this statement: "CCl4 has polar bonds, so it must be a polar molecule."
    Its four equal C–Cl dipoles are arranged symmetrically, so they cancel and CCl4 is non-polar.
13. Correct this statement: "In a Lewis structure of PCl3 only the bonds and the P lone pair need drawing."
    Every valence electron is shown: each Cl also has three lone pairs, making 13 pairs (26 electrons) in total.

Answer key (for parents and tutors)

1. What type of solid is magnesium, Mg?
   Metallic: a lattice of Mg cations in delocalised electrons.
2. What type of solid is silicon dioxide, SiO_2?
   Covalent network: Si and O atoms joined by covalent bonds in 3D.
3. What type of solid is dry ice, solid CO_2?
   Molecular: CO_2 molecules held by weak intermolecular forces.
4. Does solid potassium bromide, KBr, conduct electricity?
   No: K^+ and Br^- ions are fixed in the lattice; it conducts only when molten or dissolved.
5. Will iodine, I_2, dissolve in hexane?
   Yes: I_2 and hexane are both non-polar, so their attractions to each other are similar to those they replace.
6. Give the type of solid and the particles in each of copper, magnesium chloride and iodine.
   Copper: metallic, cations in delocalised electrons. Magnesium chloride: ionic, Mg^{2+} and Cl^- ions. Iodine: molecular, I_2 molecules (Achieved for all three).
7. Explain why copper conducts electricity as a solid, but magnesium chloride conducts only when molten or dissolved.
   Merit: copper has delocalised valence electrons that are free to move through the lattice, so it conducts as a solid. In solid $MgCl_2$ the ions are held in fixed positions; when molten or dissolved the lattice breaks up and the ions are free to move and carry charge.
8. Explain why iodine has a much lower melting point than magnesium chloride.
   Merit: melting iodine only overcomes weak intermolecular forces between I_2 molecules, which needs little energy. Melting $MgCl_2$ means breaking strong ionic bonds between Mg^{2+} and Cl^- ions throughout the lattice, which needs much more energy, so its melting point is much higher.
9. Predict and explain whether magnesium chloride and iodine will dissolve in hexane, a non-polar solvent.
   Excellence: iodine dissolves: I_2 and hexane are both non-polar, and the weak attractions between them are similar in strength to the ones broken in each. Magnesium chloride does not: hexane has no partial charges to attract the ions, so there are no attractions strong enough to overcome the strong ionic bonds.
10. Correct this statement: "When iodine melts, the covalent bonds between the iodine atoms break."
    Only the weak intermolecular forces between I_2 molecules are overcome; the I–I covalent bonds stay intact.
11. Correct this statement: "Solid sodium chloride conducts because it is made of ions."
    The ions in a solid are held in fixed positions, so it conducts only when molten or dissolved.
12. Correct this statement: "Metals conduct because their positive ions move through the metal."
    The cations stay in the lattice; it is the delocalised electrons that move and carry the current.
13. Correct this statement: "Graphite conducts because its layers can slide over each other."
    Sliding layers explain softness; graphite conducts because of the delocalised electrons in each layer.

Answer key (for parents and tutors)

1. Is ice melting endothermic or exothermic?
   Endothermic: energy is absorbed to overcome the attractions between water molecules.
2. $CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$, $\Delta rH = -890$ kJ mol^{-1}. How much energy is released by burning 4.00 g of methane? M(CH_4) = 16.0 g mol^{-1}.
   n = 4.00 ÷ 16.0 = 0.250 mol; energy = 0.250 × 890 = 222.5 kJ, so about 223 kJ released (ΔH = −223 kJ).
3. Using the same equation, what mass of methane must burn to release 1780 kJ?
   n = 1780 ÷ 890 = 2.00 mol; m = 2.00 × 16.0 = 32.0 g.
4. Use the bond enthalpy table to calculate ΔrH for $H_2(g) + Br_2(g) \rightarrow 2HBr(g)$.
   Broken: 436 + 190 = 626 kJ; formed: 2 × 370 = 740 kJ; ΔrH = 626 − 740 = −114 kJ mol^{-1}.
5. $N_2 + 3H_2 \rightarrow 2NH_3$ has $\Delta rH = -92$ kJ mol^{-1}. What is ΔrH for $2NH_3 \rightarrow N_2 + 3H_2$?
   Reversing the equation changes the sign: ΔrH = +92 kJ mol^{-1}.
6. State whether the reaction is exothermic or endothermic, and explain your choice in terms of bonds.
   Exothermic: ΔrH is negative, because more energy is released forming the O–H bonds than is absorbed breaking the H–H and O=O bonds (Achieved for exothermic with a reason).
7. Calculate the energy released when 1.00 kg of hydrogen reacts.
   n(H_2) = 1000 ÷ 2.0 = 500 mol; 2 mol H_2 releases 572 kJ, so 1 mol releases 286 kJ; energy = 500 × 286 = 143 000 kJ released, ΔH = −1.43 × 10^5 kJ (Merit for the answer with unit).
8. Calculate the mass of hydrogen that must react to release 2000 kJ.
   n(H_2) = 2000 ÷ 286 = 6.99 mol; m = 6.99 × 2.0 = 14.0 g (Excellence needs both 2 and 3 correct).
9. When the water forms as a gas, $\Delta rH = -484$ kJ mol^{-1}. Use this and H–H = 436 and O=O = 498 kJ mol^{-1} to calculate the average O–H bond enthalpy.
   Broken: 2 × 436 + 498 = 1370 kJ; formed: 4 × (O–H), since 2 H_2O have 4 O–H bonds; −484 = 1370 − 4(O–H); 4(O–H) = 1854; O–H = 463.5, about 464 kJ mol^{-1} (Excellence for the correct answer with unit; Merit for the right process with one slip).
10. Explain why ΔrH is more negative when liquid water forms than when water vapour forms.
    Excellence: going from 2 mol of water vapour to 2 mol of liquid forms attractions between water molecules, which releases energy, so condensing is exothermic. That extra 572 − 484 = 88 kJ is released on top of the energy from the reaction, making ΔrH more negative.
11. Correct this statement: "Breaking bonds releases energy, which is why fuels give out heat."
    Breaking bonds always absorbs energy; fuels release energy because forming the bonds in CO_2 and H_2O releases more.
12. Correct this statement: "ΔrH = bonds formed − bonds broken."
    ΔrH = bonds broken − bonds formed, so a reaction that forms stronger bonds gets a negative ΔrH.
13. Correct this statement: "For $N_2 + 3H_2 \rightarrow 2NH_3$, bonds formed = 3 × N–H."
    Two NH_3 molecules each have three N–H bonds, so 6 × N–H are formed: multiply by the coefficient.
14. Correct this statement: "An endothermic reaction feels hot, because it takes in heat."
    It takes energy from the surroundings, so the beaker and your hand feel colder.

Answer key (for parents and tutors)

1. Name $CH_3CH_2CH_2CH_2OH$.
   Butan-1-ol: the OH is on C1 of a four-carbon chain.
2. Name $CH_3CH(CH_3)CH_2CH_2CH_3$.
   2-Methylpentane: number from the left so the branch is on C2, not C4.
3. Name $CH_3CH_2CH{=}CHCH_3$.
   Pent-2-ene: number from the right so the double bond starts at C2, not C3; it has cis and trans isomers.
4. Name $CH_3CH_2CH_2COOH$.
   Butanoic acid: four carbons, counting the COOH carbon.
5. Is $CH_3CBr(CH_3)CH_3$ primary, secondary or tertiary, and what is its name?
   Tertiary, because the carbon holding the Br is bonded to three other carbons; its name is 2-bromo-2-methylpropane.
6. Draw the structural formula of butan-2-ol and classify it as primary, secondary or tertiary.
   $CH_3CH(OH)CH_2CH_3$ drawn with every C–H bond shown; it is secondary, because the carbon holding the OH is bonded to two other carbons (Achieved).
7. Name a constitutional isomer of butan-1-ol, also an alcohol, that is not in the bottles.
   2-Methylpropan-1-ol, $(CH_3)_2CHCH_2OH$: the same formula with a branched chain (Achieved).
8. The technician also has but-1-ene and but-2-ene. Explain which of the two forms geometric isomers.
   But-2-ene: the C=C cannot rotate, and each of its carbons holds two different groups (H and CH_3), so the CH_3 groups can sit on the same side (cis) or opposite sides (trans). But-1-ene has two H atoms on C1, so it has no geometric isomers (Merit for one requirement explained, Excellence for both requirements applied to both molecules).
9. Butan-1-ol dissolves only partly in water, but ethanol mixes completely. Discuss why, using the structure of each molecule.
   Both have a polar OH group that hydrogen bonds with water. Ethanol's non-polar part is only two carbons, so it mixes in any amount; in butan-1-ol the four-carbon non-polar chain is a bigger part of the molecule and is not attracted to water, so only some dissolves and the rest forms a layer (Achieved names chain length, Merit links it to the polar OH, Excellence compares both molecules).
10. Correct this statement: "$CH_3CH_2CH_2CH(CH_3)CH_3$ is 4-methylpentane."
    Number from the end nearer the branch: it is 2-methylpentane. Always check the other direction.
11. Correct this statement: "$CH_3CH_2CH(CH_2CH_3)CH_3$ is 2-ethylbutane."
    The longest chain runs through the ethyl group, giving five carbons: it is 3-methylpentane.
12. Correct this statement: "But-1-ene has cis and trans isomers because it has a C=C double bond."
    A double bond is not enough: each of its carbons needs two different groups, and C1 of but-1-ene has two H atoms.
13. Correct this statement: "Butan-1-ol boils higher than butane because its O–H bond takes more energy to break."
    Boiling never breaks covalent bonds; butan-1-ol boils higher because its molecules attract each other more strongly, through hydrogen bonds.

Answer key (for parents and tutors)

1. Ethene with H_2 and a Pt catalyst: give the type of reaction and the organic product.
   Addition; ethane, CH_3CH_3.
2. Chloroethane heated with KOH(aq): type and product?
   Substitution; ethanol, CH_3CH_2OH, with KCl.
3. Propan-2-ol heated with concentrated H_2SO_4: type and product?
   Elimination; propene, $CH_2=CHCH_3$, the only product, because both neighbours of C2 are CH_3 groups.
4. Butan-1-ol heated with $Cr_2O_7^{2-}/H^+$: type and product?
   Oxidation; butanoic acid, $CH_3CH_2CH_2COOH$, and the orange dichromate turns green.
5. Propene with HCl: type and major product?
   Addition; 2-chloropropane is major and 1-chloropropane minor, by Markovnikov's rule.
6. Classify 2-bromobutane as primary, secondary or tertiary, and give the reason.
   Secondary: the carbon holding the Br (C2) is bonded to two other carbons (Achieved).
7. Give the reagent and conditions that turn it into butan-2-ol, and the reaction type.
   KOH(aq) and heat; substitution, as OH replaces Br (Achieved).
8. Heated with KOH(alc), 2-bromobutane gives two alkenes. Name both, say which is major, and justify your choice.
   But-2-ene, $CH_3CH=CHCH_3$, is major and but-1-ene, $CH_2=CHCH_2CH_3$, is minor. 2-Bromobutane is asymmetric about C2, so the H can be removed from C1 or C3 along with the Br; C3 has fewer H atoms (2) than C1 (3), so removing H from C3 gives the major product, but-2-ene, which forms as cis and trans isomers (Merit for the two products and the rule, Excellence for applying it to C1 and C3).
9. Describe how bromine water could tell the alkene products apart from 2-bromobutane.
   The alkenes turn orange bromine water colourless quickly, because Br_2 adds across the C=C; 2-bromobutane has no C=C, so the colour stays (Achieved for the observation, Merit for the reason).
10. Correct this statement: "1-Bromopropane heated with KOH gives propene."
    It depends on the solvent: KOH(aq) substitutes to give propan-1-ol, and only KOH(alc) eliminates to give propene.
11. Correct this statement: "In the major product, the Br adds to the carbon with more H atoms."
    It is the H that goes to the carbon with more H atoms; the Br goes to the other carbon.
12. Correct this statement: "2-Methylpropan-2-ol turns acidified dichromate green."
    It is a tertiary alcohol, so it is not oxidised and the dichromate stays orange.
13. Correct this statement: "Polypropene is drawn with a double bond in each repeating unit."
    The double bonds open to form the chain, so the polymer has only single bonds and is saturated.

Answer key (for parents and tutors)

1. 40 mL of hydrogen is made in the first 20 s of a reaction. What is the average rate?
   40 mL ÷ 20 s = 2.0 mL s^{-1}.
2. A flask loses 0.66 g of CO_2 in 3.0 minutes. What is the average rate in g min^{-1}?
   0.66 g ÷ 3.0 min = 0.22 g min^{-1}.
3. Which two factors increase the fraction of collisions that have enough energy to react?
   Temperature and a catalyst: heating gives more particles at least Ea, and a catalyst lowers Ea; concentration and surface area only make collisions more frequent.
4. Why does a graph of gas volume against time level off?
   A reactant has been used up, so no more product forms.
5. A catalyst lowers Ea from 80 kJ mol^{-1} to 50 kJ mol^{-1} for a reaction with ΔH = −30 kJ mol^{-1}. What is ΔH with the catalyst?
   ΔH is still −30 kJ mol^{-1}: a catalyst lowers Ea but does not change the energies of the reactants or products.
6. Calculate the average rate of oxygen production over the first 40 s.
   40 mL ÷ 40 s = 1.0 mL s^{-1} (Achieved).
7. Describe how the rate changes over the 120 s, and explain the change using collision theory.
   The rate is fastest at the start and falls until it stops by about 100 s. As H_2O_2 is used up its concentration falls, so its particles collide with the catalyst surface less often, giving fewer successful collisions per second; once all the H_2O_2 has decomposed no more oxygen forms (Merit for the link between concentration and collision frequency).
8. Explain how manganese dioxide speeds up the reaction, and state what it does to the final volume of oxygen.
   The catalyst provides another pathway with a lower activation energy, so a greater fraction of collisions have enough energy to react, giving more successful collisions per second. It is not used up and does not change the amount of H_2O_2, so the final volume stays 57 mL (Merit, Excellence with the final volume justified).
9. Discuss how running the same reaction at a higher temperature would change the graph of volume against time.
   The curve would be steeper at the start and level off sooner, at the same 57 mL. Particles move faster and collide more often, and a larger fraction of collisions have at least the activation energy, so there are more successful collisions per second; the amount of H_2O_2 is unchanged, so the final volume is too (Excellence).
10. Correct this statement: "A catalyst gives the particles more energy."
    A catalyst provides another pathway with a lower activation energy; the particles' energies are unchanged.
11. Correct this statement: "A higher concentration makes the particles move faster."
    Concentration only changes how many particles are in a volume, making collisions more frequent; only temperature changes their speed.
12. Correct this statement: "Powdered marble makes more gas than chips."
    With the same mass and the acid in excess, both make the same volume; the powder just makes it sooner.
13. Correct this statement: "The rate is the number of collisions."
    The rate depends on the number of successful collisions per second; most collisions lack the energy to react.

Answer key (for parents and tutors)

1. Write the Kc expression for $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$.
   $K_c = [HI]^2 \div ([H_2][I_2])$.
2. What is the pH of 0.0050 mol L^{-1} HCl?
   pH = −log(0.0050) = 2.30.
3. What is the pH of 0.10 mol L^{-1} KOH?
   $[OH^-] = 0.10$ mol L^{-1}, so $[H_3O^+] = 1.0 \times 10^{-14} \div 0.10 = 1.0 \times 10^{-13}$ mol L^{-1} and the pH is 13.00.
4. Find $[H_3O^+]$ in a solution of pH 9.20.
   $[H_3O^+] = 10\text{^}-9.20 = 6.31 \times 10^{-10}$ mol L^{-1}.
5. For $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$, which way does the equilibrium shift when the pressure is increased?
   To the right: 3 mol of gas become 2, and fewer gas particles lower the pressure.
6. Write the Kc expression for this equilibrium.
   $K_c = [CH_3OH] \div ([CO][H_2]^2)$ (Achieved).
7. In a test vessel at equilibrium, $[CO] = 0.20$, $[H_2] = 0.30$ and $[CH_3OH] = 0.045$ mol L^{-1}. Calculate Kc and say what it shows.
   $K_c = 0.045 \div (0.20 \times 0.30^2) = 0.045 \div 0.018 = 2.5$; Kc is a little above 1, so products are slightly favoured at this temperature (Achieved for the value, Merit for the meaning).
8. Explain why the process is run at high pressure.
   The left side has 3 mol of gas and the right side 1 mol. Raising the pressure favours the side with fewer moles of gas, which lowers the pressure again, so the forward reaction is favoured and more methanol forms; the higher concentration of gas also speeds up the reaction (Merit).
9. Discuss how raising the temperature affects the amount of methanol at equilibrium, the value of Kc, and the rate.
   The forward reaction is exothermic, so heating favours the endothermic reverse reaction, which absorbs some of the added heat: less methanol forms and Kc gets smaller. But particles move faster and more collisions have at least the activation energy, so the rate rises and equilibrium is reached sooner; the plant runs at a compromise temperature (Excellence for weighing yield against rate).
10. Equipment is rinsed with 0.010 mol L^{-1} NaOH. Calculate its pH.
    $[OH^-] = 0.010$ mol L^{-1}, so $[H_3O^+] = 1.0 \times 10^{-14} \div 0.010 = 1.0 \times 10^{-12}$ mol L^{-1} and the pH is 12.00 (Achieved).
11. Correct this statement: "At equilibrium the concentrations of reactants and products are equal."
    The forward and reverse rates are equal; the concentrations are constant but usually different.
12. Correct this statement: "Adding more reactant increases Kc."
    Only temperature changes Kc; adding reactant shifts the position of equilibrium and Kc stays the same.
13. Correct this statement: "The pH of 0.020 mol L^{-1} NaOH is −log(0.020) = 1.70."
    That uses $[OH^-]$. Find $[H_3O^+] = 1.0 \times 10^{-14} \div 0.020 = 5.0 \times 10^{-13}$ mol L^{-1} first, so the pH is 12.30.
14. Correct this statement: "A weak acid is the same as a dilute acid."
    Weak means it reacts only partly with water; a weak acid can be concentrated and a strong acid can be dilute.

Answer key (for parents and tutors)

1. Find the oxidation number of Cr in $Cr_2O_7^{2-}$.
   $2x + 7(-2) = -2$, so Cr = +6.

2. Find the oxidation number of N in NO_3^- and in NO_2, and say whether N is oxidised or reduced when NO_3^- becomes NO_2.
   NO_3^-: $x + 3(-2) = -1$, so N = +5; NO_2: $x + 2(-2) = 0$, so N = +4; N falls from +5 to +4, so it is reduced.

3. Balance the half equation for hydrogen peroxide acting as a reductant: $H_2O_2 \rightarrow O_2$.
   $H_2O_2 \rightarrow O_2 + 2H^+ + 2e^-$.

4. Acidified hydrogen peroxide is added to colourless potassium iodide solution. Write the overall equation and describe what you see.
   $H_2O_2 + 2H^+ + 2e^- \rightarrow 2H_2O$ and $2I^- \rightarrow I_2 + 2e^-$ add to $H_2O_2 + 2H^+ + 2I^- \rightarrow 2H_2O + I_2$; the colourless solution turns brown as iodine forms.

5. A copper wire is put in colourless silver nitrate solution. Write the overall equation, name the oxidant, and describe two observations.
   $Cu + 2Ag^+ \rightarrow Cu^{2+} + 2Ag$; the oxidant is Ag^+; grey-silver crystals grow on the wire and the solution slowly turns blue.

6. Correct this statement: "The oxidant is the substance that gets oxidised."
   The oxidant takes electrons, so it is reduced; the reductant is the one oxidised.

7. Correct this statement: "$MnO_4^- + 8H^+ + 5Fe^{2+} + 5e^- \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O + 5e^-$"
   Electrons must cancel completely; the overall equation never shows e^-.

8. Correct this statement: "Observation: Mn^{2+} ions are formed."
   Describe what you see: the purple solution turns colourless.

9. Correct this statement: "Mn has an oxidation number of 7+ in MnO_4^-."
   Oxidation numbers put the sign first: +7. A charge such as 2+ is written after.

Answer key (for parents and tutors)

1. 2.650 g of anhydrous sodium carbonate (M = 105.99 g mol^{-1}) is made up to 250.0 mL. Find its concentration.
   n = 2.650 ÷ 105.99 = 0.02500 mol; c = 0.02500 ÷ 0.2500 = 0.1000 mol L^{-1}.

2. A student's titres are 22.60 (rough), 22.15, 22.40, 22.20 and 22.10 mL. Which are concordant, and what is the mean titre?
   22.15, 22.20 and 22.10 mL agree within 0.10 mL; mean = (22.15 + 22.20 + 22.10) ÷ 3 = 22.15 mL. 22.40 mL is left out.

3. $Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$. 20.00 mL of 0.1000 mol L^{-1} Na_2CO_3 needs 22.15 mL of HCl. Find c(HCl).
   n(Na_2CO_3) = 0.1000 × 0.02000 = 2.000 × 10^{-3} mol; n(HCl) = 2 × 2.000 × 10^{-3} = 4.000 × 10^{-3} mol; c = 4.000 × 10^{-3} ÷ 0.02215 = 0.1806 mol L^{-1}.

4. A cleaner is diluted 25.00 mL to 250.0 mL, and the diluted solution is 0.0850 mol L^{-1}. What is the concentration in the bottle?
   Dilution factor 10, so 10 × 0.0850 = 0.850 mol L^{-1}.

5. Explain why the student standardised the sodium hydroxide instead of weighing out the pellets.
   NaOH absorbs water and carbon dioxide from the air, so a weighed mass is not all NaOH and its concentration would be wrong; titrating it against a primary standard gives its true concentration.

6. Correct this statement: "I averaged all four titres, including the rough one."
   Only the concordant titres go in the mean; the rough titre only shows roughly where the end point is.

7. Correct this statement: "n(NaOH) = n($H_2C_2O_4$), so c(NaOH) = 0.04870 mol L^{-1}."
   Oxalic acid needs two NaOH per molecule, so n(NaOH) = 2 × n($H_2C_2O_4$), giving 0.09740 mol L^{-1}.

8. Correct this statement: "The vinegar's concentration is 0.07013 mol L^{-1}."
   That is the diluted solution; multiply by the dilution factor of 10 to get 0.7013 mol L^{-1} in the bottle.

9. Correct this statement: "I rinsed the burette with distilled water before filling it with NaOH."
   Rinse it with the NaOH; leftover water dilutes it, which makes the titres too large and the answer too high.

Answer key (for parents and tutors)

1. A solution gives a white precipitate with NaOH that dissolves in excess, and a white precipitate with NH_3 that also dissolves in excess. Which cation is present?
   Zn^{2+}: only zinc hydroxide redissolves in excess NaOH and in excess NH_3.
2. Write the ionic equation for a few drops of NaOH added to a solution of Cu^{2+} ions.
   $Cu^{2+} + 2OH^- \rightarrow Cu(OH)_2(s)$, a blue precipitate.
3. Excess ammonia then turns that precipitate into a deep blue solution. Write the equation.
   $Cu(OH)_2(s) + 4NH_3 \rightarrow [Cu(NH_3)_4]^{2+} + 2OH^-$.
4. A white precipitate with NaOH dissolves in excess. With NH_3 the white precipitate stays, and with KI a bright yellow precipitate forms. Name the cation and write the equation for the yellow precipitate.
   Pb^{2+}; $Pb^{2+} + 2I^- \rightarrow PbI_2(s)$.
5. Why is the sample acidified with dilute nitric acid before silver nitrate is added?
   The acid removes carbonate and hydroxide ions, which would also precipitate with Ag^+, so a precipitate can only be a halide.
6. Tank water from an old house contains 3 mg/L of copper. Is it within the drinking water standard?
   No: 3 mg/L is above the maximum acceptable value of 2 mg/L.
7. Correct this statement: "White precipitate with NaOH, so it is Zn^{2+}."
   Mg^{2+}, Al^{3+}, Zn^{2+} and Pb^{2+} all give white precipitates; only the tests in excess NaOH, then NH_3, then KI tell them apart.
8. Correct this statement: "$2NaOH + CuSO_4 \rightarrow Cu(OH)_2 + Na_2SO_4$ is my ionic equation."
   Leave out the spectator ions: $Cu^{2+} + 2OH^- \rightarrow Cu(OH)_2(s)$.
9. Correct this statement: "I tipped in lots of NaOH at once and saw a clear solution, so there was no precipitate."
   Add a drop at a time first; an amphoteric hydroxide forms and then redissolves, so pouring in excess hides it.
10. Correct this statement: "The green precipitate went brown on top, so the ion is Fe^{3+}."
    Fe^{3+} gives orange-brown at once; green turning brown on top is $Fe(OH)_2$ being oxidised by air, so the ion is Fe^{2+}.

Answer key (for parents and tutors)

1. Three repeats give crater diameters of 8.2 cm, 8.6 cm and 8.4 cm. Find the mean.
   (8.2 + 8.6 + 8.4) ÷ 3 = 8.4 cm.
2. Purpose: to find out how the slope angle of a sand tray affects the mass of sand washed off by 500 mL of water. Name the independent and the dependent variable.
   Independent: the slope angle; dependent: the mass of sand washed off.
3. Repeats at 80 cm are 7.0 cm, 7.2 cm and 9.6 cm, and the third marble hit an old crater. Find the mean you should report.
   Leave out 9.6 cm and record why: (7.0 + 7.2) ÷ 2 = 7.1 cm.
4. A 20 g marble is dropped from 0.50 m. Calculate its gravitational potential energy (g = 9.8 N/kg).
   Ep = mgh = 0.020 × 9.8 × 0.50 = 0.098 J.
5. Which change to a method makes the data more reliable?
   Doing three or more repeats at each value and checking they agree closely, with one person measuring the same way each time.
6. Explain why the crater widths rise by less with each extra 20 cm of drop height.
   The energy rises in proportion to the height, but it has to move a bowl of flour whose volume grows much faster than its width, so each extra bit of energy widens the crater less.
7. Correct this statement: "My results are reliable because I was careful."
   Reliable means repeats closely agree; quote the spread, such as all repeats within 0.2 cm, and say what in the method made that happen.
8. Correct this statement: "I put every result in the mean, even the one that bounced."
   If a result breaks the method and you can say how, leave it out of the mean and record the reason, or redo that drop.
9. Correct this statement: "I joined my points dot to dot and drew the line through zero."
   Draw a smooth curve or straight line of best fit through the means, and only through (0, 0) if the science says it must pass there.
10. Correct this statement: "My science section explains what a crater is."
    The science must explain your results: why your trend has the shape it has, using ideas such as Ep = mgh and energy spreading into the flour.

Answer key (for parents and tutors)

1. Auckland's sea level rose 2.54 mm a year from 1961 to 2020. How much is that over the 60 years, in centimetres?
   2.54 × 60 = 152.4 mm ≈ 15 cm.
2. Dunedin's rate rose from 0.69 to 1.76 mm a year. How many times faster is the later rate, to one decimal place?
   1.76 ÷ 0.69 = 2.55, so about 2.6 times faster.
3. The ocean near a town rises 3 mm a year, and the land there is being pushed up by 1 mm a year. What relative rise does the town's tide gauge record?
   3 − 1 = 2 mm a year, because the rising land cancels part of the rise.
4. Which is more valid evidence of the national trend: 120 years of tide-gauge records, or a homeowner's two photos of a beach 30 years apart?
   The tide-gauge records: measured to fractions of a millimetre over a long time, with a stated method, while photos depend on the tide and season when each was taken.
5. Give one Earth and Space Science point against a nationwide ban on new coastal homes.
   Some coasts are being pushed up by as much as 5 mm a year, which cancels much of the rise there, so the risk differs from town to town.
6. What lifts a Merit position to Excellence?
   Justifying it: weighing evidence from both sides with numbers, and saying how the validity of each source affects how much weight it gets.
7. Correct this statement: "Stats NZ is valid because it is a government website."
   Say why the information is valid: long-term measured data, a stated method and uncertainty, and agreement with other sources.
8. Correct this statement: "Melting sea ice is a main cause of sea-level rise."
   Floating sea ice already displaces its own weight of water; the rise comes from warming water expanding and from ice melting on land.
9. Correct this statement: "I only included evidence for my side so my position looks stronger."
   Report the science on both sides, then explain why the evidence for your position outweighs the rest.
10. Correct this statement: "The sea is rising the same amount everywhere in New Zealand."
    Tide gauges measure the sea against the land, and the land is sinking in some places and rising in others.

Answer key (for parents and tutors)

1. In the cross-section, which of layers A, B and C is the oldest?
   A, because it is at the bottom of undisturbed layers.
2. Is fault F older or younger than layer C?
   Younger: F cuts through C, so C was there first.
3. Put A, B, C, D, E and F in order from oldest to youngest.
   A, B, C, F, D, E: the layers by superposition, then the fault that cuts them, then the dyke that cuts the fault, then erosion and gravel E on top.
4. What rock type is schist, and which process made it at Franz Josef?
   Metamorphic; greywacke was buried deep by plate collision on the Alpine Fault and changed by heat and pressure.
5. Why are most boulders in West Coast rivers greywacke, with less schist?
   Most of the Alps are greywacke and schist is only a narrow band beside the fault, so rivers carry mostly greywacke.
6. Write one sentence linking uplift and erosion in the Southern Alps, as an Excellence answer would.
   For example: the Alpine Fault lifts the Alps about 10 mm a year, and because heavy rain, glaciers and landslides remove rock about as fast, the mountains stay roughly the same height while their valleys are cut deeper.
7. Correct this statement: "Schist is igneous because it formed with heat."
   Schist never melted: heat and pressure changed solid greywacke, so it is metamorphic.
8. Correct this statement: "The Alps are tall because plates push them up, and that is the whole story."
   Erosion matters too: the Alps rise about 10 mm a year but erosion removes rock nearly as fast, so their height stays about the same.
9. Correct this statement: "My report explains how schist forms anywhere in the world."
   Tie each process to your place: which plates, which fault, which rocks and which landforms are there.
10. Correct this statement: "The top layer is the oldest because it has been there longest."
    In undisturbed layers the bottom layer was deposited first, so it is the oldest.

Answer key (for parents and tutors)

1. Venenivibrio grows from 45 to 75 °C. Could it grow in water at 37 °C?
   No: 37 °C is below its lowest growth temperature of 45 °C.
2. Antarctic seawater is −1.9 °C, and fish body fluids freeze at about −1 °C. By how many degrees is the sea colder than that freezing point?
   −1 − (−1.9) = 0.9 °C colder.
3. Why would a human enzyme stop working in 75 °C water?
   Heat breaks the weak bonds holding the enzyme's shape, so its active site changes shape (it denatures) and the substrate no longer fits.
4. Which organism avoids freezing and which tolerates it: the toothfish or the alpine wētā?
   The toothfish avoids freezing with antifreeze glycoproteins; the alpine wētā tolerates freezing.
5. Why does growing best at 4 to 8% oxygen help Venenivibrio in a hot spring?
   Hot water holds little dissolved oxygen, so needing only a little oxygen matches what the spring supplies.
6. Write one condition, problem, adaptation chain for the toothfish, as an Excellence answer would.
   For example: sea at −1.9 °C is colder than the −1 °C at which fish fluids freeze, so ice crystals entering in seawater and food would grow and tear cells; antifreeze glycoproteins in the blood and gut bind the crystals and stop them growing, so the fish stays unfrozen.
7. Correct this statement: "The environment is extreme because it is really hot."
   Give the numbers and the reason: Champagne Pool is about 75 °C, hot enough to denature the enzymes of almost every plant and animal.
8. Correct this statement: "The toothfish's antifreeze works by adding salt to its blood."
   Its antifreeze glycoproteins bind to tiny ice crystals and stop them growing; they do not work by making the blood saltier.
9. Correct this statement: "The bacterium adapted to the heat because it wanted to survive."
   Organisms do not choose adaptations; those with heat-stable proteins survived and reproduced, so the feature became common.
10. Correct this statement: "I listed five adaptations with a sentence on each."
    Merit and Excellence need links: for each key adaptation, say which condition it answers and how it solves the problem that condition causes.

Answer key (for parents and tutors)

1. Which plate subducts under the North Island, and what type of crust is it?
   The Pacific Plate, which is oceanic crust.
2. What lowers the melting point of the mantle above a subducting plate?
   Water released from the subducting plate.
3. A magnitude 6.2 and a magnitude 7.2 earthquake: roughly how many times more energy does the bigger one release?
   One step of magnitude, so about 32 times.
4. What is the epicentre of an earthquake?
   The spot at ground level directly above the focus.
5. Which magma has the most silica, and what kind of volcano does it build?
   Rhyolite, which builds a caldera through huge explosive eruptions.
6. Name the two plates involved and the type of crust each is made of.
   Pacific Plate, oceanic crust; Australian Plate, continental crust (Achieved).
7. Explain how tectonic processes form the magma that feeds Ruapehu.
   Achieved: the Pacific Plate subducts and melts to make magma that rises. Merit: the denser oceanic plate sinks under the continental plate; water squeezed out of it lowers the melting point of the mantle, which partly melts into basaltic magma that rises because it is less dense. Excellence: the basaltic magma pools under the continental crust and melts some of it, adding silica, which turns it into andesitic magma; each step is linked to the next.
8. Explain how andesitic magma produces a steep, layered cone.
   Achieved: andesite has medium silica, is sticky and has some gas; it erupts ash and lava. Merit: sticky lava cools before it can flow far, so it builds up near the vent; explosive ash eruptions add layers. Excellence: alternating layers of ash and short, thick lava flows pile up near the vent eruption after eruption, so the steep sides and the layers both come from the medium silica and the trapped gas.
9. A shallow magnitude 6 earthquake and a deep magnitude 6 earthquake happen under the central North Island. Explain which one is more likely to damage buildings near the epicentre.
   The shallow one (Achieved). Merit: its seismic waves travel a shorter distance to the surface, so they lose less energy and the shaking at the epicentre is stronger. Excellence: both release the same energy, but waves from the deep focus spread out and lose energy on the way up, so they are felt over a wider area but more weakly; the shallow focus concentrates strong shaking (higher MM intensity) near the epicentre, which causes more damage.
10. Correct this statement: "The Pacific Plate melts because of friction as it rubs against the Australian Plate."
    Water released from the sinking plate lowers the melting point of the mantle above it; that is the main cause of melting.
11. Correct this statement: "The epicentre is where the earthquake happens underground."
    The focus is the underground starting point of the rupture; the epicentre is the spot at ground level directly above it.
12. Correct this statement: "A magnitude 7 is a bit bigger than a magnitude 6."
    Magnitude is logarithmic: one step up releases about 32 times more energy.
13. Correct this statement: "Andesite volcanoes are steep because the lava is hot and flows fast."
    Andesite is sticky and cools close to the vent, so short lava flows and ash layers pile up steeply.

Answer key (for parents and tutors)

1. What makes a tsunami different from a wind wave?
   A tsunami moves the whole water column, from sea floor to surface; a wind wave moves only the surface water.
2. Find the speed of a tsunami where the ocean is 1000 m deep, in m/s.
   $v = \sqrt{(9.8 \times 1000)} = \sqrt{9800} = 99$ m/s.
3. What happens to a tsunami's wavelength as it moves into shallow water?
   It gets shorter, because the front slows and the waves bunch up.
4. Why do strike-slip earthquakes seldom cause large tsunami?
   They move the sea floor sideways, with little vertical movement, so little water is displaced.
5. Give two ways heavy rain makes a landslide more likely.
   It adds weight to the slope, and the water pressure pushes grains apart and cuts friction.
6. Describe a tsunami wave, referring to the water column.
   A tsunami is a series of waves in which the whole water column, from sea floor to surface, is displaced by a sudden disturbance (Achieved).
7. Explain how this earthquake generates a tsunami, including the energy changes.
   Achieved: the sea floor is lifted and pushes the water up. Merit: the locked upper plate is bent down and stores elastic energy; when the fault slips it springs up, lifting the water column, which gains gravitational potential energy. Excellence: gravity pulls the raised water back down, and its gravitational potential energy becomes kinetic energy of waves spreading out in all directions; the larger the area and height of the uplift, the more water is displaced and the larger the tsunami.
8. Suppose the ocean between the source and a coast 1000 km away is 4000 m deep on average. Calculate how long the tsunami takes to arrive, in hours.
   $v = \sqrt{(9.8 \times 4000)} = 198$ m/s; $t = 1\,000\,000 \div 198 = 5050$ s; $5050 \div 3600 = 1.4$ hours (Merit for the working with units).
9. Explain the changes in speed, wavelength and amplitude as the tsunami approaches New Zealand's coast.
   Achieved: it slows down and gets taller. Merit: friction with the shallowing sea floor slows the wave, so the wavelength shortens and the amplitude increases. Excellence: in deep water it travels at hundreds of km/h with little energy loss, which is why warnings go Pacific-wide; near the coast the front slows first, the back catches up, the wavelength shortens, and the same energy in a shorter, slower wave makes it much taller, so it floods far inland.
10. Correct this statement: "A tsunami is a giant wind wave that is tall out at sea."
    It is made by moving the whole water column, and in the deep ocean it is usually less than a metre high.
11. Correct this statement: "The tsunami speeds up as it reaches the shore, which is why it is so powerful."
    It slows down in shallow water; it grows taller because the waves bunch up and the energy is squeezed into a shorter wave.
12. Correct this statement: "Every big earthquake under the sea makes a big tsunami."
    A tsunami needs vertical movement of the sea floor; strike-slip quakes move sideways and seldom make large tsunami.
13. Correct this statement: "Rain causes landslides by washing the soil away."
    Rain adds weight and its water pressure pushes grains apart, cutting friction until the driving force wins.

Answer key (for parents and tutors)

1. What stops a main sequence star from collapsing under gravity?
   Outward pressure from the energy released by fusion in its core balances gravity.
2. Where on the HR diagram are white dwarfs, and why are they dim?
   Bottom left: they are hot but tiny, so their small surface gives out little energy.
3. If a star were moved to 3 times its distance from us, what fraction of its brightness would we see?
   $1 \div 3^2 = 1/9$ of its brightness.
4. What does a star of 30 Sun masses become at the end of its life?
   A black hole, after a supernova.
5. How far is 4.24 light-years in km, using 1 light-year = 9.5×10^{12} km?
   $4.24 \times 9.5 \times 10^{12} = 4.0 \times 10^{13}$ km.
6. Compare the colour, surface temperature and position on the HR diagram of the two stars.
   Alpha Centauri A: yellow, about the Sun's temperature, on the main sequence near the middle; Gamma Crucis: red, cooler, at the top right among the giants (Achieved).
7. Explain how Gamma Crucis can be cooler than Alpha Centauri A but far more luminous.
   Merit: luminosity depends on temperature and surface area, so a cooler star can be more luminous if it is much larger. Excellence: each square metre of Gamma Crucis gives out less energy than Alpha Centauri A, but its surface area is so much larger that its total output is far greater, which puts it at the top right of the HR diagram; it looks bright from Earth despite being further away.
8. Explain how a Sun-like star changes from the main sequence into a red giant, referring to gravity, fuel use and energy.
   Achieved: it runs out of hydrogen in its core and swells into a red giant. Merit: without fusion support, gravity squeezes the core, turning gravitational potential energy into heat; hydrogen fuses in a shell, and the outer layers expand and cool. Excellence: the core heats until helium fuses into carbon; the extra energy pushes the outer layers out, so the star becomes larger, cooler (red) and more luminous, moving up and right on the HR diagram.
9. Explain why a star of 15 Sun masses ends very differently from Alpha Centauri A.
   Achieved: it will end in a supernova instead of a white dwarf. Merit: its strong gravity heats the core enough to fuse elements up to iron, then the core collapses. Excellence: iron fusion absorbs energy, so outward pressure fails and gravity collapses the core; the rebound makes a supernova and leaves a neutron star, whereas Alpha Centauri A, under 8 Sun masses, sheds a planetary nebula and leaves a white dwarf.
10. Correct this statement: "A red star is cool, so it must be dim and low on the HR diagram."
    Colour gives temperature only; a red giant is cool but huge, so it is very luminous and sits at the top right.
11. Correct this statement: "Massive stars live longest because they have the most fuel."
    They burn it far faster because gravity makes their cores hotter, so they live only millions of years.
12. Correct this statement: "The Sun will explode as a supernova."
    The Sun is under 8 Sun masses, so it will become a red giant, then a planetary nebula and a white dwarf.
13. Correct this statement: "The temperature axis on an HR diagram increases to the right."
    Temperature increases to the left: hot blue stars on the left, cool red stars on the right.

Answer key (for parents and tutors)

1. Why did the solar nebula flatten into a disc as it collapsed?
   As it shrank it spun faster, and the spin flattened it into a rotating disc.
2. Why could water ice exist as a solid beyond the frost line but not close to the Sun?
   Beyond the frost line the disc was cold enough for water to freeze; near the Sun it was too hot, so water stayed as gas.
3. Jupiter is 5.204 AU from the Sun. Use $T^2 = a^3$ to find its period in years.
   $T^2 = 5.204^3 = 140.9$, so $T = \sqrt{140.9} = 11.87$ years.
4. A star dims by 1% during a transit. What is the planet's radius as a fraction of the star's?
   $(r \div R)^2 = 0.01$, so $r \div R = \sqrt{0.01} = 0.1$, a tenth of the star's radius.
5. Give two pieces of evidence that Phobos may be a captured asteroid.
   It is small and lumpy, and it is made of dark carbon-rich rock like many asteroids.
6. Describe a protoplanetary disc.
   A flat, spinning disc of gas and dust around a newly formed star, which is the raw material for planets and moons (Achieved).
7. Explain how rocky planets like these form from the disc, referring to changes in temperature.
   Achieved: dust grains stick together and grow into planets. Merit: close to the star it is hot, so only rock and metal condense; grains collide and stick into planetesimals, which attract each other by gravity and grow into protoplanets. Excellence: collisions turn kinetic energy into heat, so young planets melt, iron sinks to make a core and lighter rock a mantle; as the disc and planets cool, solid crusts form, giving small, dense rocky planets.
8. Explain how the transit method detected these planets.
   Achieved: the star gets dimmer when a planet passes in front. Merit: the planet blocks a small fraction of the star's light, giving a regular dip; the time between dips gives the period. Excellence: the depth of the dip, (planet radius ÷ star radius)², gives the planet's size, so Earth-sized planets give small dips, easier to detect around a small star; repeated dips at fixed intervals confirm each planet.
9. Explain why the habitable zone of TRAPPIST-1 is much closer to its star than the Sun's habitable zone is to the Sun.
   Merit: a red dwarf is cool and much less luminous than the Sun, so it gives out less energy each second. Excellence: the energy reaching a planet falls with the square of distance, so to receive enough energy for liquid water a planet must orbit much closer to a dim star; the zone is also narrower.
10. Earth's Moon has rock very like Earth's mantle but a tiny iron core. Explain how this evidence supports the collision theory and rules out capture.
    Merit: the matching rock means the Moon is made from Earth's material, which a captured body from elsewhere would not be. Excellence: a giant impact blasted out mantle rock, which is low in iron, so the Moon has a small core; capture cannot explain the matching composition, and co-accretion would give the Moon Earth's large iron share.
11. Correct this statement: "There is no gravity in space, so planets just keep moving."
    The Sun's gravity pulls every planet towards it; that pull is what keeps bending its path into an orbit.
12. Correct this statement: "The gas giants are big because they are further from the Sun's gravity."
    They are big because ices could freeze in the cold outer disc, giving cores large enough to pull in gas.
13. Correct this statement: "Earth's Moon was captured as it flew past."
    Its rock matches Earth's mantle and it has little iron, which fits a giant impact, not capture.
14. Correct this statement: "The habitable zone is the same distance from every star."
    It depends on the star's luminosity: further out for hot bright stars, very close in for red dwarfs.

Answer key (for parents and tutors)

1. A 54 g rock has a volume of 20 cm^3. Find its density.
   $\rho = m \div V = 54 \div 20 = 2.7\ g\ cm^{-3}$.

2. Find the pressure from seawater (ρ = 1025 $kg\ m^{-3}$) 200 m below the surface, ignoring the air. Use g = 9.8 $N\ kg^{-1}$.
   $P = \rho gh = 1025 \times 9.8 \times 200 = 2\,009\,000$ Pa, about 2.0 MPa.

3. Explain why water under forming sea ice sinks.
   Sea ice holds little salt, so the water left behind is saltier and close to freezing, which makes it denser than the water around it.

4. Which kind of heat transfer carries most heat through the outer core, and which through the crust?
   Convection in the liquid outer core; conduction through the rigid crust.

5. Does rising air or sinking air bring cloud, and why?
   Rising air: it moves into lower pressure, expands and cools, so its water vapour condenses into cloud.

6. Describe two sources of the heat inside the Earth.
   Achieved: any two of heat left from Earth's formation (collisions and iron sinking to the core), radioactive decay of uranium, thorium and potassium isotopes releasing energy from their nuclei, and latent heat given out as the outer core freezes onto the inner core.

7. Explain how heat is carried from the outer core up through the mantle.
   Merit: the outer core heats the base of the mantle by conduction; that rock expands, becomes less dense than the rock above and rises; under the plates it loses heat by conduction, becomes denser and sinks, so the convection current carries heat outward. Excellence adds why: rock is a poor conductor, but hot mantle rock can flow, so moving rock carries the heat far faster.

8. Discuss how the rainwater is heated and why it returns to the surface, linking heat transfer, density and pressure.
   Excellence: hot rock above magma several kilometres down heats the water in the cracks by conduction, as fast-vibrating particles of rock collide with water particles. The heated water expands, so it becomes less dense than the cold water above and is pushed up, while cold, denser rainwater sinks in to replace it: a convection loop through the cracks. The high pressure at depth stops the water boiling even above 100 °C; as it rises the pressure falls, so some boils to steam near the surface. Naming conduction or saying hot water rises earns Achieved; the density explanation earns Merit; linking the heat source, conduction, convection and pressure into one chain earns Excellence.

9. Correct this statement: "Hot air rises because heating makes its particles lighter."
   The mass stays the same; the particles spread apart, so the volume increases and the density falls, and denser surroundings push it up.

10. Correct this statement: "The mantle is a sea of liquid magma, so it convects like water in a pot."
    The mantle is solid rock that flows very slowly because it is so hot; only small pockets melt, mostly where pressure drops.

11. Correct this statement: "Heat rises."
    Hot fluid rises because it is less dense; heat itself moves in every direction by conduction and radiation, from hotter to colder.

12. Correct this statement: "The core stays hot because the Sun's heat soaks down into the Earth."
    Sunlight only warms the top few metres; the interior's heat is left from Earth's formation and made by radioactive decay.

Answer key (for parents and tutors)

1. How much energy warms 2.0 kg of water by 3.0 °C? Use c = 4200 J kg^{-1} °C^{-1}.
   Q = mcΔT = 2.0 × 4200 × 3.0 = 25 200 J.
2. 8400 J is absorbed by 0.50 kg of dry sand (c = 800 J kg^{-1} °C^{-1}). Find its temperature rise.
   ΔT = Q ÷ (mc) = 8400 ÷ (0.50 × 800) = 21 °C.
3. Using NIWA's table, how much bigger is Alexandra's July daily range than Dunedin's?
   8.9 − 4.3 = 4.6 °C bigger.
4. Explain why a cloudy winter night is usually warmer than a clear one.
   The cloud absorbs the longwave infrared the ground gives off and re-emits some of it back down, so less heat escapes to space.
5. Explain why the sky is blue.
   Gas molecules scatter short blue wavelengths far more than long red ones, so scattered blue light reaches your eyes from all over the sky.
6. Which way does the breeze blow on a beach on a clear night, and why?
   From the land out to sea: the land cools faster than the sea, so air over the sea is warmer and rises, and denser air from over the land flows out to replace it.
7. Describe what latent heat is.
   Achieved: the energy absorbed or released when a substance changes state without changing temperature; evaporation absorbs it and condensation releases it.
8. Explain why the air cools as it rises over the Alps, and why rain falls on the West Coast.
   Merit: as the air rises, the pressure on it falls, so it expands and cools. Once it has cooled enough, its water vapour condenses into cloud droplets, which grow and fall as rain on the western side of the ranges.
9. Discuss why the air reaching the Canterbury Plains is warmer and drier than it was at the same height over the Tasman Sea.
   Excellence: condensation releases latent heat into the rising air, so above the cloud base it cools more slowly than dry air would. The water falls out as rain on the West Coast, so the air that crosses the main divide has lost much of its moisture. As it descends on the eastern side, the rising pressure compresses it and it warms at the faster rate of dry air all the way down. It therefore reaches the plains warmer than it was at the same height on the western side, and drier, because its water stayed behind as rain while the latent heat that water carried stayed in the air. This is the föhn effect. Describing latent heat earns Achieved; explaining the cooling and condensation earns Merit; linking latent heat release, the loss of water and warming by compression earns Excellence.
10. Correct this statement: "Water has a high heat capacity, so it heats up quickly."
    A high heat capacity means it takes more energy for each degree, so water heats up, and cools down, slowly.
11. Correct this statement: "Greenhouse gases reflect heat back down to Earth."
    They absorb outgoing longwave infrared and re-emit it in all directions, some of it back toward the surface.
12. Correct this statement: "The sky is blue because it reflects the colour of the sea."
    Air molecules scatter short blue wavelengths far more than long red ones, so blue light reaches you from all over the sky.
13. Correct this statement: "Sunsets are red because the Sun cools down in the evening."
    At sunset the light's path through the air is much longer, so the blue is scattered out and mainly red and orange are transmitted.

Answer key (for parents and tutors)

1. Theory says the height h a ball falls is proportional to t^2, where t is the time. What should you plot to get a straight line?
   h against t^2.
2. At a fixed voltage, current I is proportional to 1/R. What should you plot to get a straight line?
   I against 1/R.
3. A pendulum's period is 1.40 s. Find T^2.
   $T^2 = 1.40^2 = 1.96\ s^2$.
4. A graph of I against 1/R has a line of best fit through the origin and (0.10 Ω^{-1}, 0.60 A). Find the gradient and write the equation.
   Gradient = 0.60 ÷ 0.10 = 6.0 A Ω (that is, 6.0 V), so I = 6.0 ÷ R.
5. Explain why timing 10 swings gives a more accurate period than timing one.
   The reaction-time error, about 0.2 s, is the same for any timing, so over 10 swings it is a ten times smaller share of the time, and dividing by 10 shrinks it in the period too.
6. Their graph of d against t curves upward, steeper and steeper. What should they plot to get a straight line?
   d against t^2.
7. Find t^2 for d = 0.40 m.
   $t^2 = 1.26^2 = 1.5876 \approx 1.59\ s^2$.
8. The straight-line graph has its line of best fit through the origin and (4.00 s^2, 1.00 m). Find the gradient and write the equation.
   Gradient = 1.00 m ÷ 4.00 s^2 = 0.25 m s^{-2}, so $d = 0.25t^2$.
9. Name a controlled variable that would change the results if it changed, and say why.
   The angle of the ramp: a steeper ramp gives the marble a bigger acceleration, so it would cover each distance faster.
10. Correct this statement: "The relationship is $T^2 = 4.02\ L$, so I wrote $y = 4.02x$."
    Write the equation in the real variables with units: $T^2 = 4.02\ L$, T in seconds and L in metres.
11. Correct this statement: "I worked out the gradient from my first and last data points."
    Use points that lie exactly on the line of best fit, far apart, because data points off the line give a different gradient.
12. Correct this statement: "I kept the mass of the bob the same, so that is my controlled variable."
    Mass has no effect on the period; for Merit, describe a control that would change the results, such as the starting angle.
13. Correct this statement: "My graph of T against L is a curve, so there is no relationship."
    A smooth curve is a relationship; plot a transformed variable, such as T^2 against L, to make it straight.

Answer key (for parents and tutors)

1. A 60 kg jumper falls freely for 15 m. Find their speed. Use $g = 9.8\ N\ kg^{-1}$.
   $v = \sqrt{(2gh)} = \sqrt{(2 \times 9.8 \times 15)} = \sqrt{294} = 17.1\ m\ s^{-1}$.

2. A cord with $k = 80\ N\ m^{-1}$ is stretched by 20 m. Find its tension.
   $F = kx = 80 \times 20 = 1600\ N$.

3. How much elastic potential energy does that cord store?
   $E_p = \frac{1}{2}kx^2 = \frac{1}{2} \times 80 \times 20^2 = 16\,000\ J$.

4. A 70 kg jumper moving at $14\ m\ s^{-1}$ is brought to rest in 2.0 s. Find the average net force.
   $\Delta p = m\Delta v = 70 \times 14 = 980\ kg\ m\ s^{-1}$, so $F = \Delta p \div \Delta t = 980 \div 2.0 = 490\ N$.

5. Explain, using impulse, why a stiffer cord would hurt the jumper more.
   The jumper's change in momentum is the same either way, but a stiffer cord stops them in a shorter time, so by $F\Delta t = \Delta p$ the force on them is bigger.

6. Correct this statement: "The jumper is fastest at the lowest point because they have fallen furthest."
   They are momentarily still at the lowest point; they are fastest where the tension equals the weight, before the bottom.

7. Correct this statement: "In $E_p = \frac{1}{2}kx^2$, I used $x = 40$ m, the whole fall."
   x is how far the cord has stretched, $40 - 12 = 28$ m, not the distance fallen.

8. Correct this statement: "The stretchy cord makes the change in momentum smaller."
   The change in momentum is the same; the cord makes the stopping time longer, so the force is smaller.

9. Correct this statement: "I copied a good paragraph from a website and referenced it."
   Copied or closely reworded text is not evidence of your understanding; explain it in your own words with your own calculations.

Answer key (for parents and tutors)

1. Light goes from air into glass (n = 1.50) at an angle of incidence of 35°. Find the angle of refraction.
   $\sin\theta_2 = 1.00 \times \sin 35° \div 1.50 = 0.5736 \div 1.50 = 0.3824$, so $\theta_2 = 22.5°$.
2. Use the table: what is the speed of light in diamond (n = 2.4)?
   $v = c \div n = 3.00 \times 10^8 \div 2.4 = 1.25 \times 10^8$ m s^{-1}.
3. Find the critical angle for light going from water (n = 1.33) into air.
   $\sin\theta c = 1.00 \div 1.33 = 0.7519$, so $\theta c = 48.8°$.
4. A converging lens has f = 20 cm, and an object is 60 cm away. Find the image distance and the magnification.
   1/di = 1/20 − 1/60 = 2/60, so di = 30 cm; m = 30 ÷ 60 = 0.5 (real, inverted, diminished).
5. A concave make-up mirror has f = 30 cm, and a face is 10 cm in front of it. Find the image distance and describe the image.
   1/di = 1/30 − 1/10 = −2/30, so di = −15 cm; m = 15 ÷ 10 = 1.5, so the image is virtual, upright and enlarged 1.5 times, 15 cm behind the mirror.
6. Describe the nature of the image Hemi sees.
   Virtual, upright and enlarged, because the label is inside the focal length (Achieved).
7. Calculate the image distance and the height of the image of a letter.
   1/di = 1/8.0 − 1/6.0 = 3/24 − 4/24 = −1/24, so di = −24 cm (virtual, on the label's side); m = 24 ÷ 6.0 = 4.0; hi = 4.0 × 2.0 = 8.0 mm (Merit for the full working with units).
8. Hemi lifts the lens until it is 12 cm from the label. Explain what happens to the image, with a calculation.
   Now 1/di = 1/8.0 − 1/12 = 1/24, so di = +24 cm and m = 24 ÷ 12 = 2.0: the label is beyond F, so the image becomes real and inverted, twice the size, 24 cm on Hemi's side of the lens. Light from the label really meets there, so the image could be caught on a screen, and with his eye well back from it Hemi sees the print upside down (Excellence links the calculation to the change from virtual and upright to real and inverted).
9. Explain, in terms of the speed of light, why the glass lens changes the direction of the light.
   Light slows down when it enters glass (n = 1.5, so $v = 2.0 \times 10^8$ m s^{-1}) and speeds up when it leaves; it meets the curved surfaces at an angle to the normal, so it refracts, bending towards the normal going in and away from the normal coming out, and the curved shape bends rays from each point towards a common point (Merit, with Snell's law named).
10. Correct this statement: "The ray hits the surface at 30°, so I put 30° into Snell's law."
    Angles are measured from the normal, so a ray 30° from the surface has an angle of incidence of 60°.
11. Correct this statement: "For the diverging lens I used f = +12 cm and got a real image."
    A diverging lens has f negative (−12 cm), and its image is always virtual, with di negative.
12. Correct this statement: "Light changes frequency when it goes into glass, which is why its wavelength changes."
    The frequency stays the same; the speed drops, so by $v = f\lambda$ the wavelength gets shorter.
13. Correct this statement: "Total internal reflection happens when light goes from air into glass at a big angle."
    TIR only happens going from a higher n to a lower n (glass to air), at more than the critical angle.

Answer key (for parents and tutors)

1. A wave has a frequency of 4.0 Hz and a wavelength of 0.60 m. Find its speed.
   $v = f\lambda = 4.0 \times 0.60 = 2.4\ m\ s^{-1}$.
2. Find the period of that wave.
   $T = 1/f = 1 \div 4.0 = 0.25\ s$.
3. Find the wavelength of a 2.4 GHz Wi-Fi signal.
   $\lambda = c \div f = 3.00 \times 10^8 \div 2.4 \times 10^9 = 0.125\ m$ (12.5 cm).
4. Water waves travel at 0.30 m s^{-1} in deep water and 0.20 m s^{-1} in shallow water. They meet the boundary at 30° to the normal. Find the angle in the shallow water.
   $\sin\theta_2 = \sin 30° \times 0.20 \div 0.30 = 0.5 \times 0.667 = 0.333$, so $\theta_2 = 19.5°$.
5. Two dippers in phase make waves with $\lambda = 2.0$ cm. A point is 9.0 cm from one dipper and 12.0 cm from the other. Is it on a nodal or an antinodal line?
   Path difference = 12.0 − 9.0 = 3.0 cm = 1.5λ, an odd number of half wavelengths, so it is on a nodal line.
6. Calculate the speed of the swell.
   $v = \lambda \div T = 100 \div 8.0 = 12.5\ m\ s^{-1}$ (Achieved).
7. Describe what happens to the waves as they pass through the entrance, and why.
   They diffract: the wavelength (100 m) is much bigger than the 12 m gap, so the waves spread out into the marina as curved wavefronts, reaching boats that are not in line with the entrance; the wavelength, frequency and speed do not change (Merit with the reason).
8. Inside, the water gets shallower. Explain what happens to the speed, frequency, wavelength and amplitude of the waves.
   In shallower water the waves slow down; the frequency stays the same because it is set by the source (each wave arriving must pass on), so by $v = f\lambda$ the wavelength gets shorter, and the amplitude grows as the energy is squeezed into slower, shorter waves (Excellence for all four, each with a reason).
9. A second entrance is opened further along the breakwater. Explain why boats at some moorings now rock a lot while boats at others hardly move.
   The two entrances act as two sources with the same frequency, in phase, so the waves interfere. At moorings where the distances to the two entrances differ by a whole number of wavelengths, crest meets crest (constructive, antinodal), so boats rock a lot; where they differ by an odd number of half wavelengths, crest meets trough (destructive, nodal), so boats hardly move (Excellence needs path difference).
10. Correct this statement: "The waves slow down in shallow water, so their frequency goes down."
    The source sets the frequency, so it stays the same; the speed falls, so by $v = f\lambda$ the wavelength gets shorter.
11. Correct this statement: "Diffraction through the gap makes the wavelength longer."
    Diffraction only spreads the wave; its speed, frequency and wavelength are unchanged because it stays in the same material.
12. Correct this statement: "A nodal line is where the crests from both sources meet."
    Crest meets crest on antinodal lines; nodal lines are where crest meets trough, a path difference of an odd number of half wavelengths.
13. Correct this statement: "12 waves in 4.0 s, 2.5 cm apart: $v = 3.0 \times 2.5 = 7.5\ m\ s^{-1}$."
    Change cm to m first: $v = 3.0 \times 0.025 = 0.075\ m\ s^{-1}$.

Answer key (for parents and tutors)

1. A cyclist speeds up uniformly from 2.0 m s^{-1} to 8.0 m s^{-1} in 4.0 s. What is her acceleration?
   $a = (v_f - v_i) \div t = (8.0 - 2.0) \div 4.0 = 1.5$ m s^{-2}.

2. How far does she travel in those 4.0 s?
   $d = \frac{1}{2}(v_i + v_f)t = \frac{1}{2} \times (2.0 + 8.0) \times 4.0 = 20$ m.

3. A ball is thrown straight up at 14.7 m s^{-1}. How high does it rise?
   Up is positive: $0 = 14.7^2 + 2 \times (-9.8) \times d$, so $d = 216.09 \div 19.6 = 11.0$ m.

4. A rock rolls horizontally off a cliff 44.1 m high at 5.00 m s^{-1}. How far from the foot of the cliff does it land?
   Vertically $44.1 = \frac{1}{2} \times 9.8 \times t^2$, so $t^2 = 9.00$ s^2 and $t = 3.00$ s; horizontally $d = 5.00 \times 3.00 = 15.0$ m.

5. A plane heads north at 70.0 m s^{-1} through air that is moving east at 24.0 m s^{-1}. What is its velocity over the ground?
   $v = \sqrt{(70.0^2 + 24.0^2)} = \sqrt{5476} = 74.0$ m s^{-1}; $\tan\theta = 24.0 \div 70.0$, $\theta = 18.9°$, so 74.0 m s^{-1} at 18.9° east of north.

6. Describe the force on the ball during its flight and what it does to the horizontal and vertical parts of its velocity.
   Only the weight acts, straight down. There is no horizontal force, so the horizontal velocity stays the same; the vertical velocity decreases on the way up, is zero at the top and increases on the way down, changing at 9.8 m s^{-2} (Achieved for one correct statement, Merit for linking the force to each component).

7. Calculate the horizontal and vertical components of the ball's initial velocity.
   $v_x = 30.0 \cos 25.0° = 27.19$ m s^{-1}, about 27.2 m s^{-1}; $v_y = 30.0 \sin 25.0° = 12.68$ m s^{-1}, about 12.7 m s^{-1} (Achieved for either).

8. By calculating, decide whether the ball clears the fence.
   Time to travel 60.0 m across: $t = 60.0 \div 27.19 = 2.2068$ s (keep the unrounded value in the calculator). Height then: $d = v_i t + \frac{1}{2}at^2 = 12.68 \times 2.2068 - 4.9 \times 2.2068^2 = 27.98 - 23.86 = 4.12$ m. Check it is still in the air: time of flight $= 2 \times 12.68 \div 9.8 = 2.59$ s, longer than 2.21 s. So the ball is 4.12 m up when it reaches the fence and clears the 3.00 m fence (Merit for the method with one slip, Excellence for the correct height and a concluding sentence).

9. Explain why the ball's speed is smallest at the top of its path, but not zero.
   The speed combines both components. At the top the vertical component has fallen to zero, so the speed is just the horizontal component, its smallest value; that component stays at 27.2 m s^{-1} because no horizontal force acts, so the speed is never zero (Excellence links both components to the forces).

10. Correct this statement: "At the top of its path the ball has stopped, so its acceleration is zero there."
    Only the vertical velocity is zero at the top; the weight still acts, so the acceleration is 9.8 m s^{-2} downwards all the way.

11. Correct this statement: "Time to reach the posts = 45.0 m ÷ 25.0 m s^{-1}, using the launch speed."
    Horizontal distance uses the horizontal component: $t = 45.0 \div (25.0 \cos\theta)$.

12. Correct this statement: "A ball thrown up at 14.7 m s^{-1}: $v_f^2 = 14.7^2 + 2 \times 9.8 \times d$, so d comes out negative."
    With up as positive, $a = -9.8$ m s^{-2}, so $0 = 14.7^2 - 2 \times 9.8 \times d$ and $d = 11.0$ m.

13. Correct this statement: "The heavier ball has more weight, so it falls faster and lands sooner."
    Without air resistance every object accelerates at 9.8 m s^{-2}, because the bigger weight has a bigger mass to move.

Answer key (for parents and tutors)

1. What net force gives a 1500 kg car an acceleration of 2.4 m s^{-2}?
   $F = ma = 1500 \times 2.4 = 3600$ N.

2. A box is pushed with 30.0 N east and 40.0 N north at the same time. What is the resultant force?
   $F = \sqrt{(30.0^2 + 40.0^2)} = \sqrt{2500} = 50.0$ N; $\tan\theta = 40.0 \div 30.0$, $\theta = 53.1°$, so 50.0 N at 53.1° north of east.

3. A 40.0 N force pushes at right angles on the end of a spanner 0.250 m long. What torque does it make?
   $\tau = Fd = 40.0 \times 0.250 = 10.0$ N m.

4. A 30.0 kg child sits 1.50 m from the pivot of a seesaw. How far from the pivot, on the other side, must a 45.0 kg child sit to balance it?
   Weights: $30.0 \times 9.8 = 294$ N and $45.0 \times 9.8 = 441$ N; anticlockwise torque $= 294 \times 1.50 = 441$ N m, so $441 \times d = 441$ and $d = 1.00$ m.

5. A 0.200 kg puck on a string moves in a horizontal circle of radius 0.800 m at 3.00 m s^{-1} on a frictionless table. What is the tension in the string?
   The tension is the centripetal force: $F = mv^2 \div r = 0.200 \times 3.00^2 \div 0.800 = 2.25$ N.

6. State the two conditions for the board to be in equilibrium.
   The net force is zero (up forces = down forces) and the net torque about any point is zero (clockwise torques = anticlockwise torques) (Achieved).

7. By taking torques about B, calculate the size and direction of the force the bolt at A exerts on the board.
   About B, the board's weight acts $1.50 - 1.00 = 0.50$ m to the right and the diver 2.00 m to the right, both clockwise: $300 \times 0.50 + 600 \times 2.00 = 150 + 1200 = 1350$ N m. The bolt is 1.00 m to the left of B, so $F_A \times 1.00 = 1350$ and $F_A = 1350$ N, and it must act downwards to make an anticlockwise torque on that side (Merit).

8. Calculate the force from support B.
   Up = down: $F_B = 1350 + 300 + 600 = 2250$ N upwards. Check about A: $F_B \times 1.00 = 300 \times 1.50 + 600 \times 3.00 = 450 + 1800 = 2250$ N m (Merit for one force, Excellence for both with directions).

9. The diver walks slowly from above B to the far end. Discuss how the forces at A and B change, and why.
   With the diver x metres right of B, $F_A = 150 + 600x$: the diver's distance from B grows, so the clockwise torque grows, and the bolt must pull down harder, from 150 N above B up to 1350 N at the end. F_B balances everything, $F_B = F_A + 900$, so it rises from 1050 N to 2250 N. Excellence links each change to the torque and force conditions.

10. Correct this statement: "Drawing friction, then a separate centripetal force arrow, on a car going round a corner."
    The centripetal force is the friction here, so draw one arrow, labelled friction, pointing to the centre.

11. Correct this statement: "Torque of the plank's weight = 200 N × 4.00 m, using the plank's length."
    A uniform plank's weight acts at its centre, so use the distance from the pivot to the centre: 200×2.00.

12. Correct this statement: "The table pushes up on the book and the book pushes down on the table, so those balance and the book stays still."
    Those are a third-law pair on different objects; the book stays still because its weight and the table's support force on it balance.

13. Correct this statement: "In a circle, the object flies outwards when the string breaks."
    With no force it moves in a straight line along the tangent, the direction it was moving at that instant.

Answer key (for parents and tutors)

1. What is the momentum of a 1200 kg car travelling at 15.0 m s^{-1}?
   $p = mv = 1200 \times 15.0 = 18\,000$ kg m s^{-1} in the car's direction.

2. A 0.0600 kg tennis ball hits a wall at 20.0 m s^{-1} and bounces straight back at 15.0 m s^{-1}. What is its change in momentum?
   Away from the wall is positive: $\Delta p = 0.0600 \times (15.0 - (-20.0)) = 0.0600 \times 35.0 = 2.10$ kg m s^{-1} away from the wall.

3. A 60.0 kg skater and a 40.0 kg skater stand still on ice and push each other apart. The 60.0 kg skater moves off at 2.00 m s^{-1}. What is the other skater's velocity?
   Total momentum is 0 before, so $60.0 \times 2.00 + 40.0 \times v = 0$, $v = -120 \div 40.0 = -3.00$ m s^{-1}: 3.00 m s^{-1} in the opposite direction.

4. A 60.0 kg student runs up stairs 3.50 m high in 4.00 s. What power does she develop lifting herself?
   $W = mgh = 60.0 \times 9.8 \times 3.50 = 2058$ J; $P = W \div t = 2058 \div 4.00 = 514.5$ W, about 515 W.

5. A spring with k = 50.0 N m^{-1} is stretched by 0.120 m. How much elastic potential energy does it store?
   $E_p = \frac{1}{2}kx^2 = \frac{1}{2} \times 50.0 \times 0.120^2 = 0.360$ J.

6. Calculate the momentum of the moving wagon, with its unit.
   $p = mv = 1500 \times 2.00 = 3000$ kg m s^{-1} along the track (Achieved).

7. Calculate the speed of the coupled wagons.
   Momentum is conserved: $3000 = (1500 + 1000) \times v$, $v = 3000 \div 2500 = 1.20$ m s^{-1} in the same direction (Merit).

8. Show that kinetic energy is not conserved in the coupling, and say where it goes.
   Ek before = $\frac{1}{2} \times 1500 \times 2.00^2 = 3000$ J; Ek after = $\frac{1}{2} \times 2500 \times 1.20^2 = 1800$ J; 1200 J has become heat and sound in the coupling, so the collision is inelastic (Merit).

9. The coupled wagons then run into a spring buffer with $k = 2.40 \times 10^5$ N m^{-1}. Calculate how far the buffer compresses as it stops them.
   All 1800 J is stored in the spring: $\frac{1}{2}kx^2 = 1800$, $x^2 = 2 \times 1800 \div 240\,000 = 0.0150$ m^2, $x = 0.122$ m (Excellence).

10. Discuss whether a stiffer buffer (bigger k) would be better for the wagons and their load.
    The wagons' change in momentum is the same, $2500 \times 1.20 = 3000$ kg m s^{-1}, whatever the buffer. A stiffer spring stores the same 1800 J in a smaller compression ($x = \sqrt{(2Ek \div k)}$), so it stops them over a shorter distance and in a shorter time, and by $F = \Delta p \div \Delta t$ the force on the wagons and load is bigger. A softer buffer is gentler, as long as it is long enough to compress the extra distance (Excellence links Δp, time, force and the energy stored).

11. Correct this statement: "A ball hits the wall at 20 m s^{-1} and bounces back at 15 m s^{-1}, so $\Delta v = 20 - 15 = 5$ m s^{-1}."
    Directions matter: $\Delta v = -15 - 20 = -35$ m s^{-1}, a change of 35 m s^{-1} away from the wall.

12. Correct this statement: "Momentum was conserved in the collision, so the kinetic energy must have been conserved too."
    Momentum is conserved in every collision with no outside force; kinetic energy is conserved only in elastic ones.

13. Correct this statement: "Doubling the compression of a spring doubles the energy it stores."
    $E_p = \frac{1}{2}kx^2$, so doubling x makes the energy four times as big.

14. Correct this statement: "Work to climb stairs = 60 kg × 3.5 m = 210 J."
    The force is the weight, mg: $W = 60 \times 9.8 \times 3.5 = 2058$ J.

Answer key (for parents and tutors)

1. How many protons and how many neutrons are in $^{239}_{94}\text{Pu}$?
   94 protons and 239 − 94 = 145 neutrons.

2. Complete the alpha decay: $^{241}_{95}\text{Am} \rightarrow \, ? + \, ^{4}_{2}\text{He}$.
   A = 241 − 4 = 237, Z = 95 − 2 = 93: $^{237}_{93}\text{Np}$ (neptunium-237).

3. Iodine-131 (Z = 53) is a beta emitter. Write the product.
   A stays 131, Z = 53 + 1 = 54: $^{131}_{54}\text{Xe}$ (xenon-131), with $^{0}_{-1}\text{e}$.

4. What fraction of a radioactive sample is left after 4 half-lives?
   $(½)^4 = 1/16$.

5. Which radiation is stopped by a sheet of paper, and why does it travel so short a distance?
   Alpha: its +2 charge and large mass make it ionise strongly, and every ionisation uses up some of its energy, so it is stopped after a very short distance.

6. A uranium-235 nucleus absorbs a neutron and splits into barium-141 (Z = 56), krypton-92 and some neutrons. How many neutrons are released?
   Before: A = 235 + 1 = 236 and Z = 92. After: Z of krypton = 92 − 56 = 36, and A left over = 236 − 141 − 92 = 3, so 3 neutrons are released: $^{1}_{0}\text{n} + \, ^{235}_{92}\text{U} \rightarrow \, ^{141}_{56}\text{Ba} + \, ^{92}_{36}\text{Kr} + 3\,^{1}_{0}\text{n}$.

7. Explain where the energy released in this fission comes from, and how a reactor keeps the rate of fission steady.
   The total mass of the barium, krypton and three neutrons is slightly less than the mass of the uranium and the neutron it absorbed. That missing mass Δm is released as energy $E = \Delta mc^2$, mostly as kinetic energy of the fragments, which heats the fuel; because c^2 is so large, a tiny Δm gives a huge energy. Each fission releases 3 neutrons, so the rate could grow very fast; control rods absorb the spare neutrons so that on average one from each fission causes the next, and a moderator slows neutrons so they can be captured. Connecting the mass loss to the energy, and the neutron count to the control of the chain reaction, is what makes this Excellence.

8. Correct this statement: "In beta decay, one of the atom's orbiting electrons is thrown out."
   The beta electron comes from the nucleus, where a neutron turns into a proton and an electron, so Z goes up by 1.

9. Correct this statement: "After two half-lives, all of the sample has decayed."
   Each half-life halves what is left, so after two half-lives a quarter is still there.

10. Correct this statement: "Gamma rays are the most ionising because they go through everything."
    Gamma is the least ionising; it penetrates furthest precisely because it rarely interacts with atoms.

11. Correct this statement: "In fission the mass number is lost and turned into energy."
    Mass number and atomic number are both conserved; the energy comes from the products having slightly less mass, by $E = mc^2$.

Answer key (for parents and tutors)

1. Plates 4.0 cm apart have 200 V across them. What is the field strength?
   $E = V \div d = 200 \div 0.040 = 5.0 \times 10^{3}$ V m^{-1} (5000 V m^{-1}).

2. What force does a proton feel in that field?
   $F = Eq = 5.0 \times 10^{3} \times 1.6 \times 10^{-19} = 8.0 \times 10^{-16}$ N, in the direction of the field.

3. A dust grain carries a charge of 4.8×10^{-18} C. How many extra electrons does it have?
   $n = q \div e = 4.8 \times 10^{-18} \div 1.6 \times 10^{-19} = 30$ electrons.

4. An electron crosses from the negative to the positive plate of a pair 3.0 mm apart with 1500 V across them. How much energy does it gain?
   $E = 1500 \div 0.0030 = 5.0 \times 10^{5}$ V m^{-1}; $E_p = Eqd = 5.0 \times 10^{5} \times 1.6 \times 10^{-19} \times 0.0030 = 2.4 \times 10^{-16}$ J.

5. A field of 2.0×10^{4} V m^{-1} pushes a charged drop with a force of 6.4×10^{-14} N. What is the drop's charge?
   $q = F \div E = 6.4 \times 10^{-14} \div 2.0 \times 10^{4} = 3.2 \times 10^{-18}$ C.

6. Describe the electric field between the plates.
   Uniform: straight, parallel, evenly spaced lines at right angles to the plates, pointing from the positive plate to the negative plate (Achieved).

7. Calculate the electric field strength between the plates.
   $E = V \div d = 3000 \div 0.040 = 7.5 \times 10^{4}$ V m^{-1} (Achieved).

8. Calculate the size of the electric force on the smoke particle, and state its direction.
   $q = ne = 120 \times 1.6 \times 10^{-19} = 1.92 \times 10^{-17}$ C; $F = Eq = 7.5 \times 10^{4} \times 1.92 \times 10^{-17} = 1.4 \times 10^{-12}$ N, towards the positive plate because the particle is negative (Merit: two linked steps and a direction).

9. The particle starts next to the negative plate. Calculate the energy the field gives it by the time it reaches the positive plate.
   $E_p = Eqd = 7.5 \times 10^{4} \times 1.92 \times 10^{-17} \times 0.040 = 5.8 \times 10^{-14}$ J; check: $qV = 1.92 \times 10^{-17} \times 3000 = 5.76 \times 10^{-14}$ J (Merit).

10. The supply is turned down to 1500 V. Discuss how this changes the force on the particle and the energy it gains crossing the gap.
    Achieved: a smaller voltage gives a weaker field and a smaller force. Merit: d is fixed, so halving V halves E ($E = V/d$), and with the same charge $F = Eq$ halves too. Excellence: E and F both halve while the particle still crosses the same 0.040 m, so $E_p = Eqd$ halves to 2.9×10^{-14} J (the same as qV with half the voltage); the particle arrives later and with half the energy.

11. Correct this statement: "$E = 5.0 \times 10^{4}$ V m^{-1}, so the electron gains 5.0×10^{4} J of energy."
    That is the field strength, not an energy; the energy is $E_p = Eqd$, which here is only 4.0×10^{-17} J.

12. Correct this statement: "Field lines go from the negative plate to the positive plate, the way the electrons move."
    Field lines show the push on a positive charge, so they always run from the positive plate to the negative plate.

13. Correct this statement: "With the plates 5.0 mm apart, $E = 250 \div 5.0 = 50$ V m^{-1}."
    Convert to metres first: $E = 250 \div 0.0050 = 5.0 \times 10^{4}$ V m^{-1}, a thousand times bigger.

14. Correct this statement: "A drop with 4 extra electrons has a charge of 4 C."
    Each electron carries 1.6×10^{-19} C, so $q = ne = 4 \times 1.6 \times 10^{-19} = 6.4 \times 10^{-19}$ C.

Answer key (for parents and tutors)

1. Find the total resistance of a 4.0 Ω and a 12 Ω resistor in parallel.
   $1/R_t = 1/4.0 + 1/12 = 4/12$, so $R_t = 12 \div 4 = 3.0\ \Omega$.

2. A 9.0 V battery drives 0.30 A round a circuit. How much charge flows in 2.0 minutes?
   $q = It = 0.30 \times 120 = 36$ C (2.0 minutes = 120 s).

3. A lamp has 6.0 V across it and a resistance of 4.0 Ω. What is its power?
   $P = V^2 \div R = 6.0^2 \div 4.0 = 9.0$ W.

4. A 5.0 Ω resistor in series with two 10 Ω resistors in parallel is connected to 20 V. What is the total current?
   The pair is $10 \div 2 = 5.0\ \Omega$; $R_t = 5.0 + 5.0 = 10\ \Omega$; $I = V \div R = 20 \div 10 = 2.0$ A.

5. In question 4, what is the current in each 10 Ω resistor?
   The 5.0 Ω resistor takes $2.0 \times 5.0 = 10$ V, leaving $20 - 10 = 10$ V across the pair; $I = 10 \div 10 = 1.0$ A in each, half of 2.0 A.

6. Show that the two lamps together have a resistance of 3.0 Ω.
   $1/R_t = 1/12 + 1/4.0 = 1/12 + 3/12 = 4/12$, so $R_t = 12 \div 4 = 3.0\ \Omega$ (Achieved).

7. Calculate the current in the ceiling lamp.
   $R_t = 1.0 + 3.0 = 4.0\ \Omega$; $I_t = 12 \div 4.0 = 3.0$ A; the rheostat takes $3.0 \times 1.0 = 3.0$ V, leaving $12 - 3.0 = 9.0$ V across the lamps; $I = 9.0 \div 4.0 = 2.25$ A, about 2.3 A (Merit: a chain of steps).

8. Explain why the reading lamp carries a third of the ceiling lamp's current.
   The lamps are in parallel, so both have the same 9.0 V; the reading lamp has three times the resistance, so by $I = V/R$ it has a third of the current: 0.75 A against 2.25 A (Merit for the reason with the formula).

9. Calculate the energy the reading lamp transfers in 2.0 hours.
   $P = VI = 9.0 \times 0.75 = 6.75$ W; $t = 2.0 \times 3600 = 7200$ s; $E = Pt = 6.75 \times 7200 = 48\,600$ J, about 4.9×10^4 J (Merit).

10. The ceiling lamp burns out. Discuss what happens to the brightness of the reading lamp.
    Achieved: there is one fewer path, so the total resistance goes up and the current falls. Merit: with the supply fixed at 12 V, R_t rises to $1.0 + 12 = 13\ \Omega$ and I_t falls to 0.92 A, so the rheostat's voltage falls ($V = IR$) to 0.92 V. Excellence: that leaves 11.1 V across the reading lamp, up from 9.0 V, and its current rises from 0.75 A to 0.92 A, so its power $P = VI$ rises from 6.75 W to about 10.2 W and it glows brighter.

11. Correct this statement: "Current gets used up as it goes through each lamp, so less comes back to the battery."
    The current returning to the battery equals the current leaving it; the lamps transfer energy, not charge.

12. Correct this statement: "$1/R_t = 1/6.0 + 1/12 = 0.25$, so $R_t = 0.25\ \Omega$."
    0.25 is $1/R_t$; turn it over to get $R_t = 4.0\ \Omega$, which must be smaller than the smallest branch.

13. Correct this statement: "When one branch breaks, the other lamp keeps the same voltage, so nothing else changes."
    The total current changes, so the voltage across the series resistor changes, and so does the voltage across the parallel part.

14. Correct this statement: "The current splits in parallel, so each branch gets half."
    Both branches have the same voltage, so the current splits by $I = V/R$: a branch with twice the resistance takes half the current.

Answer key (for parents and tutors)

1. What force acts on 0.50 m of wire carrying 4.0 A at right angles to a 0.20 T field?
   $F = BIL = 0.20 \times 4.0 \times 0.50 = 0.40$ N.
2. The same wire is turned to lie along the field lines. What is the force now?
   0 N, because current parallel to the field feels no force.
3. A proton moves at 3.0×10^5 m s^{-1} at right angles to a 0.80 T field. What force acts on it?
   $F = Bqv = 0.80 \times 1.6 \times 10^{-19} \times 3.0 \times 10^5 = 3.8 \times 10^{-14}$ N.
4. A 2.0 m rod moves at 5.0 m s^{-1} across a 0.10 T field. What voltage is induced between its ends?
   $V = BvL = 0.10 \times 5.0 \times 2.0 = 1.0$ V.
5. At what speed would the same rod need to move to induce 0.25 V?
   $v = V \div (BL) = 0.25 \div (0.10 \times 2.0) = 1.25$ m s^{-1}.
6. State the direction of the force on side P, and the rule you used.
   Upwards, towards the top of the page: fingers along the field to the right, thumb out of the page, and the palm faces up (Achieved).
7. Calculate the size of the force on side P.
   $F = NBIL = 25 \times 0.30 \times 1.2 \times 0.040 = 0.36$ N (Merit: L in metres and all 25 turns counted).
8. In the position shown, the short ends of the coil run along the field. Explain why they feel no force.
   Their current runs parallel to the field lines, and a force needs current that crosses the field, so F = BIL is zero (Merit for the reason).
9. The battery is removed and the coil is spun so each long side moves at 0.50 m s^{-1}. Calculate the biggest voltage the whole coil can produce.
   One side of one turn: $V = BvL = 0.30 \times 0.50 \times 0.040 = 6.0 \times 10^{-3}$ V; both long sides of all 25 turns add: $6.0 \times 10^{-3} \times 2 \times 25 = 0.30$ V (Excellence for counting both sides and every turn).
10. Explain where the coil must be in its turn to give that biggest voltage, and where it gives none.
    Achieved: biggest when the coil lies flat, as shown. Merit: then P and Q move up and down, at right angles to the field, so they cut field lines fastest. Excellence: when the coil stands upright, across the field, P and Q move sideways along the field lines, cut none, and V = BvL gives zero because only the part of the velocity across the field counts; between these positions the voltage rises and falls.
11. Correct this statement: "In V = BvL the two V's are the same thing, so a 12 V generator means v = 12."
    Capital V is the voltage in volts and small v is the speed in m s^{-1}; rearrange to $v = V \div (BL)$.
12. Correct this statement: "For an electron moving right, point your thumb right and read the force off your palm."
    The slap rule is for positive charge or conventional current; for an electron, reverse the force you find.
13. Correct this statement: "The side of the coil that lies along the field feels the same force as the other sides."
    Current parallel to the field feels no force; only current that crosses the field lines is pushed, most strongly at right angles.
14. Correct this statement: "The positive pole of the magnet is on the left."
    Magnets have north and south poles; positive and negative describe electric charge, and field lines run from north to south.