PHYSICAL SCIENCES
Grade 11
TERM 1
RESOURCE PACK

Contents

WORKSHEETS

Topic 1 – Vectors in Two Dimensions

WORKSHEET

1. A forward horizontal force of 50 N is applied to a crate. A second horizontal force of 180 N is applied to the crate in the opposite direction. Determine the magnitude and direction of the resultant force acting on the crate. (2)

2. The athlete at point A runs 150 m east, then 70 m west and then 100 m east. Determine the resultant displacement of the athlete relative to point A. (2)

3. Three forces act on an object in the vertical plane. Two forces of 500 N and 300 N act vertically upwards and the third force of 600 N acts vertically downwards. Determine the resultant force acting on the object. (2)

4. An aircraft flies 8 km north from an airport and then 12 km east.

   4.1 Use the tail-to-head method to draw a neat labelled displacement vector diagram. Draw in the resultant displacement vector. (3)

   4.2 Determine the magnitude and direction of the resultant displacement of the aircraft relative to the airport. (5)

5. Draw the following force vectors (not necessarily to scale) in the Cartesian plane acting from the origin:

   5.1 F_1 = 20 N acts to the right in the horizontal plane.

   5.2 F_2 = 50 N acts upwards in the vertical plane.

   5.3 F_3 = 80 N acts to the left in the horizontal plane.

   5.4 F_4 = 90 N acts downwards in the vertical plane. (4)

6. Consider the four forces in question 5.

   6.1 Determine the resultant horizontal force and the resultant vertical force. (4)

   6.2 Use the tail-to-tail method to calculate the magnitude and direction of the resultant of the two forces in Question 6.1. Draw a neat labelled vector diagram to support your calculation. (7)

   6.3 Now use the tail-to-head method to draw a neat labelled vector diagram. (3)

7. A drone at point P is flown 2 km north, then 5 km east and then 8 km south. Find the magnitude and direction of the resultant displacement of the drone from point P. Draw a neat labelled displacement vector diagram to support your calculation. (8)

8. Resolve each of the following vectors into their perpendicular components. In each case draw a neat, labelled vector diagram (not necessarily to scale).

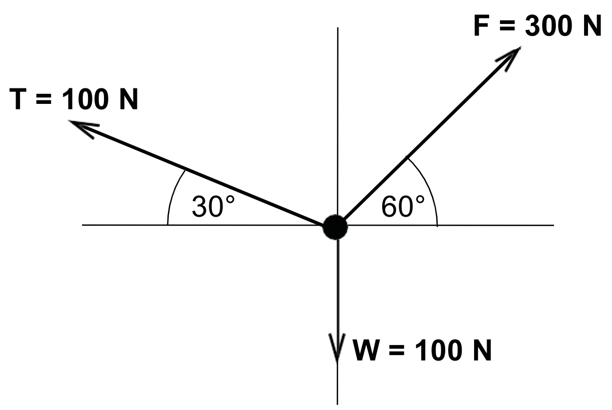
8.1 A 100 N force which acts at 30° above the horizontal. (6)

8.2 A displacement of 280 m on a bearing of 070°. (6)

8.3 A 400 N force which acts at 50° to the vertical. (6)

8.4 A 500 N force which acts at 40° below the horizontal. (6)

9. Three forces T, F and W act on an object as shown in the diagram below.



9.1 Determine the perpendicular components of force F. (6)

9.2 Determine the perpendicular components of force T. (6)

9.3 Determine the magnitude and direction of the resultant force acting on the object. Draw a neat labelled vector diagram to support your calculation. (8)

CONSOLIDATION EXERCISE

TOTAL: 40 MARKS

1. Define a resultant vector. (2)

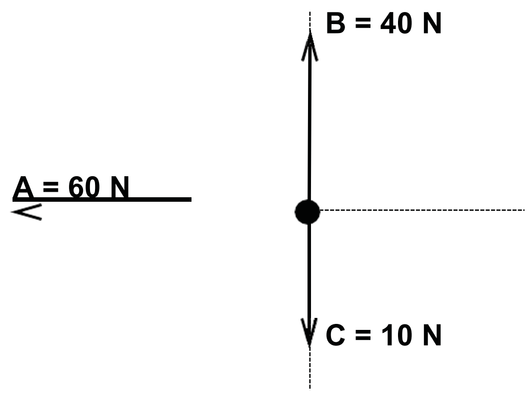
2. A block is pulled by two horizontal forces of 15 N and 25 N to the left, and by two horizontal forces of 10 N and 30 N to the right.

2.1 Draw these four force vectors in the Cartesian plane (acting at the origin). (2)

2.2 Find the magnitude and direction of the resultant force. (2)

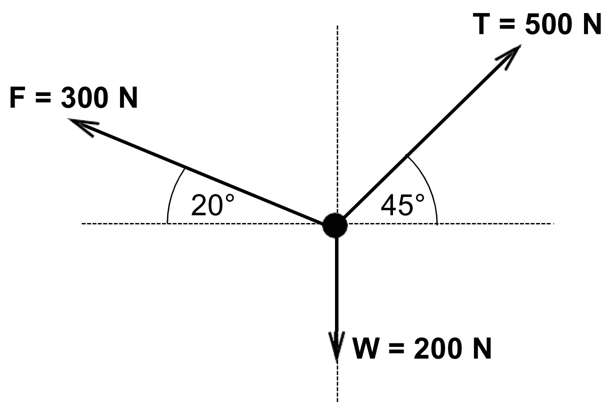
3. A learner hikes 8 km north and 12 km west. Using the tail-to-head method, determine the magnitude and direction of the learner's resultant displacement. (5)

4. Three forces, A, B and C act on an object as shown in the diagram. Determine the magnitude and direction of the resultant force acting on the object.



(6)

5. Consider the three forces acting on an object as shown in the diagram below.



5.1 Calculate the horizontal and vertical components of force T. (4)

5.2 Calculate the horizontal and vertical components of force F. (4)

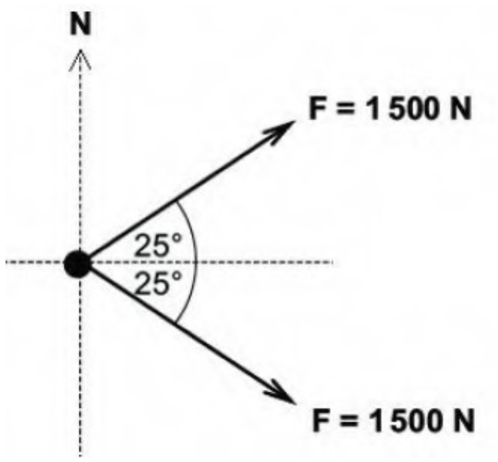
5.3 Determine the magnitude and direction of the resultant horizontal force. (2)

WORKSHEETS

5.4 Determine the magnitude and direction of the resultant vertical force. (2)

5.5 Using the tail-to-tail method, draw a neat labelled force diagram and determine the magnitude and direction of the resultant force acting on the object. (5)

6. The diagram below shows a top view of a tug boat that is pulled by two forces. North is shown.
Use the component method to find the magnitude and direction of the resultant force acting on the tugboat. State the direction as a bearing, clockwise from north.



(6)
[40]

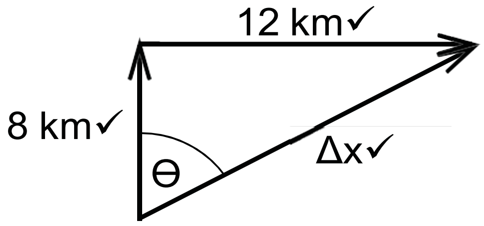
MARKING GUIDELINES

1. Choose forward as the positive (+) direction.
Then: $R = +50 + (-180) = -130 = 130\text{ N}$ ✓ backwards ✓ (2)

2. Choose east as the positive (+) direction.
Then: $\Delta x = +150 + (-70) + 100 = 180\text{ m}$ ✓ east ✓ (2)

3. Choose upwards as the positive (+) direction.
Then: $R = +500 + 300 + (-600) = +200 = 200\text{ N}$ ✓ upwards ✓ (2)

4. **4.1**



(3)

4.2 $x^2 = 8^2 ✓ + 12^2 ✓$

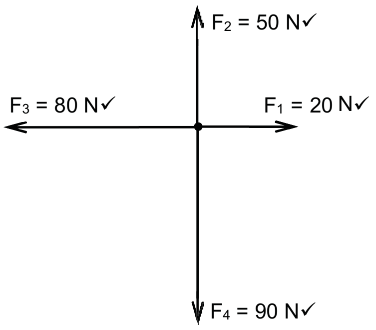
$x = \sqrt{208} = 14{,}42\text{ km}$ ✓

$\tan\theta = \frac{12}{8}$

$\theta = \tan^{-1}\left(\frac{12}{8}\right)$ ✓ $= 56{,}31^\circ$

$x = 14{,}42\text{ km}$ on a bearing of $056{,}31^\circ$ ✓ (5)

5.

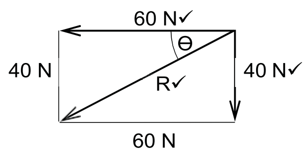


(4)

6. **6.1** $R_x = +20 + (-80) = -60 = 60\text{ N}$ left ✓

$R_y = +50 + (-90) = -40 = 40\text{ N}$ downwards ✓ (4)

6.2



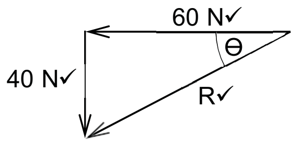
$R^2 = 60^2 + 40^2$ ✓

$R = \sqrt{5\,200} = 72{,}11\ \text{N}$ ✓

$\tan\theta = \frac{40}{60} \therefore \theta = \tan^{-1}\left(\frac{40}{60}\right) = 33{,}69°$ ✓

$R = 72{,}11\ \text{N}$ at $33{,}69°$ below the horizontal ✓ (7)

6.3



(3)

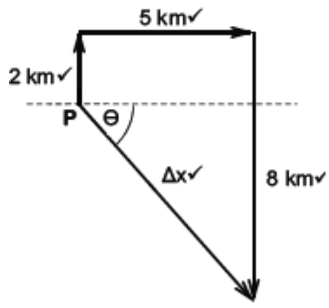
7. $x^2 = 5^2 + 6^2$ ✓

$\Delta x = \sqrt{61} = 7{,}81\ \text{km}$ ✓

$\tan\theta = \frac{6}{5}$

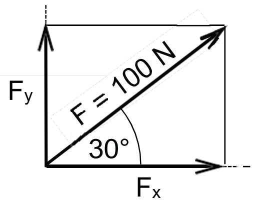
$\theta = \tan^{-1}\left(\frac{6}{5}\right) = 50{,}19°$ ✓

$\Delta x = 7{,}81\ \text{km}$ on a bearing of $140{,}19°$ ✓



(8)

8. 8.1

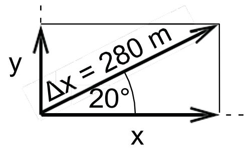


$F_x = F\cos 30° = (100)\cos 30° = 86{,}60\ \text{N}$ ✓ right ✓

$F_y = F\sin 30° = (100)\sin 30° = 50\ \text{N}$ ✓ upwards ✓

✓✓ vector diagram (6)

8.2

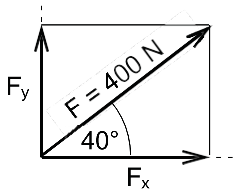


$x = \Delta x\cos 20° = (280)\cos 20° = 263{,}11\ \text{m}$ ✓ east ✓

$y = \Delta x\sin 20° = (280)\sin 20° = 95{,}77\ \text{m}$ ✓ north ✓

✓✓ vector diagram (6)

8.3

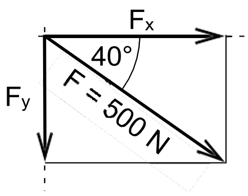


$F_x = F\cos 40° = (400)\cos 40° = 306{,}42\ \text{N}$ ✓ right ✓

$F_y = F\sin 40° = (400)\sin 40° = 257{,}11\ \text{N}$ ✓ upwards ✓

✓✓ vector diagram (6)

8.4



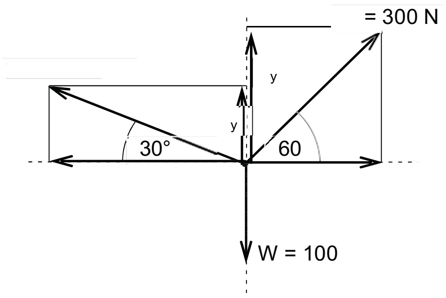
$F_x = F.\cos 40° = (500).\cos 40° = 383{,}02\ \text{N}$ ✓ right ✓

$F_y = F.\sin 40° = (500).\sin 40° = 321{,}39\ \text{N}$ ✓ downwards ✓

✓✓ vector diagram (6)

9. **9.1** $F_x = (300)\cos 60° = 150\ \text{N}$ ✓right✓

$F_y = (300)\sin 60° = 259,81\ \text{N}$ ✓up✓ (4)



9.2 $T_x = (100)\cos 30° = 86,60\text{N}$ ✓left ✓

$T_y = (100)\sin 30° = 50\text{N}$ ✓up✓ (4)

9.3 $R_x = +150 + (-86,60) = 63,4\ \text{N}$ ✓right

$R_y = +259,81 + 50 + (-100) = 209,81\ \text{N}$ ✓up

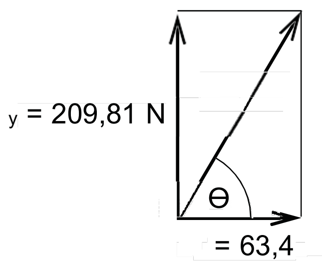
$R^2 = 63,4^2 + 209,81^2$ ✓

$R = \sqrt{48\,039,80} = 219,18\ \text{N}$ ✓

$\tan\theta = \dfrac{209,81}{63,4}$

$\theta = \tan^{-1}\left(\dfrac{209,81}{63,4}\right) = 73,19°$ ✓

$R = 219,18\ \text{N}$ at $73,19°$ above the horizontal ✓



✓✓ vector diagram

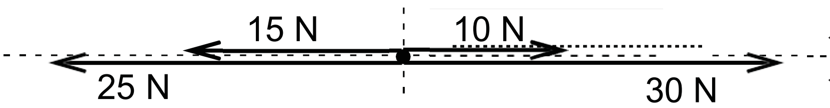
(8)

CONSOLIDATION EXERCISE

TOTAL: 40 MARKS

1. A single vector which has the same effect as two or more vectors acting together OR The vector sum of two or more vectors. ✓✓ (2)

2. 2.1



✓forces to the right
✓forces to the left (2)

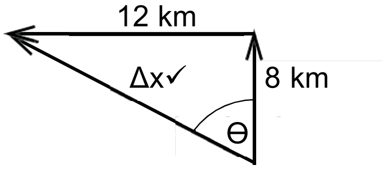
2.2 Right is positive (+): $R = +10 + 30 + (-15) + (-25)$ ✓ $= 0$ N ✓ (2)

3. $\Delta x^2 = 8^2 + 12^2$ ✓

$\Delta x = \sqrt{208} = 14,42$ km ✓

$\tan\theta = \frac{12}{8}$ $\theta = \tan^{-1}\left(\frac{12}{8}\right) = 56,3°$ ✓

$\Delta x = 14,42$ km on a bearing of $303,7$ ✓ (5)



4. The resultant vertical force is: $R_y = +40 + (-10) = 30$ N upwards ✓

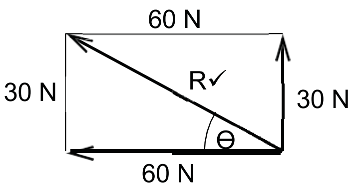
The resultant horizontal force is: $R_x = 60$ N left ✓

$R^2 = 60^2 + 30^2$ ✓

$R = \sqrt{4\,500} = 67,08$ N ✓

$\tan\theta = \frac{30}{60}$ $\theta = \tan^{-1}\left(\frac{30}{60}\right) = 26,6°$ ✓

$R = 67,08$ N at $26,6°$ above the horizontal ✓ (6)

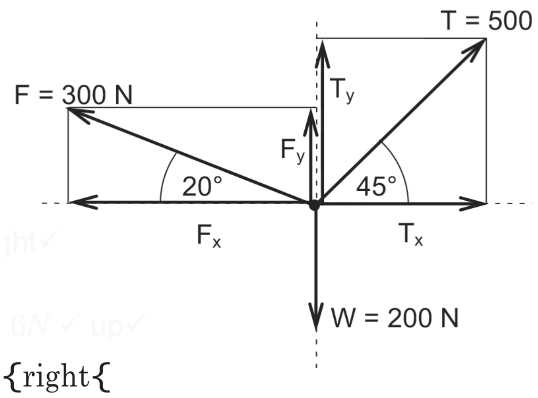


5. 5.1 $T_x = (500)\cos 45° = 353,55$ N ✓ right ✓

$T_y = (500)\sin 45° = 353,55$ N ✓ up ✓ (4)

5.2 $F_x = (300)\cos 20° = 281,91$ N ✓ left ✓

$F_y = (300)\sin 20° = 102,61$ N ✓ up ✓ (4)



5.3 $R_x = +353,55 + (-281,91) = 71,64$ N ✓ right ✓ (2)

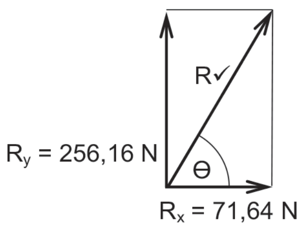
5.4 $R_y = +353,55 + 102,61 + (-200) = 256,16$ N ✓ up ✓ (2)

5.5 $R^2 = 71,64^2 + 256,16^2$ ✓

$R = \sqrt{70\ 750,33} = 265,99$ N ✓

$\tan \theta = \frac{256,16}{71,64}$ $\theta = \tan^{-1}\left(\frac{256,16}{71,64}\right) = 74,4°$ ✓

$R = 265,99$ N (at $74,4°$ above the horizontal)



(5)

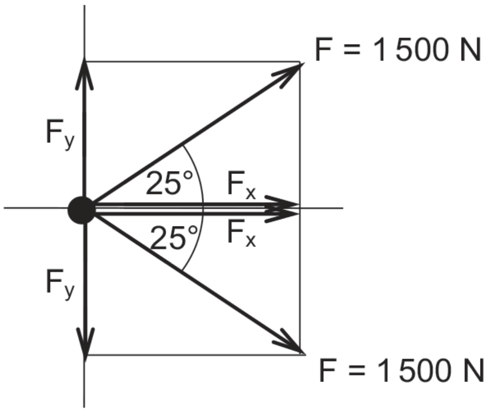
6. $F_x = (1\ 500)\cos 25° = 1\ 359,46$ N right

$F_y = (1\ 500)\sin 25° = 633,93$ N upwards

$R_x = +1\ 359,46 + 1\ 359,46 = 2\ 718,92$

$R_y = +633,93 + (-633,93) = 0$

$R = 2\ 718,92$ N at bearing of $090°$



(6)

[40]

WORKSHEETS

Topic 2 – Newton's Laws and Application of Newton's Laws

WORKSHEET

1. A 3 kg box is resting on a horizontal surface. The coefficient of static friction between the surface and the box is 0,34.

1.1 Calculate the weight of the box. (2)

1.2 Calculate the maximum force of static friction between the box and the surface. (3)

2. Rugby players are trying to push a 500 kg scrum machine along horizontal ground. The coefficient of static friction between the scrum machine and the ground is 0,65.

2.1 Calculate the normal force acting on the scrum machine. (2)

2.2 If the players exert a horizontal force of 3 000 N on the scrum machine, will the scrum machine move? Give a reason for your answer. (3)

3. The brakes on a 20 kg cart are locked so that the rubber wheels cannot turn. A child pushes horizontally to the right on the cart until it just begins to slide. The maximum horizontal force he applies is 150 N. After that the child is able to keep the cart sliding with a horizontal force of 80 N.

3.1 Define a normal force. (2)

3.2 Explain the difference between static and kinetic friction. (2)

3.3 Calculate the coefficients of static and kinetic friction between the rubber wheels and the ground. (5)

4. A 5 kg box is resting on a plane inclined at 30° to the horizontal. The coefficient of static friction between the box and the plane is 0,63.

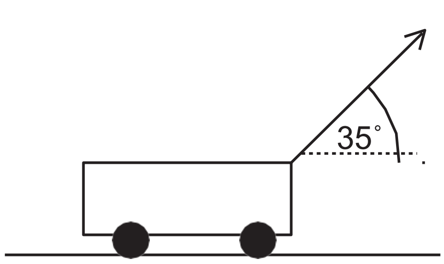
4.1 Define a frictional force. (2)

4.2 Draw a neat, fully labelled force diagram showing all the forces acting on the box. Now draw and label the horizontal (w_x) and vertical (w_y) components of the weight (w) of the box. Label the 30° angle. (6)

4.3 Calculate the maximum static frictional force between the box and the inclined plane. (4)

4.4 Use a calculation to explain why the box does not slide down the slope. (3)

5. A 50 N force is applied to a trolley at an angle of 35° to the horizontal.



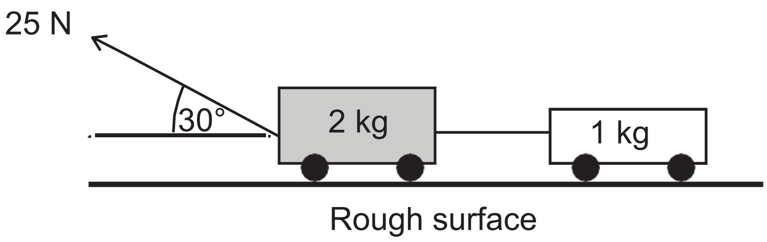
Calculate the normal force acting on the trolley if the mass of the trolley is 6 kg. (4)

6. **6.1** Draw a fully labelled force diagram for the scrum machine in Question 2 (above) while it is sliding along the ground. (5)

6.2 Draw a fully labelled free-body diagram for the cart in Question 3 (above) before it starts to move. (5)

6.3 Draw a fully labelled free-body diagram for the box in Question 4 (above). (3)

7. Two trolleys of mass 2 kg and 1 kg are joined together by a light string. A force 25 N is applied to the 2 kg trolley at 30° to the horizontal. The system moves to the left along a rough horizontal surface as shown in the diagram below.



7.1 Draw a fully labelled force diagram for the 1 kg trolley. (4)

7.2 Draw a fully labelled free-body diagram for the 2 kg trolley. (5)

8. State Newton's first law of motion. (2)

9. Explain what is meant by the term "inertia". (2)

10. List three different types of motion and state whether or not a net force is acting during each type of motion. (6)

11. What property of an object determines how much inertia it has? (1)

12. A teacher is walking along the corridor carrying a full cup of coffee, when a student runs in front of her. She stops suddenly and spills her coffee. Use Newton's first law to explain why the coffee spills forwards when the teacher stops suddenly. (3)

13. Many car passengers have suffered neck injuries when struck by cars from behind. Use Newton's first law to explain how headrests help to guard against this type of injury. (4)

14. A 8 kg box is placed on a table. A horizontal force of magnitude 68 N is applied to the right on the box. A frictional force of magnitude 27 N is present between the surface and the box.

14.1 Draw a force diagram indicating all of the forces acting on the box. (4)

14.2 Calculate the acceleration of the box. (4)

15. Two crates, 4 kg and 6 kg respectively, are connected with a thin inextensible rope. A force of 89 N is applied to the right. The frictional forces on the 4 kg and 6 kg are 19,6 N and 29,4 N respectively.

15.1 Calculate the acceleration of the crates. (6)

15.2 Calculate the magnitude of the tension T in the rope that connects the boxes. (2)

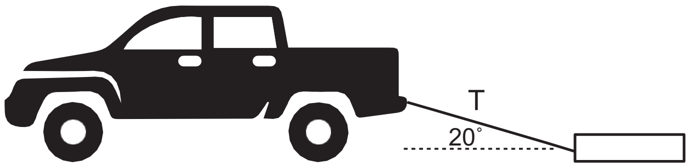
16. A man is pulling a 30 kg box to the left along a rough horizontal plane with an inextensible rope that makes an angle of 45° above the horizontal. He applies a force of 250 N and the coefficient of kinetic friction between the box and the surface is 0,6.

16.1 Draw a fully labelled force diagram for the box. (4)

16.2 Calculate the kinetic frictional force acting on the box. (5)

16.3 Calculate the acceleration of the box. (5)

17. A 2 000 kg truck pulls a 200 kg log with a constant acceleration. The engine of the truck produces a forward force of 10 000 N. The tow rope makes an angle of 20° with the horizontal. Ignore the effect of friction, and the mass of the tow rope. The tow rope is inextensible.

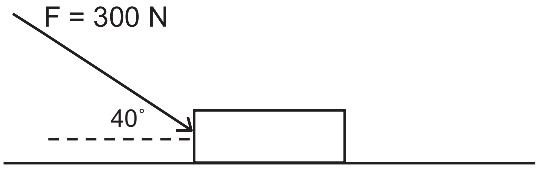


Calculate the:

17.1 acceleration of the truck; and (7)

17.2 magnitude of the tension T in the tow rope between the truck and the log. (2)

18. A force of 300 N, acts downwards on a 30 kg block at 40° to the horizontal as shown in the diagram below. The block accelerates to the right along a rough horizontal surface.



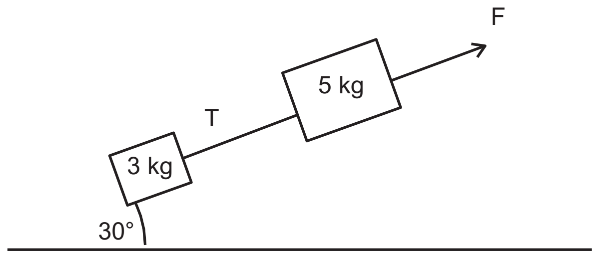
18.1 Calculate the magnitude and direction of the component of the 300 N force that accelerates the block horizontally. (3)

18.2 If the acceleration of the block is 2 m·s^{-2}, calculate the magnitude of the frictional force acting on the block. (4)

18.3 Calculate the vertical force exerted by the block on the plane. (4)

19. A rocket (of mass 2 000 kg) is launched vertically upwards with an acceleration of 20 m·s^{-2}. Calculate the magnitude and direction of the thrust of the rocket's engines. (4)

20. Two crates, 3 kg and 5 kg respectively, are connected with a thin rope. They are pulled up a rough plane which is inclined at 30° to the horizontal. A force F is applied parallel to the plane as shown in the diagram accelerating the system of crates at 2 m·s^{-2} up the slope. The frictional forces acting on the 3 kg and 5 kg crates are 10 N and 17 N respectively.



20.1 Draw a fully labelled free-body diagram for each crate. (9)

20.2 Calculate the component of the weight of each crate parallel to the slope. (4)

20.3 Calculate the magnitude of the applied force F and the tension T in the rope. (4)

21. State Newton's third law of motion. (2)

22. Identify two action-reaction pairs of forces present in each of the following situations:

22.1 A boy pushes a car along the road. (4)

22.2 A light bulb hangs from the ceiling by means of a cord. (4)

22.3 A ball is thrown up into the air. (4)

22.4 A donkey pulls a cart. (4)

23. State Newton's law of Universal Gravitation. (3)

24. The two moons of Mars are Phobos and Deimos.
Mass of Phobos = 1,1 × 10^{16} kg
Radius of Phobos = 11,1 km.
The distance between the centres of Mars and Phobos is 9 377 km.
Mass of Mars = 6,4 × 10^{23} kg.

24.1 Calculate the gravitational force of Mars on Phobos. (4)

24.2 Calculate the magnitude of the gravitational acceleration on the surface of Phobos. (3)

24.3 By what factor would the acceleration due to gravity differ on the surface of Deimos, which has half the radius of Phobos and one tenth of its mass? (3)

25. The James Webb Space Telescope will have a mass of 6 500 kg and will orbit the Earth (mass 6×10^{24} kg) approximately 1 500 000 km away from its centre. Calculate the magnitude of the Earth's gravitational force on the telescope. (3)

26. Mars One is an organisation based in the Netherlands that has put forward plans to land the first humans on Mars. They aim to establish a permanent human colony there by 2027, with no plan of returning to Earth. The average distance between the centres of Earth and Mars is $2{,}25 \times 10^{8}$ km. The planet has a mass of $6{,}42 \times 10^{23}$ kg, and a radius of 3 380 km.

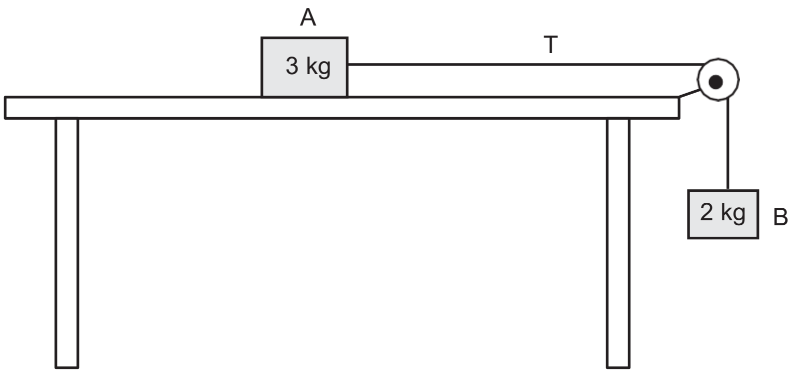
26.1 Calculate the magnitude of the acceleration due to gravity on the surface of Mars. (3)

26.2 Calculate the magnitude of the weight of a 500 kg spaceship on Mars. (2)

CONSOLIDATION EXERCISE

TOTAL: 63 MARKS

1. Two blocks (A and B) are connected by light string and set up as shown in the diagram below.



The string passes over a frictionless pulley. The coefficients of static and kinetic friction are 0,40 and 0,28 respectively. When the system of masses is released, block A slides across the table.

1.1 Define a frictional force. (2)

1.2 Calculate the magnitude of the maximum static frictional force acting on block A. (2)

1.3 Calculate the force of kinetic friction acting on the 3 kg block. (3)

1.4 Draw a fully labelled free-body diagram for each block. (6)

1.5 State Newton's second law. (3)

1.6 Calculate the acceleration of the system of blocks and the magnitude of the tension T in the string. (6)

2. A 1 000 kg roller coaster free-wheels down a track that is inclined at 60° to the horizontal.

2.1 Draw a fully labelled free-body diagram of all the forces acting on the roller coaster. (3)

2.2 Calculate the parallel and perpendicular components of the weight of the roller coaster with respect to the inclined track. (4)

2.3 The coefficient of friction between the wheels and track is 0,3. Calculate the force of friction acting on the roller coaster. (3)

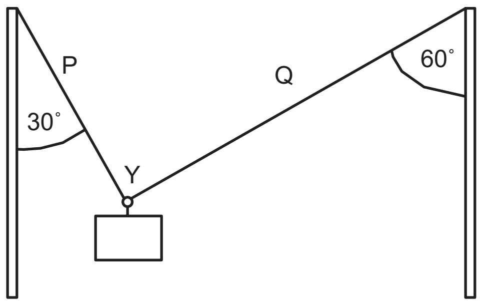
2.4 How would the force of friction be affected if the mass of the roller coaster was increased? Explain your answer. (3)

2.5 Calculate the net force acting on the roller coaster. (3)

2.6 How would the magnitude of the net force change if the angle of the inclined track was decreased? Assume that friction remains constant. Explain your answer. (2)

2.7 Calculate the acceleration of the roller coaster. (4)

3. Two light ropes are strung between two vertical struts. A mass *m* of weight *w* hangs from the ropes attached to a ring at point Y.



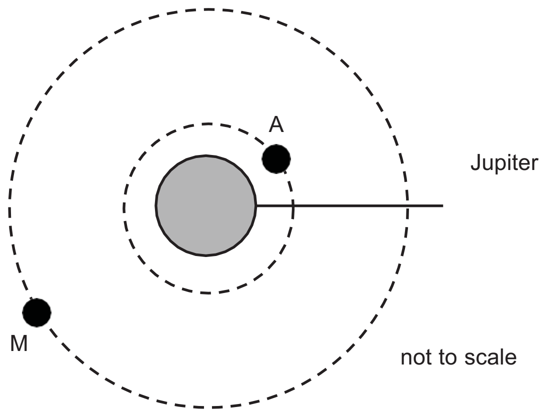
3.1 Draw a fully labelled free-body diagram of all the forces acting at point Y. (3)

3.2 Are the forces acting at point Y in equilibrium? Explain your answer. (2)

3.3 The tension in rope P is 600 N. Calculate the tension in rope Q. (4)

3.4 Calculate the mass *m* hanging from the two ropes. (4)

4. The diagram below shows the circular orbits of two of Jupiter's moons: Adrastea A and Megaclite, M.
Use the following data in your calculations.
Orbital radius of A = $1,3 \times 10^8$ m
The acceleration due to gravity at A = $7,5 \text{ m·s}^{-2}$



4.1 Calculate the mass of Jupiter. (3)

4.2 If the value of *g* at Adrastea's position is 34 090 times bigger than that at Megaclite's position, calculate the orbital radius of Megaclite without using the given value of *g* at A or the mass of Jupiter that you calculated in question 4.1. (3)

[63]

MARKING GUIDELINES

1.1 $w = mg$ = ^3h^9, 8h = 29, 40 N down{ (2)

1.2 $f_s^{max} = n_s N$ = ^0, 34h^29, 4h = 10, 00 N{ (3)

2.1 $w = mg$ = ^500h^9, 8h = 4 900 N{
Therefore N = 4 900 N up and perpendicular to the ground { (2)

2.2 $f_s^{max} = n_s N$ = ^0, 65h^4900h = 3 185 N{
The machine will not move because the applied force of 3 000 N
is less than f_s^{max} {✓ (3)

3.1 The force exerted by a surface ✓ on an object in contact with it. ✓ (2)

3.2 Static friction is the frictional force that occurs between a stationary object and the surface on which it is resting ✓, whereas kinetic friction occurs when an object slides across a surface. ✓ (2)

3.3 $w = mg$ = ^20h^9, 8h = 196 N

Therefore N = 196 N{

$f_s^{max} = n_s N$

$n_s = \frac{f_s^{max}}{N} = \frac{150}{196}$ {= 0, 77{

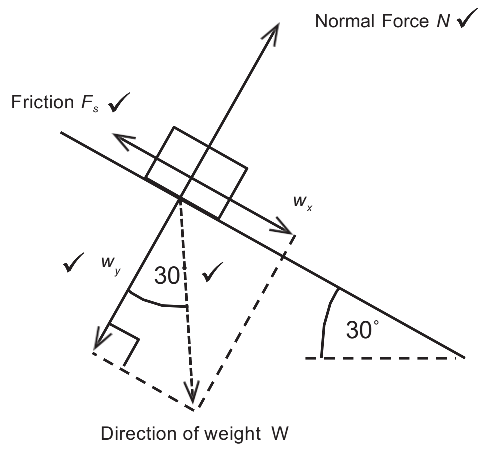
$f_k = n_k N$

$n_k = \frac{f_k}{N} = \frac{80}{196}$ {= 0, 41{

Coefficients of static and kinetic friction do NOT have a unit. (5)

4.1 The force that opposes the motion of an object ✓ and acts parallel to the surface the object is in contact with. ✓ (2)

4.2



✓ The magnitude of the normal force = the magnitude of w_y.

✓ The magnitude of the normal force = the magnitude of w_x.

NB: Weight should not be shown as a vector because its components have been included in the diagram. However, we need to show the angle 30° so we can show the direction of weight.

(6)

4.3 $N = w_y = w\cos 30° = mg\cos 30° = \text{^}5\text{h^}9,8\text{h}\cos 30°\{= 42,44\ \text{N}\{$

$f_s^{max} = n_s N\{= \text{^}0,63\text{h^}42,44\text{h} = 26,73\ \text{N}\{$ **(4)**

4.4 $w_x = w\sin 30° = mg\sin 30°\{= \text{^}5\text{h^}9,8\text{h}\sin 30° = 24,50\ \text{N}\{$

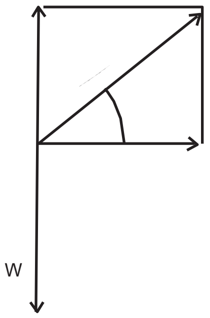
$f_s^{max} > w_x\ \{$ **(3)**

5. $F_y = F\sin 35° = \text{^}50\text{h}\sin 35° = 28,68\ \text{N}\{\text{up}$

$w = mg = \text{^}6\text{h^}9,8\text{h} = 58,80\ \text{N}\{\text{down}$

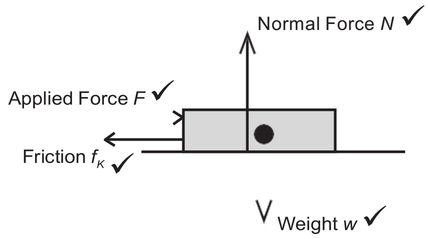
$F_{down} = 58,80 - 28,68 = 30,12\ \text{N}\{\text{down}$

$N = 30,12\ \text{N}\ \ \text{up}\{$



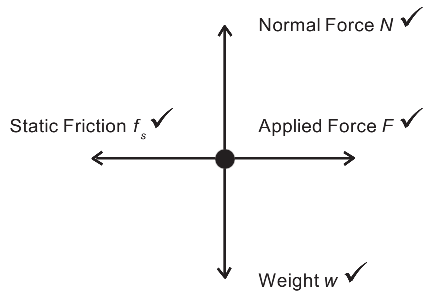
(4)

6. **6.1**



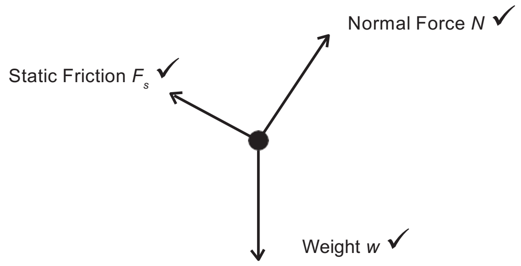
Applied force > Friction✓ (5)

6.2



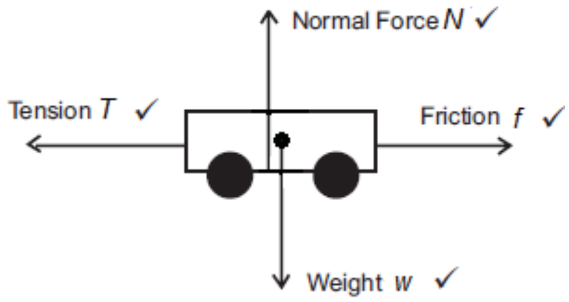
Applied force = Friction✓ (5)

6.3

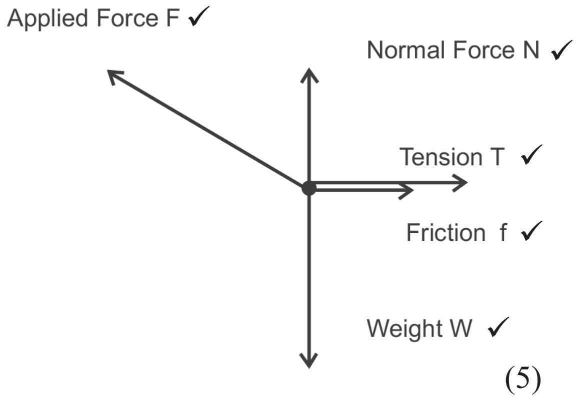


(3)

7. **7.1**



7.2



(5)

NB Normal force = weight
Tension can be equal to friction or tension can be greater than friction.
Deduct a mark for each of these errors. (4)

8. An object continues in a state of rest or constant velocity unless it is acted upon by a net force. ✓✓ (2)

9. A property of a body which resists any change in its state of motion. ✓✓ (2)

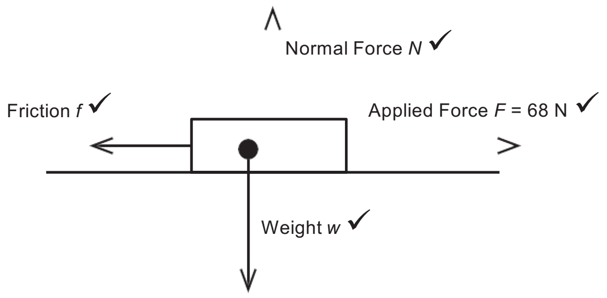
10. A body remains at rest.✓ The net force is zero. ✓
A body travels at constant velocity. ✓ The net force is zero. ✓
A body accelerates. ✓ The net force is NOT zero. ✓ (6)

11. Mass✓ (1)

12. The hand exerts a net backward force on the cup✓. This net force does not act on the coffee✓. According to Newton's first law, the coffee will continue moving forward at constant velocity✓ and spill over the front of the cup. (3)

13. The back of the seat exerts a net forward force on the passenger's back✓. This net force does not act on the passenger's head✓. According to Newton's first law, the head will remain at rest✓ (and will be left behind). The neck muscles would experience tremendous strain as they pull the head forward. A head rest will exert a net force forward on the head✓, so the entire body would accelerate forward. (4)

14. **14.1**



(4)

14.2 Choose right as positive:

$F_{net} = ma$

$F - f\{= ma$

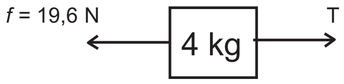
68 - 27 = ^8ha{

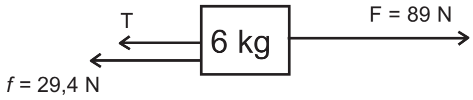
41 = ^8ha

$a = 5{,}13\ \text{m·s}^{-2}$ ✓ to the right ✓

(4)

15. 15.1





4 kg:

Choose right as positive:

$$F_{net} = ma$$
$$T - f = (4)a \checkmark$$
$$T - 19,6 = 4a$$
$$T = 19,6 + 4a \checkmark \quad \text{(i)}$$

6 kg:

$$F_{net} = ma$$
$$F - T - f = (6)a \checkmark$$
$$89 - T - 29,4 = 6a \checkmark$$
$$T = 59,6 - 6a \quad \text{(ii)}$$

Set equation (i) equal to equation (ii)

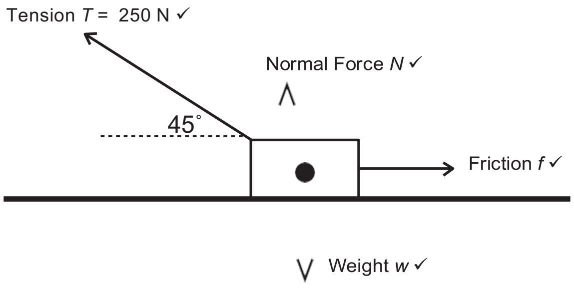
$$19,6 + 4a = 59,6 - 6a$$

$$10a = 40$$

$a = 4\ \text{m·s}^{-2}$ ✓ to the right ✓ (6)

15.2 $T = 19,6 + 4(4) \checkmark = 35,6\ \text{N} \checkmark$ (2)

16. 16.1



(4)

16.2 $T_y = T\sin 45° = (250)\sin 45° = 176,78\ \text{N up} \checkmark$

$w = mg = (30)(9,8) = 294\ \text{N down} \checkmark$

The downward force of box on ground is: $F_{down} = 294 - 176,78 = 117,22\ \text{N down}$

Therefore: $N = 117,22\ \text{N up} \checkmark$

$f_k = \mu_k N = (0,6)(117,22) = 70,33\ \text{N} \checkmark$ to the right ✓ (5)

16.3 $T_x = T\cos 45° = (250)\cos 45° = 176,78$ N left ✓

$F_{net} = ma$

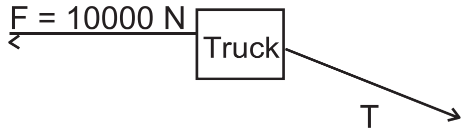
$T_x - f$ ✓ $= ma$

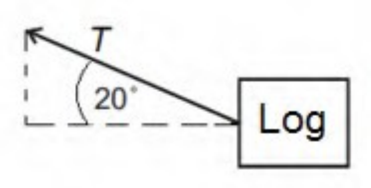
$176,78 - 70,33 = (30)a$ ✓

$106,45 = (30)a$

$a = 3,55\ \text{m·s}^{-2}$ ✓ to the left ✓ (5)

17. 17.1





$T_x = T\cos 20°$ ✓

Truck:	Log:
Choose left as positive:	
$F_{net} = ma$	$F_{net} = ma$
$F - T_x = 2\,000\ a$ ✓	$T_x = (200)a$ ✓
$10\,000 - T\cos 20° = 2\,000a$	$T\cos 20° = 200\ a$ ✓ (ii)
$T\cos 20° = 10\,000 - 2\,000\ a$ ✓ (i)	

Set equation (i) equal to equation (ii)

$10\,000 - 2\,000a = 200a$

$10\,000 = 2\,200a$

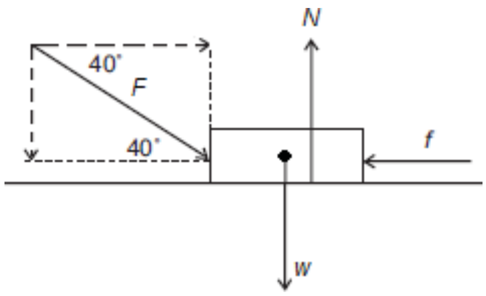
$a = 4,55\ \text{m·s}^{-2}$ ✓ to the left ✓ (7)

17.2 $T\cos 20° = 200a$

$T\cos 20° = 200(4,55)$ ✓ $= 910$ N

$\therefore T = 968,40$ N ✓ (2)

18. 18.1



$F_x = F\cos 40° = 300\cos 40°$ ✓ $= 229,81$ N ✓ to the right ✓ (3)

18.2 Choose right as positive:

$F_{net} = ma$

$F_x - f${$= ma$

$229,81 - f =$ ^30h(2){

$229,81 - f = 60$

$f = 169,81$ N{to the left{ (4)

18.3 $F_y = F\sin 40° = 300\sin 40° = 192,84$ N down{

$w = mg =$ ^30h^9,8h $= 294$ N down{

$F_{down} = 294 + 192,84${$= 486,84$ N down{ (4)

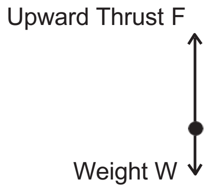
19. Choose up as positive:

$F_{net} = ma$

$F - w =$ ^2 000h(20){

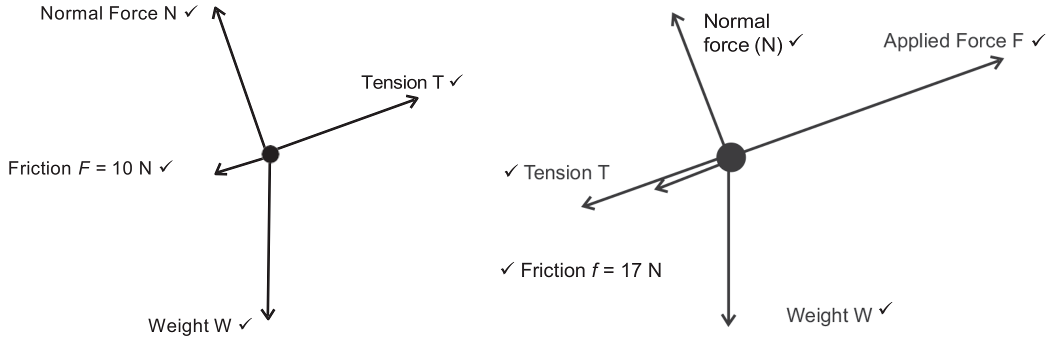
$F - 49\ 000${$= 40\ 000$

$F = 89\ 000$ N{up{



(4)

20. 20.1 3 kg: 5 kg:



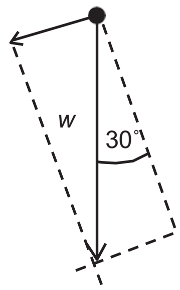
(9)

20.2 3 kg:

$w_x = w\sin 30° =$ ^3h^9,8hsin 30°{$= 14,7$ N down slope{

5 kg:

$w_x = w\sin 30° =$ ^5h^9,8hsin 30°{$= 24,5$ N down slope{



(4)

20.3 3 kg:

Choose up the slope as positive:

$F_{net} = ma$

$T - f =$ ^3h(2){

$T - 10 = 6$

$T = 16$ N{

5 kg:

$F_{net} = ma$

$F - T - f =$ ^5h(2){

$F - 16 - 17 = 10$

$F = 43$ N{ (4)

21. When object A exerts a force on object B✓, object B simultaneously exerts an oppositely directed force of equal magnitude on object A.✓ (2)

22. **22.1** Action: Forward force of boy on car.✓
Reaction: Backward force of car on boy.✓
Action: Backward force of foot on road.✓
Reaction: Forward force of road on foot.✓ (4)

22.2 Action: Downward force of Earth on light bulb.✓
Reaction: Upward force of light bulb on Earth.✓
Action: Downward force of light bulb on cord.✓
Reaction: Upward force of cord on light bulb.✓ (4)

22.3 Action: Upward force of hand on ball.✓
Reaction: Downward force of ball on hand.✓
Action: Downward force of Earth on ball.✓
Reaction: Upward force of ball on Earth.✓ (4)

22.4 Action: Forward force of donkey on cart.✓
Reaction: Backward force of cart on donkey.✓
Action: Backward force of hoof on road.✓
Reaction: Forward force of road on hoof.✓ (4)

23. Every object in the universe attracts every other object in the universe with a force that is directly proportional to the product of their masses✓ and inversely proportional to the square of the distance between their centres.✓ (2)

24. **24.1**

$$F = G\frac{m_1 m_2}{r^2}$$

$$F = (6,7\times10^{-11})\frac{(1,1\times10^{16})(6,4\times10^{23})\checkmark}{(9\,377\,000)^2\checkmark}$$

$$F = 5,36\times10^{15}\ \text{N}\checkmark\ \text{towards Mars}\checkmark$$

(4)

24.2

$$g_{Phobos} = G\frac{M_{Phobos}}{(d_{Phobos})^2}$$

$$g_{Phobos} = (6,7\times10^{-11})\frac{(1,1\times10^{16})\checkmark}{(11,1\times10^3\checkmark)^2}$$

$$g_{Phobos} = 5,98\times10^{-3}\ \text{m}\cdot\text{s}^{-2}\checkmark$$

(3)

24.3

$$g_{Phobos} = G\frac{M}{d^2}$$

$$g_{Deimos} = G\frac{\frac{1}{10}M\checkmark}{\left(\frac{1}{2}d\checkmark\right)^2} = G\frac{\frac{1}{10}M}{\frac{1}{4}d^2} = \frac{1}{10}\times\frac{4}{1}\left(G\frac{M}{d^2}\right) = \frac{2}{5}g_{Phobos}\checkmark$$

Decrease by a factor of $\frac{2}{5}$ (3)

25. $F = G\frac{m_1 m_2}{r^2}$

$F = (6,7 \times 10^{-11})\frac{(6\ 500)(6 \times 10^{24})✓}{(1,5 \times 10^{9}✓)^2}$ (3)

$F = 1,16\ \text{N}✓$

26. 26.1

$g_{Mars} = G\frac{M_{Mars}}{(d_{Mars})^2}$

$g_{Mars} = (6,7 \times 10^{-11})\frac{(6,42 \times 10^{23})✓}{(3\ 380 \times 10^{3})^2✓}$

$g_{Mars} = 3,77 \times 10^{-3}\ m.s^{-2}✓$ (3)

26.2 $W = mg = (500)(3,77✓) = 1\ 885\ \text{N}✓$ (2)

MARKING GUIDELINES

CONSOLIDATION EXERCISE

TOTAL: 63 MARKS

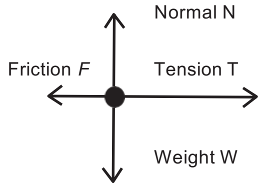
Solutions:

1.1 The force that opposes the motion of an object✓ and acts parallel to the surface the object is in contact with.✓ (2)

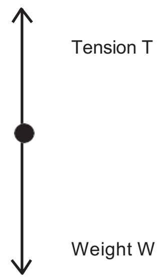
1.2 $f_s^{max} = n_s N$ = ^0, 4h^3h^9, 8h{= 11, 76 N{ (2)

1.3 $f_k = n_k N$ = ^0, 28h^3h^9, 8h{= 8, 23 N{to the left (3)

1.4 3 kg:



2 kg:



One mark for each correct force which is also labelled correctly.

(6)

1.5 When a net force, F_{net}, is applied to an object of mass, m, it accelerates in the direction of the net force✓. The acceleration, a, is directly proportional to the net force✓ and inversely proportional to the mass✓. (3)

1.6 3 kg:

Choose right as positive:

$F_{net} = ma$

T - f = ^3ha{

T - 8, 23 = 3a

T = 8, 23 + 4a{ (i)

2 kg:

Choose down as positive:

$F_{net} = ma$

w - T = ^2ha{

19, 6 - T = 2a

T = 19, 6 - 2a{ (ii)

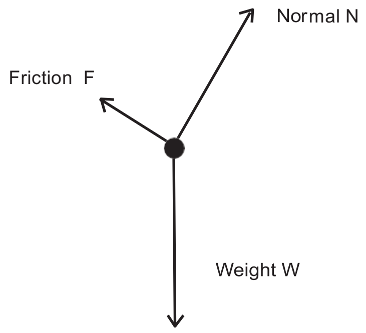
Set equation (i) equal to equation (ii)

8, 23 + 4a = 19, 6 - 2a

6a = 11, 37

a = 1, 90 $\text{m}\cdot\text{s}^{-2}$ ✓ to the right and downwards ✓ (6)

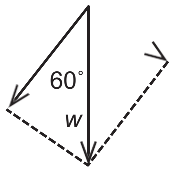
2.1



1 mark for each correctly labelled force

(3)

2.2



$w_x = w \sin 60$c = ^1 000h^9, 8hsin 60c{= 8 489, 05 N{down the slope
$w_y = w \cos 60$c = ^1 000 # 9, 8hcos 60c{= 4 900 N{perpendicular to the slope (4)

2.3 f = nN = ^0, 3h^4 900h{= 1 470 N{up the slope{ (3)

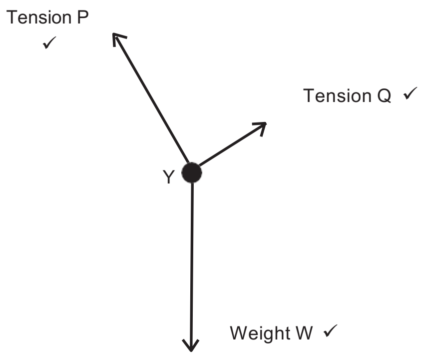
2.4 If mass increases, weight w increases✓; w_y increases, N increases✓.
Therefore friction increases.✓ (3)

2.5 $F_{net} = w_x$ - f{= 8 487, 05 - 1 470 = 7 017, 05 N{ down the slope{ (3)

2.6 The net force will decrease✓ because w_x decreases✓ (only if we assume friction to be constant). (2)

2.7 $F_{net} = ma$
7 017, 05{= (1 000{) a
$a = 7{,}02\ \text{m·s}^{-2}$ ✓ down the slope ✓ (4)

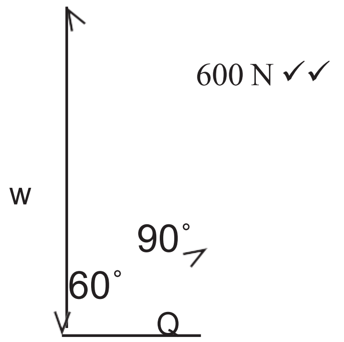
3.1



(3)

3.2 Yes✓ Point Y remains at rest therefore the net force acting on point Y is zero✓ (2)

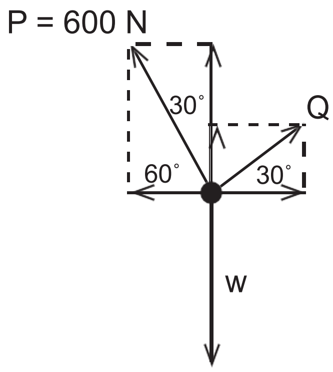
3.3 Triangle of forces method:



$\tan 30° = \frac{Q}{600}$ ✓

$Q = 600 \tan 30° = 346,41$ N✓ (4)

OR Components method:



$P_x = P\cos 60° = (600)\cos 60°$ ✓ $= 300$ N✓

$P_x = Q_x$ ✓ $= Q\cos 30°$

$300 = Q\cos 30°$

$Q = 346,41$ N✓ (4)

3.4 Triangle of forces:

$\cos 30° = \frac{600}{w}$ ✓

$w = \frac{600}{\cos 30°} = 692,82$ N✓

$m = \frac{w}{g} = \frac{692,82}{9,8 ✓} = 70,70$ kg✓ (4)

OR Components method:

$P_y = P\sin 60° = (600)\sin 60° = 519,62$ N✓

$Q_y = Q\sin 30° = (346,41)\sin 30° = 173,21$ N✓

$w = P_y + Q_y = 519,62 + 173,21 = 692,83$ N✓

$m = \frac{w}{g} = \frac{692,83}{9,8} = 70,70$ kg✓ (4)

4.1 $g = G\dfrac{M}{d^2}$

$$M = \frac{gd^2}{G} = \frac{(7,5)(1,3 \times 10^8)^2 \checkmark}{(6,7 \times 10^{-11})} = 1,89 \times 10^{27}\ \text{kg} \checkmark \qquad (3)$$

4.2 $g_A = G\dfrac{M_J}{d_A^2}$ $\qquad$ $GM_J = g_A d_A^2$

$g_M = G\dfrac{M_J}{d_M^2}$ $\qquad$ $GM_J = g_M d_M^2$

$GM_J = g_A d_A^2 = g_M d_M^2 \checkmark$

$$d_M^2 = \frac{g_A d_A^2}{g_M} = \frac{34\,090 \checkmark}{1} \times (1,3 \times 10^8)^2 = 5,76 \times 10^{20}$$

$d_M^2 = 5,76 \times 10^{20}$

$\therefore\ d_M = 2,40 \times 10^{10}\ \text{m} \checkmark$ $\qquad$ (3)

WORKSHEETS

TOPIC 3: Atomic Combinations (Molecular Structure)

WORKSHEET

MULTIPLE CHOICE

1. The type of particle which results from the covalent bonding of atoms is called:

A an ion.
B an atom.
C a molecule.
D an isotope. (2)

2. The bond in the H_2O molecule is described as polar covalent because :

A the shared electrons are closer to the oxygen atom than the hydrogen atom.
B the shared electrons are closer to the hydrogen atom than the oxygen atom.
C there is a large electronegativity difference between the two atoms.
D electrons are transferred from hydrogen atoms to oxygen atoms. (2)

3. The CCl_4 molecule is considered to be non-polar because :

A the shape of the molecule is linear.
B the electronegativity difference is very small.
C the molecule is asymmetrical.
D the molecule is symmetrical. (2)

4. Consider the methane molecule (CH_4). How much energy is required to break the chemical bonds in the molecule (in $kJ.mol^{-1}$)?

A 412
B 348
C 1648
D 1996

BOND	BOND ENERGY
C – C	348
C = C	619
C = C	835
C - H	412
C = O	799
O - H	463
O = O	499

(2)

LONG QUESTIONS

1. Copy and complete the following table:

MOLECULE	CO_2	CH_4	SF_6	NH_3
What is the central atom in the molecule?				
Shape of molecule				
Are the molecular shapes IDEAL or NON-IDEAL?				
Does the molecule contain polar bonds?				
Is the molecule polar or non-polar?				

(20)

2. A water molecule is polar while a carbon dioxide molecule is non-polar.

    2.1 What is the difference between a polar and a non-polar molecule? (4)

    2.2 Use electronegativity difference to determine the type of bond present in the carbon dioxide molecule. (2)

    2.3 State the shapes of water and carbon dioxide molecules. (2)

    2.4 Explain why carbon dioxide, which contains polar bonds, is non-polar. (2)

3. What is the nature of the charges on the H and O atoms in the H_2O molecule? Explain your answer. (2)

4. H_2O can form a dative covalent bond to form H_3O^+. Use the Lewis diagram for a water molecule to help explain the idea of a dative covalent bond. (6)

5. Consider the following list of molecules:

Cl_2 H_2O BF_3 HCl CO_2 NH_3

5.1 Which of the following molecules is polar covalent and which are non-polar covalent? (6)

5.2 CO_2 contains polar bonds, but is considered to be a non-polar molecule. Explain why this is so. (3)

5.3 Name the shape of each molecule in the list. (7)

6. Consider a molecule of hydrogen sulfide (H_2S).

6.1 Draw the Lewis diagram for hydrogen sulfide. (2)

6.2 Identify the central atom in H_2S. (1)

6.3 How many lone pairs of electrons are present in H_2S molecule? (1)

6.4 How many bonding pairs of electrons are present in the H_2S molecule. (1)

6.5 What is the molecular shape of this molecule? (1)

6.6 Is this an IDEAL or a NON-IDEAL molecular shape? Explain your answer. (3)

7. The table below lists the bond energies of certain covalent bonds.

BOND	O = O	O-O	C - C	C = O	C - H	H - H	H - O
BOND ENERGY ($kJ.mol^{-1}$)	494	142	346	499	413	435	459

7.1 Use the information from the table to compare the length and strength of an O – O bond to the length and strength of an O = O bond. (3)

Consider the chemical equation shown below:

$$2C_2H_2 + 7O_2 \rightarrow 4CO_2 + 6H_2O$$

7.2 Calculate the total energy absorbed to break the bonds of the reactants. (5)

7.3 Calculate the total energy released on bond formation of the products. (4)

7.4 How much excess energy was released in the whole reaction? (3)

CONSOLIDATION EXERCISE

MULTIPLE CHOICE

1. A covalent bond will form between two atoms when...

A there is repulsion between the nuclei of two approaching atoms.
B there is attraction between the electrons of two approaching atoms.
C one atom transfers an electron to another atom.
D the potential energy of the atoms is at its lowest. (2)

2. In VSEPR theory, the greatest amount of repulsion between orbitals will be between:

A lone pair and lone pair.
B bonding pair and lone pair.
C bonding pair and bonding pair.
D bonding pair and central atom. (2)

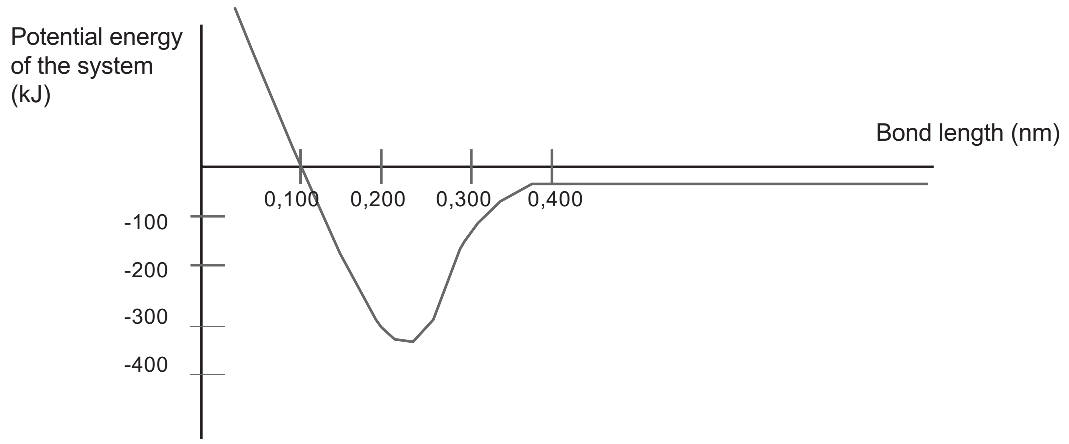
3. The HBr molecule forms a dipole because the...

(i) Br atom is more electronegative than the H atom.
(ii) H atom is more electronegative than the Br atom.
(iii) HBr molecule is polar.

Which of the above statements is/are true?

A Only (i) is true.
B Both (i) and (iii) are true.
C Both (ii) and (iii) are true.
D Only (ii) is true. (2)

Study the energy diagram below which represents the formation of a covalent bond between two atoms. Use this diagram to answer Questions 4 and 5.



4. The bond energy of the of the chemical bond is ...

A 0 kJ
B 30 kJ
C 330 kJ
D 200 kJ (2)

5. The bond length between the two atoms forming the chemical bond is ...

A 0,200 nm
B 0,370 nm
C 0,240 nm
D 0,050 nm (2)

6. Using the table alongside, calculate the total energy required to break the bonds of the reactants when methane reacts with oxygen to form carbon dioxide and water. The reaction equation is written below.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

BOND	BOND ENERGY (kJ.mol^{-1})
C – C	348
C = C	619
C = C	835
C - H	412
C = O	799
O - H	463
O = O	499

A 911 kJ.mol^{-1}
B 1 410 kJ.mol^{-1}
C 2 646 kJ.mol^{-1}
D 3 644 kJ.mol^{-1} (2)

LONG QUESTIONS

1. Consider the table below. Redraw this table in your answer books and complete it in the spaces provided.

CHEMICAL FORMULA OF COMPOUND	ELECTRO-NEGATIVITY DIFFERENCE	NON-POLAR COVALENT, POLAR COVALENT OR IONIC BOND	SHAPE OF MOLECULE	TYPE OF MOLECULE (POLAR OR NON-POLAR)
Cl_2				
CF_4				
CO_2				
HB_r				
NH_3				
H_2O				
BF_3				

(28)

2. Draw Lewis structures for:

2.1 a water molecule.

2.2 a carbon dioxide molecule. (4)

3. **3.1** Define the term electronegativity. (2)

3.2 Consider the following molecules:

F_2 HCl CH_4 H_2O NH_3 SF_6

a) Assign electronegativity values to each atom. (6)

b) Calculate the electronegativity difference for the bonds ineach molecule. (6)

c) Identify which of the molecules contain polar covalent or non-polar covalent bonds. (6)

d) Identify the shapes of each molecule using VSEPR theory. (6)

4. Consider the following list of molecules:

HF BCl_3 CF_4 NH_3 CO_2 SCl_6

4.1 Draw Lewis diagrams for the molecules HF and NH_3 to show the bonding that takes place. (4)

4.2 Which of the molecules in the list are non-polar? Explain your answer. (6)

4.3 According to VSEPR theory, what are the shapes of molecules BCl_3, CF_4, NH_3 and SCl_6? (4)

4.4 NH_3 is said to have a non-ideal shape where SCl_6 is said to have an ideal shape. What is the difference between molecules with these different shape classifications? (2)

5. For each of the following bonding pairs, say which bond is more polar. Show all calculations and indicate the partially positive (δ^+) and partially negative (δ^-) poles on each bond.

5.1 C – O and C – N (3)

5.2 P – Br and P – Cl (3)

5.3 C – O and C - S (3)

6. Ammonia (NH_3) is able to make a dative covalent bond with a hydrogen ion (H^+) forming the ammonium cation (NH_4^+)

6.1 Draw the Lewis diagram for a molecule of ammonia. (2)

6.2 Explain why the hydrogen ion can form a dative covalent bond with ammonia. (2)

6.3 Draw a Lewis diagram of the resulting ammonium cation. (3)

7. **7.1** Define the term 'bond energy'. (2)

7.2 What is the relationship between bond energy and bond length in a stable molecule? (2)

7.3 Consider the table of bond energies and bond lengths below. Use the table to answer the following questions

a) Cl_2 and I_2 are both examples of diatomic halogen molecules (Group 17). Explain why I_2 has a smaller bond energy than Cl_2. (2)

b) Explain why I_2 has a larger bond length compared to Cl_2. (2)

c) Explain why the bond energies of the different carbon to carbon bonds differ from single to triple bonds. (3)

BOND	BOND ENERGY ($kJ.mol^{-1}$)	BOND LENGTH (pm)
Cl - Cl	242	199
C - C	347	540
C = C	614	340
C = C	839	120
I - I	151	266

8. Consider the reaction between oxygen and hydrogen which is used to form water:

$$O_2 + 2H_2 \rightarrow 2\,H_2O$$

BOND	BOND ENERGY ($kJ.mol^{-1}$)
O=O	498
O - H	463
H - H	436

Using the table of bond energies supplied, calculate the following quantities.

8.1 The amount of energy required to break the bonds in the reactants. (3)

8.2 The amount of energy released on formation of bonds of products. (2)

8.3 The total amount of energy released from the reaction in the formation of H_2O. (2)

MARKING GUIDELINES

MULTIPLE CHOICE

1.1 C ✓✓ All molecules are made from non-metal atoms only in their structure.

1.2 A ✓✓ The electronegativity of O is greater than that of H, thus the shared electron pair will be closer to the O atom and result in the bond becoming polar. Water is an asymmetric molecule and will thus will have a definite δ^+ and δ^- end, hence polar covalent.

1.3 D ✓✓ The central C atom is surrounded by 4 Cl atoms to form a tetrahedral shape. Tetrahedrons are symmetrical arrangements hence the molecule will be non-polar covalent due to symmetry.

1.4 C ✓✓ There are 4 × C – H bonds in the molecule, thus it is simply 4 × 416 kJ.mol^{-1} to give a total amount of energy to break the bonds as 1 648 kJ.mol^{-1} (8)

LONG QUESTIONS

1. Complete the following table

MOLECULE	CO_2	CH_4	SF_6	NH_3
WHAT IS THE CENTRAL ATOM IN THE MOLECULE?	C ✓	C ✓	S ✓	N ✓
SHAPE OF MOLECULE	Linear ✓	Tetrahedral ✓	Octahedral ✓	Pyramidal ✓
ARE THE MOLECULAR SHAPES IDEAL OR NON-IDEAL?	IDEAL ✓	IDEAL ✓	IDEAL ✓	NON-IDEAL ✓
DOES THE MOLECULE CONTAIN POLAR BONDS?	Yes ✓	Yes ✓	Yes ✓	Yes ✓
IS THE MOLECULE POLAR OR NON-POLAR?	Non-polar ✓	Non-polar ✓	Non-polar ✓	Polar ✓

(20)

2. **2.1** A polar molecule – A molecule with a distinct region of charge ✓ at either end of the molecule due to one atom having a larger electronegativity than the other. ✓
A non-polar molecule – There is no distinct region of charge due to a zero electronegativity difference between the atoms ✓ or the molecule is perfectly symmetrical. ✓ (4)

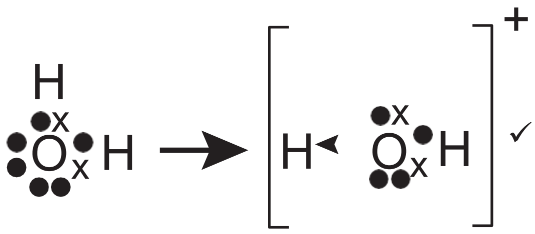
2.2 $\left.\begin{array}{l}\text{C : 2,5}\\ \text{O : 3,5}\end{array}\right\}$ electronegativity difference is 1,0 ✓ thus bonds are polar covalent ✓ (2)

2.3 water – angular ✓
carbon dioxide – linear ✓ (2)

2.4 Carbon dioxide is non-polar due to the symmetry of the molecule. ✓ $\overset{\delta^-}{O} = \overset{\delta^+}{C} = \overset{\delta^-}{O}$
There is no distinct region of δ^+ and δ^-, thus the molecule is considered non-polar even though it has polar bonds. ✓ (2)

3. In the water molecule, H has a δ^+ charge and O has a δ^- charge.✓ This is due to the electronegativity of O being greater than the electronegativity of H. ✓ (2)

4. H_2O has two lone pairs of electrons. ✓ One of these lone pairs can be used to fill the empty outermost energy level of the H^+ ion.✓ This now forms a dative covalent bond between H_2O and H^+ ✓ producing the H_3O^+ ion. ✓



✓✓ (for correct diagram)

(6)

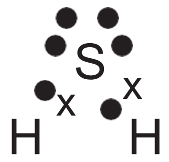
5. **5.1** Polar covalent : H_2O ✓ HCl ✓ NH_3 ✓
Non-polar covalent : Cl_2 ✓ BF_3 ✓ CO_2 ✓ (6)

5.2 CO_2 is a symmetrical molecule ✓ meaning that it does not have two definite regions of polarity ✓, that is, a δ+ side and a δ- side. Even though the bonds are polar due to the electronegativity difference between C and O, there is no distinct polarity within the molecule, hence it is non-polar. ✓

$$\overset{\delta^-}{O} = \overset{\delta^+}{C} = \overset{\delta^-}{O}$$
(3)

5.3 Cl_2: linear ✓
H_2O: angular ✓
BF_3: trigonal planar ✓
HCl: linear ✓
CO_2: linear ✓
NH_3: trigonal pyramidal ✓ (6)

6. **6.1**



✓ correct atoms and shape

✓ correct electron arrangement (2)

6.2 S ✓ (1)

6.3 two ✓ (1)

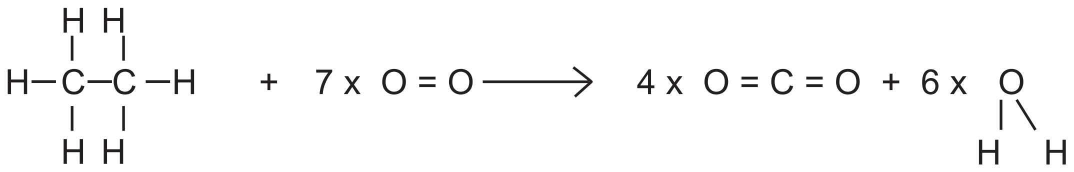
6.4 two ✓ (1)

6.5 angular ✓ (1)

6.6 NON-IDEAL ✓✓- the central atom has lone pairs of electrons around it. ✓ (3)

7. **7.1** The O = O bond requires more energy to break the bond compared to the O – O bond. ✓
The greater the amount of energy required, the shorter the bond length,✓ thus the O = O bond will be shorter in length in comparison to the O – O bond. ✓ (3)

7.2



2 × (C – C) = 692 ✓ + 7 × (O = O) = 3 458 ✓
2 × (6 × C – H) = 4 956 ✓
Total energy to break bonds of reactants = 5 648 + 3 458 ✓
Total = 9 106 kJ.mol^{-1} ✓ (5)

7.3 4 × (2 × C = O) = 3 992 kJ.mol^{-1} ✓ + 6 × (2 × O – H) = 5 508 kJ.mol^{-1} ✓
Total energy released on bond formation of products = 3 992 + 5 508 ✓
Total = 9 500 kJ.mol^{-1} ✓ (4)

7.4 Excess energy = (energy to break bonds) - (energy released in new bond formation)
= 9 106 – 9 500 ✓
= –394 kJ.mol^{-1} ✓
Thus, 394 kJ.mol^{-1} of excess energy was released ✓ (3)

MARKING GUIDELINES

CONSOLIDATION EXERCISE

TOTAL : 122 MARKS

MULTIPLE CHOICE

1. D ✓✓ When atoms approach each other, there are both attractive and repulsive forces between the atoms. Only when these forces are balanced will a covalent bond be formed and the potential energy of the system will be at its lowest. (2)

2. A ✓✓ Lone pair-lone pair electron repulsions are the largest of all the valance electron pair repulsions. (2)

3. B ✓✓ Br has an electronegativity of 2,8 and H has an electronegativity of 2,1. This gives an electronegativity difference of 0,7 which makes the bond polar. HBr is also a linear molecule which will form definite δ+ and δ- ends as a result of this difference, thus HBr will be polar. (2)

4. C ✓✓ The bond energy will be at the position where the potential energy in the system is the lowest and the bond is stable. This is represented by the lowest point of the graph and the value is read off the y-axis of the graph. (2)

5. C ✓✓ At the point where the potential energy in the system is the lowest is where the bond is most stable. This is where the atoms now establish a stable chemical bond and the bond length is fixed. This is now read off the x – axis of the graph. (2)

6. C ✓✓ This is the sum of the bond energies of four C – H bonds and two O = O bonds as there are 2 moles of O_2 in the reactants. This adds up to 2 646 $kJ.mol^{-1}$. (2)

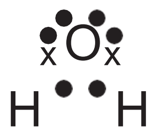
LONG QUESTIONS

1. Consider the table below. Redraw this table in your answer books and complete in the space provided.

CHEMICAL FORMULA OF COMPOUND	ELECTRO-NEGATIVITY DIFFERENCE BETWEEN ATOMS IN BOND	NON-POLAR COVALENT, POLAR COVALENT OR IONIC BOND	SHAPE OF MOLECULE	IDEAL OR NON IDEAL SHAPE
Cl_2	0 ✓	Non-polar covalent ✓	Linear ✓	IDEAL ✓
CF_4	1,5 ✓	Non-polar covalent ✓	Tetrahedral ✓	IDEAL ✓
CO_2	1,0 ✓	Non-polar covalent ✓	Linear ✓	IDEAL ✓
HBr	0,7 ✓	Polar covalent ✓	Linear ✓	IDEAL ✓
NH_3	0,9 ✓	Polar covalent ✓	Pyramidal ✓	NON-IDEAL ✓
H_2O	1,4 ✓	Polar covalent ✓	Angular ✓	NON-IDEAL ✓
BF_3	2,0 ✓	Non-polar covalent ✓	Trigonal planar ✓	IDEAL ✓

(28)

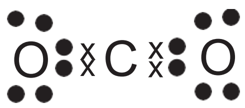
2. 2.1



✓ correct shape

✓ electrons arranged correctly (2)

2.2



✓ correct shape

✓ electrons arranged correctly (2)

3. 3.1 This is the measure of the amount of attraction ✓ that an atom exerts on a shared electron pair ✓ within a chemical bond. (2)

3.2 a) F_2 : F = 4,0 ✓ HCl : H = 2,1 ✓ Cl = 3,0 CH_4 : C = 2,5 ✓ H = 2,1

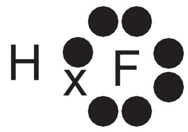
H_2O : H = 2,1 ✓ O = 3,5 NH_3 : N = 3,0 ✓ H = 2,1 SF_6 : S = 2,5 ✓ F = 4,0 (6)

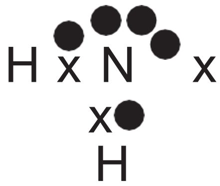
b) F_2 : EN difference 4,0 – 4,0 = 0 ✓
HCl: EN difference 3,0 – 2,1 = 0,9 ✓
CH_4: EN difference 2,5 – 2,1 = 0,4 ✓
H_2O: EN difference 3,5 – 2,1 = 1,4 ✓
NH_3: EN difference 3,0 – 2,1 = 0,9 ✓
SF_6: EN difference 4,0 – 2,5 = 1,5 ✓ (6)

c) F_2: non-polar covalent ✓
HCl: polar covalent ✓
CH_4: polar covalent ✓
H_2O: polar covalent ✓
NH_3: polar covalent ✓
SF_6: polar covalent ✓ (6)

d) F_2 = linear ✓
HCl = linear ✓
CH_4 = tetrahedral ✓
H_2O = angular ✓
NH_3 = trigonal pyramidal ✓
SF_6 = octahedral ✓ (6)

4. 4.1





Two marks for each correct structure. (4)

4.2 BCl_3 ✓ CF_4 ✓ CO_2 ✓ SCl_6 ✓
symmetrical molecules hence non-polar ✓✓ (6)

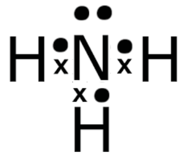
4.3 BCl_3: trigonal planar ✓
CF_4 : tetrahedral ✓
NH_3: trigonal pyramidal ✓
SCl_6 : octahedral ✓ (4)

4.4 NH_3 - has lone pair of electrons around central atom hence NON-IDEAL ✓
SCl_6 - has no lone pairs of electrons around central atom, hence IDEAL ✓ (2)

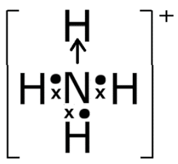
5. 5.1 δ^+ δ^- ✓
C – O EN difference (C – O) = 3,5 – 2,5 = 1,0 ✓
C – N EN difference (C – N) = 3,0 – 2,5 = 0,5 ✓ (3)

5.2 δ^+ δ^- ✓
P – Cl EN difference (P – Cl) = 3,0 – 2,1 = 0,9 ✓
P – Br EN difference (P – Br) = 2,8 – 2.1 = 0,7 ✓ (3)

5.3 δ^+ δ^- ✓
C – O EN difference (C - O) = 3,5 – 2,5 = 1,0 ✓
C – S EN difference (C – S) = 2,5 – 2,5 = 0 ✓ (3)

6.1

✓✓ (2)

6.2 N has a lone pair of electrons in the ammonia molecule which it can share with the H^+ ion which has an empty valence energy level. ✓✓ (2)

6.3

✓✓ for the correct Lewis diagram
✓ There is now an arrow replacing the lone pair of electrons to indicate dative covalent bond (3)

7.1 The bond energy of a compound is the energy needed to break one mole of its molecules into separate atoms. ✓✓ (2)

7.2 As the bond length gets larger, so the amount of energy required to break the bond gets smaller. ✓✓ (2)

7.3 a) I_2 is made up of much larger atoms than in Cl_2 and thus has a much greater bond length. ✓The larger the bond length, the less the bond energy. ✓ (2)
b) I_2 is made up of much larger atoms compared to Cl_2. ✓ The larger the atoms, the larger the bond length between the atoms. ✓ (2)
c) The more bonds there are between two atoms, the shorter the bond length.✓ This means that the amount of energy required to break the bonds will be more, thus bond energy will increase.✓ The carbon triple bond required 839 $kJ.mol^{-1}$ of energy to break the bonds while the carbon single bond only requires 347 $kJ.mol^{-1}$ to break the bond.✓ (3)

8.1 O = O 498 $kJ.mol^{-1}$ ✓
2 × H – H 872 $kJ.mol^{-1}$ ✓
Total 1 370 $kJ.mol^{-1}$ ✓ (3)

8.2 4 × O – H : 1 852 $kJ.mol^{-1}$ ✓✓ (2)

8.3 Energy released = 1 370 – 1 852 ✓
= –482 $kJ.mol^{-1}$ ✓ (2)

TOPIC 4: Intermolecular Forces and Chemistry of Water

WORKSHEET

MULTIPLE CHOICE

1. Which one of the following statements represents the best explanation for the term ‘electronegativity’?

A A measure of the tendency of an atom to attract a bonding pair of electrons.
B A measure of the tendency of an atom to attract an electron.
C A measure of the strength of a covalent bond.
D A measure of the strength of an ionic bond. (2)

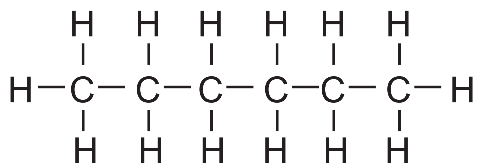
2. Sodium chloride ($NaC\ell$) is a solid which is soluble in water. Which one of the following describes the intermolecular forces that exist between sodium chloride and water in solution?

A Ion-dipole
B Dipole-dipole
C Ion-induced dipole
D Induced dipole-dipole (2)

3. Hydrogen bonding is a type of intermolecular force that can exist between the molecules of certain compounds. Which one of the statements below best describes the conditions under which hydrogen bonding is most likely to occur? It occurs between:

A small molecules which contain hydrogen atoms.
B molecules in which hydrogen is bonded to small atoms with high electronegativity.
C large molecules which contain both hydrogen and oxygen atoms.
D molecules in which hydrogen is bonded to small atoms with low electronegativity. (2)

4. Consider the structure of hexane.



A molecule of hexane is considered to be non-polar. Which one of the following statements best describes the reason why hexane is non-polar?

A Hexane contains only single bonds between atoms.
B The electronegativity difference between C and H atoms is so small as to be considered non-polar.
C Hexane is a linear molecule hence is symmetrical.
D The charge distribution of electrons within the hexane molecule is symmetrical.
(2)

LONG QUESTIONS

1. Calcium chloride is prepared according to the following balanced chemical equation:

$$Ca(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2\ (g)$$

Hydrochloric acid is produced for this preparation by the ionisation of hydrogen chloride gas in water.

1.1 Name the type of bonding that is present in a molecule of hydrogen chloride. (1)

1.2 Define the term 'electronegativity'. (2)

1.3 Make use of the Pauling scale of electronegativities, as provided in the Periodic Table, to explain the type of bonding found in hydrogen chloride and crystalline calcium chloride. (4)

1.4 HCl molecules are described as 'dipoles'. Explain what is meant by this term. (2)

1.5 Calcium chloride is soluble in water. The structure of its crystal lattice is broken down by the water molecules to form aqueous ions in solution.

1.5.1 Name the type of crystal lattice of which calcium chloride is an example. (1)

1.5.2 Name the types of intermolecular forces present between:
a) calcium chloride ions in the crystal lattice. (1)
b) the water molecules of the solvent. (1)
c) the water and the crystal lattice. (1)

1.5.3 Using diagrams to illustrate your answer, explain how the crystal lattice of calcium chloride is broken down during the dissolving process. (5)

2. Use only substances from the list below when answering Question 2.1 to 2.6 (Only write down the question number and the formula of the substance next to it.) The state symbols (phase indicators) represent the physical state of each of the substances at room temperature.

$SiO_2(s)$ $HC\ell(g)$ $H_2O(\ell)$ $PH_3(g)$ $Mg(s)$ $Br_2(g)$ $KF(s)$

Select one substance from the list that has:

2.1. pure covalent intramolecular bonds. (1)

2.2 a high melting point due to the strong electrostatic attraction between the cations and anions in the crystal lattice. (1)

2.3 hydrogen bonding intermolecular forces. (1)

2.4 a very high melting point due to its giant covalent network structure. (1)

2.5 delocalised valence electrons. (1)

2.6 dipole – dipole intermolecular forces. (1)

3. Consider the Table below which shows the boiling points of the halogens.

Halogens	F_2	Cl_2	Br_2	I_2
Boiling point (°C)	-188	-35	59	184

3.1 Name the specific type of interatomic bond that occurs between atoms in the F_2 molecule. (2)

3.2 The table show an increase in the boiling points of the halogens from F_2 to I_2. Explain this trend by making reference to the relevant intermolecular force between the halogen molecules and the factor influencing its strength. (4)

4. Consider the following pairs of substances.

HCl and CO $NaCl$ and CCl_4 KBr and H_2S CCl_4 and Br_2

Which of the pairs will have:

4.1 ion-dipole intermolecular forces? (2)

4.2 dipole – dipole intermolecular forces? (2)

4.3 ion – induced dipole intermolecular forces? (2)

4.4 induced dipole – induced dipole intermolecular forces? (2)

5. Water is considered to be a highly remarkable substance that has many properties that are beneficial to life forms on earth. One of the interesting factors with regards to this is the fact that ice is able to float on water.

5.1 Explain why ice is able to float on water. (2)

5.2 Why is this beneficial to aquatic life? (1)

CONSOLIDATION EXERCISE

TOTAL: 47 MARKS

1. Hydrogen fluoride (HF) can be prepared by treating calcium fluoride (CaF) with an acid.

1.1 Define the term 'electronegativity'. (2)

1.2 Use electronegativity differences to explain the difference in the type of bonding found in HF and CaF_2. (4)

1.3 Using a Lewis diagram, illustrate fully how bonding occurs in CaF_2. (4)

1.4 HF is described as a 'polar molecule'. Explain what is meant by this term. (2)

1.5 In fact, HF is an example of a group of three molecules which exhibit what is known as hydrogen bonding. What TWO identifying characteristics are crucial in a molecule being able to exhibit hydrogen bonding? (2)

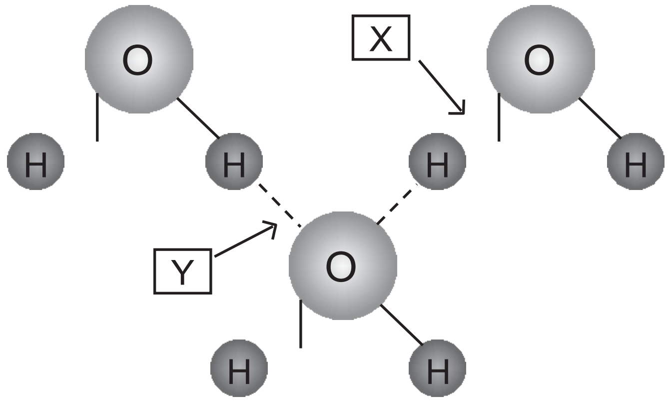
2. Two crystalline solids, P and Q have melting points of 710°C and 723°C respectively. At 700°C, substance P conducts electricity but Q does not. At 750°C, both P and Q conduct electricity.

2.1 What can be deduced from the melting points about the relative magnitude of the forces between the particles in P and Q? (2)

2.2 Explain the difference observed in electrical conductivity between P and Q. (4)

2.3 You are told that one of the solids is barium and the other is potassium iodide. Which is P and which is Q? (2)

3. Consider the diagram below, showing an arrangement of water molecules in the liquid phase.



3.1 Explain the term 'interatomic bond'. (1)

3.2 Name the specific type of interatomic bond represented by the letter X in the diagram. (2)

3.3 Define the term 'intermolecular force'. (2)

3.4 Name the specific type of intermolecular force represented by the letter Y in the diagram. (1)

3.5 State two properties of the oxygen atom that make this type of intermolecular force (Y) possible. (2)

3.6 What is the partial charge (δ^+ or δ^-) on the hydrogen atom in a water molecule? (1)

4. Diagram 1 below shows the crystal lattice structure of the giant ionic solid sodium chloride.

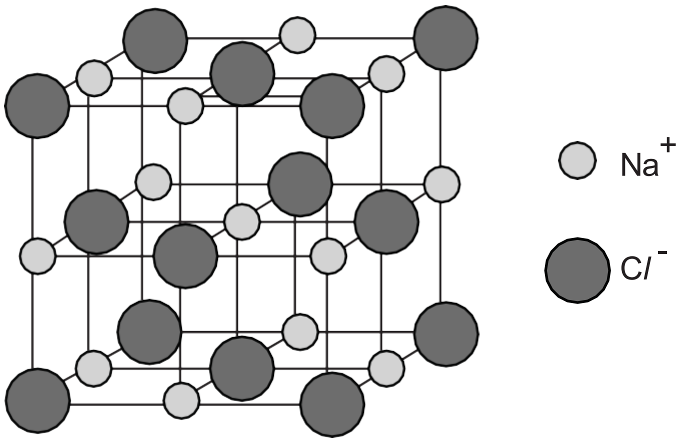


Diagram 1

4.1 Define the term 'ionic bond'. (2)

4.2 With reference to the crystal lattice structure, explain why sodium chloride has a very high melting point (801 °C). (3)

4.3 Sodium chloride dissolves in water. The ions are surrounded by water molecules as shown in Diagram 2 below.

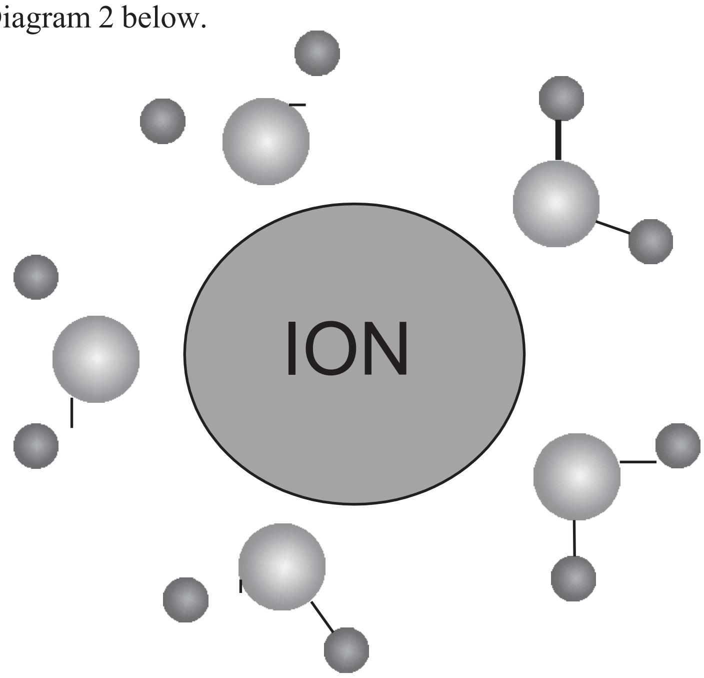


Diagram 2

a) Name the specific type of force between the ion and the water molecules. (1)

b) Is the ion shown in the above diagram a sodium ion (Na^+) or a chloride ion ($C\ell^-$)? Explain. (2)

c) A relatively large amount of water is needed to dissolve a small amount of sodium chloride. Explain why this is so by referring to the structure of sodium chloride and the strengths of the forces involved. (4)

5. **5.1** Explain what is meant by the term 'Heat of vaporisation'. (2)

5.2 Explain why in the early morning just before dawn breaks, the temperature of the air suddenly drops. (2)

(47)

MARKING GUIDELINES

MULTIPLE CHOICE

1. A ✓✓ This question is a direct understanding of the definition so learners must learn this. (2)

2. A ✓✓ Sodium chloride is an ionic compound; water is a dipole. (2)

3. B ✓✓ The criteria for a molecule to be able to exert hydrogen bonding intermolecular forces is when a H atom is bonded to a small atom of high electronegativity such as N, O or F. (2)

4. D ✓✓ Hexane is a non-polar molecule as it is perfectly symmetrical and thus the distribution of electrons in the electron cloud is symmetrical hence no region of δ^+ or δ^-. (2)

LONG QUESTIONS

1.1 Polar covalent bonding ✓ (1)

1.2 The measure of the tendency of an atom to attract ✓ a shared pair of electrons ✓ within the chemical bond. (2)

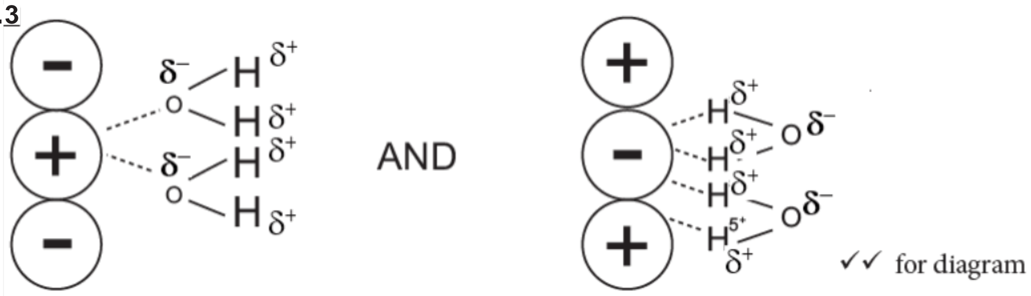
1.3 HCl Electronegativity difference = 3,5 – 2,1 = 1,4 ✓
$CaCl_2$ Electronegativity difference = 3.5 – 1,0 = 2,5 ✓
Pauling scale states that electronegativity difference greater than 2,0 will make the substance ionic in character. $CaCl_2$ is greater that 2,0 hence will be ionic ✓whereas HCl at 1,4 will be polar covalent in character as Pauling scale states that from 0 to 2,0, substance will be covalent. ✓ (4)

1.4 HCl molecules have two distinct regions of charge ✓ δ^+ and δ^- at either end of the molecule ✓ (2)

1.5 **1.5.1** Ionic crystal lattice ✓ (1)

1.5.2 a) ion – ion (ionic) ✓
b) hydrogen bonding (dipole) ✓
c) ion – dipole ✓ (3)

1.5.3



Polar water molecules surround the ions in the crystal lattice creating an ion-dipole intermolecular force. ✓ A single ion-dipole intermolecular force is not strong enough to overcome the very strong ion-ion forces within the lattice. ✓ More water molecules thus move to surround the ions to create a combined ion-dipole force that will overcome the forces within the crystal lattice. ✓ The ions are then removed from the lattice and go into solution. (5)

2.1 Br_2 or PH_3 — Atoms in the molecule with equal electronegativities, hence electronegativity difference of 0, hence a pure covalent bond (non-polar) ✓ (1)

2.2 KF — This is the only ionic substance in the list and contains cations and anions. These are very strong forces of attraction, thus a very high boiling point ✓ (1)

2.3 H_2O — H is bonded to the small O atom which has a high electronegativity. ✓ (1)

2.4 SiO_2 — This is solid made of covalent bonds only hence called a covalent network solid. These covalent bonds are very strong hence a very high melting point. ✓ (1)

2.5 Mg — A pure metal with metallic bonding between atoms, Contains delocalised valence electrons. ✓ (1)

2.6 HCl — There is an electronegativity difference of 1,4 between atoms, hence it is a dipole. ✓ (1)

3. 1 Non-polar ✓ covalent ✓ (The electronegativity difference between two F atoms is 0, hence will be non-polar). (2)

3.2 All halogen molecules will have London/dispersion intermolecular forces between them ✓. The size of the halogen molecules increases as one moves down the Table. This means that the electron cloud density increases allowing for a greater surface area ✓ meaning that there will be more points of contact for intermolecular forces to occur. There will be stronger intermolecular forces ✓ between the molecules and more energy needed ✓ to overcome these forces. (4)

4.1 KBr and H_2S ✓✓ (2)
4.2 HCl and CO ✓✓ (2)
4.3 NaCl and CCl_4 ✓✓ (2)
4.4 CCl_4 and Br_2 ✓✓ (2)

5.1 Ice has a lower density compared to liquid water at around temperatures of 4 °C ✓. This is due to the fact that the hydrogen bonding intermolecular forces are further apart in the solid phase compared to water in the liquid phase at these very cold temperatures. ✓ (Thus due to the increase in the distance when the intermolecular forces act in the solid phase the density of ice decreases and it floats. In the liquid phase at very cold temperatures, the water molecules can approach each other more closely, hence the density of water increases at these temperatures). (2)

5.2 Ice will float, cold water will sink ✓ – thus aquatic life can survive at the bottom of the ocean/river. (1)

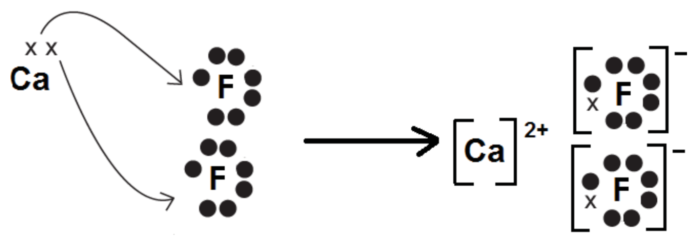
CONSOLIDATION EXERCISE

TOTAL: 47 MARKS

1.1 The measure of the amount of attraction ✓ an atom has on a shared pair of electrons ✓ (2)

1.2 HF : electronegativity difference = 1,9 ✓
CaF : electronegativity difference = 3,0 ✓
HF will be expected to be covalent ✓ although it does have some ionic character due to the relatively large electronegativity difference. CaF_2 will be strongly ionic ✓ due to a very high electronegativity difference. (4)

1.3



(4)

1.4

HF has two distinct regions of charge on the molecule ✓✓ $\overset{\delta^+}{H} - \overset{\delta^-}{F}$ (2)

1.5 The H atom in the molecule must be bonded to a small atom ✓ of very high electronegativity.✓ (2)

2.1 Very high melting points indicate that there are very strong intermolecular forces between the particles in each solid. ✓✓ (2)

2.2 At 700°C, both P and Q are still in the solid phase. The fact that P is able to conduct electricity tells us it must have charges that are free to move in the solid phase ✓. This means that P must be a metal with delocalised electrons hence the conductivity ✓. Q has no free charges in the solid phase ✓ thus will not be able to conduct electricity, thus Q cannot be a metallic substance. Q conducts when molten therefore it is an ionic substance. ✓ (4)

2.3 P = Barium ✓ (metallic substance thus has delocalised electrons hence conductivity)
Q = Potassium iodide ✓ (ionic substance where the ions are held in the crystal lattice and not free to move) (2)

3.1 A bond that exists within a molecule between the atoms in that molecule. ✓ (1)

3.2 Polar ✓ covalent bond ✓ (It will be polar due to the electronegativity difference between H and O) (2)

3.3 This is the force of attraction between molecules in a system. ✓✓ (2)

3.4 Hydrogen bonding intermolecular force. ✓ (1)

3.5 O is a very small atom in terms of its atomic size. ✓
O has a very high electronegativity. ✓ (2)

3.6 δ^+ ✓
(H will not have any electrons near its nucleus as the high electronegativity of O will pull the shared electron pair away from the H atom and towards itself, leaving the H atom δ^+) (1)

4.1 Force of attraction that occurs between cations and anions in a crystal lattice ✓✓
(Bond formed by transfer of electrons) ✓ (2)

4.2 The Na^+ cations are surrounded by Cl^- anions and vice versa. This means that there are many strong electrostatic forces of attraction ✓ between the cations and anions leading to very strong inter-particle (inter-ionic) forces. ✓ Large amounts of energy will be needed to overcome these forces, ✓ hence a very high melting point. (3)

4.3 a) Ion-dipole intermolecular force ✓ (1)

4.3 b) Na^+ ✓ – the O end of the water molecule is attracted to the ion. The O end is δ^- thus it is attracted to a positive ion, hence the sodium cation. ✓ (2)

4.3 c) The ion-dipole force between the water molecule and the ion is a strong intermolecular force, yet is not stronger that the ion-ion electrostatic forces within the crystal lattice. ✓✓ Water thus needs to accumulate around an ion so that the combined ion-dipole intermolecular forces ✓eventually will overcome the ion-ion forces ✓ and the ion is only then removed from the lattice and goes into solution.(4)

5.1 This is the amount of energy one mole of water will absorb before it is able to escape to the gaseous phase ✓✓ (2)

5.2 Energy is absorbed by the water molecules that sit on grass and plants (dew) just before the sun rises. ✓ This allows the water molecule to escape to the gas phase with a certain kinetic energy. This means that energy is taken away from the system hence it begins to feel much colder as there is less energy in the system's surroundings. ✓ (2)

FORMAL EXPERIMENT

FORMAL EXPERIMENT

GRADE 11 TERM 1: PHYSICS

Verification of Newton's Second Law of Motion

a \ F 60 marks

a \ $\frac{1}{m}$ 50 marks

This section provides guidance and assessment of the learner's knowledge and understanding when carrying out a virtual experiment using the NECT video of the same name.

If your class is carrying out the experiment using laboratory apparatus and taking down their own results, you must set up your classroom appropriately and give the learners the relevant instructions. You may find it useful to refer to the Technical Instructions which precede the Learner's Instructions while preparing for this experiment.

If the learners are proceeding with the virtual experiment, then continue with the NECT programme by using the information, handouts and marking guidelines contained in this section of this Resource Book.

Formal Experiment

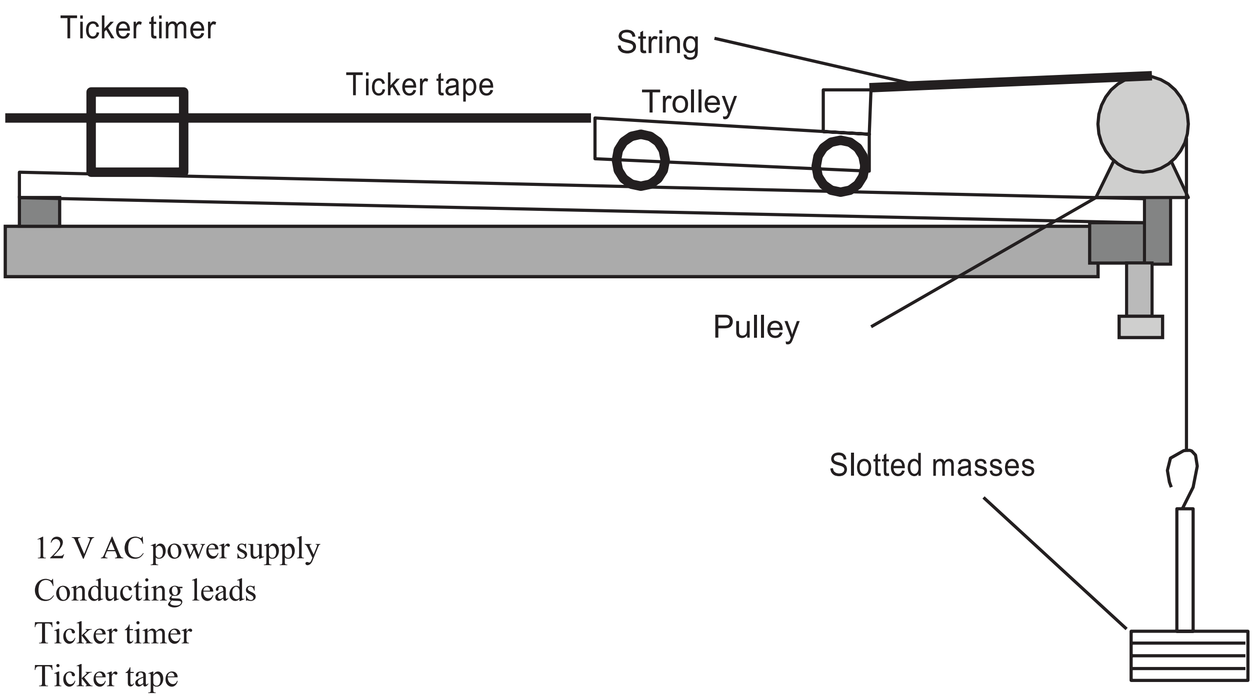
TECHNICAL INSTRUCTIONS

Newton's Second Law of Motion: When a net force, F_{net}, is applied to an object of mass, m, it accelerates in the direction of the net force. The acceleration, a, is directly proportional to the net force and inversely proportional to the mass.

$$F_{net} = ma$$

AIM: To verify the relationship between acceleration and net force of the system of constant mass. **60 marks**

APPARATUS:



12 V AC power supply
Conducting leads
Ticker timer
Ticker tape
Trolley track
Trolley
10 g slotted mass holder with 4 × 10 g mass pieces
Light inextensible string
Clamp (to hold the pulley on the track)
Freely running (almost frictionless) pulley
Books (to raise one end of the trolley track)
Mass meter
Prestik

METHOD

A. Setting up a friction compensated track

1. Clamp a pulley to the one end of the track.
2. Place a stopper on the track in front of the pulley to stop the trolley before it bumps into the pulley.
3. Position the track at the edge of a table so that when a weight is hung from the pulley it can fall freely to the ground.
4. Connect the ticker timer unit to the AC power pack with the two connecting leads.
5. Position the ticker timer unit on the other end of the track. Ensure it is firmly in place by attaching it to the track with some Prestik.
6. Raise the end of the track which has the ticker timer unit on it by placing a few books under it.
7. Measure a length of ticker tape equal to the length of the track + 10 cm. Run the ticker tape through the ticker tape unit and attach the tape to one end of the trolley.
8. Place the trolley on the raised end on the track and hold it in a position which will allow it to run down the track to the other end.
9. Start the ticker timer and release the trolley, allowing it to run freely down the track while it pulls the tape through the timer.
10. Stop the timer when the trolley reaches the stopper at the other end.
11. Examine the ticker tape as follows:
    - 11.1 If the gaps between the dots on the tape increase gradually along the length of the tape, the trolley is accelerating. Lower the height of the track a little (by removing a book or two). Repeat the procedure from step 6.
    - 11.2 If the gaps between the dots on the tape are of equal length, the trolley is running at constant velocity. Move on to Part B of the procedure.

B. Investigating the relationship between acceleration and net force on a system with constant mass.

1. Measure the mass of the trolley.
2. Ensure that the track is stable and secure.
3. Cut a length of string which extends from the trolley at its maximum height and for about 5 cm over the pulley.
4. Attach one end of the string to the trolley and the other end to the hook of the slotted mass holder.

5. Place four of the slotted mass pieces on the trolley.
6. Feed a new length of ticker tape through the ticker timer and attach it to the trolley. Label the tape with the mass of the slotted mass holder (and the mass pieces on it).
7. Hold the trolley on the track while you position the string over the pulley. Hook the slotted mass holder onto the other end of the string and allow it to hang freely over the edge of the table.
8. Start the timer and release the trolley and the mass holder so that the trolley accelerates down the track as the mass holder falls to the ground.
9. Repeat steps 6 to 8 four more times, by moving one of the four slotted mass pieces from the trolley to the mass holder each time.

NAME:____GRADE:_________

Formal Experiment

NEWTON'S SECOND LAW OF MOTION

THEORY

Newton's Second Law of Motion: When a net force, F_{net}, is applied to an object of mass, m, it accelerates in the direction of the net force. The acceleration, a, is directly proportional to the net force and inversely proportional to the mass.

$$F_{net} = ma$$

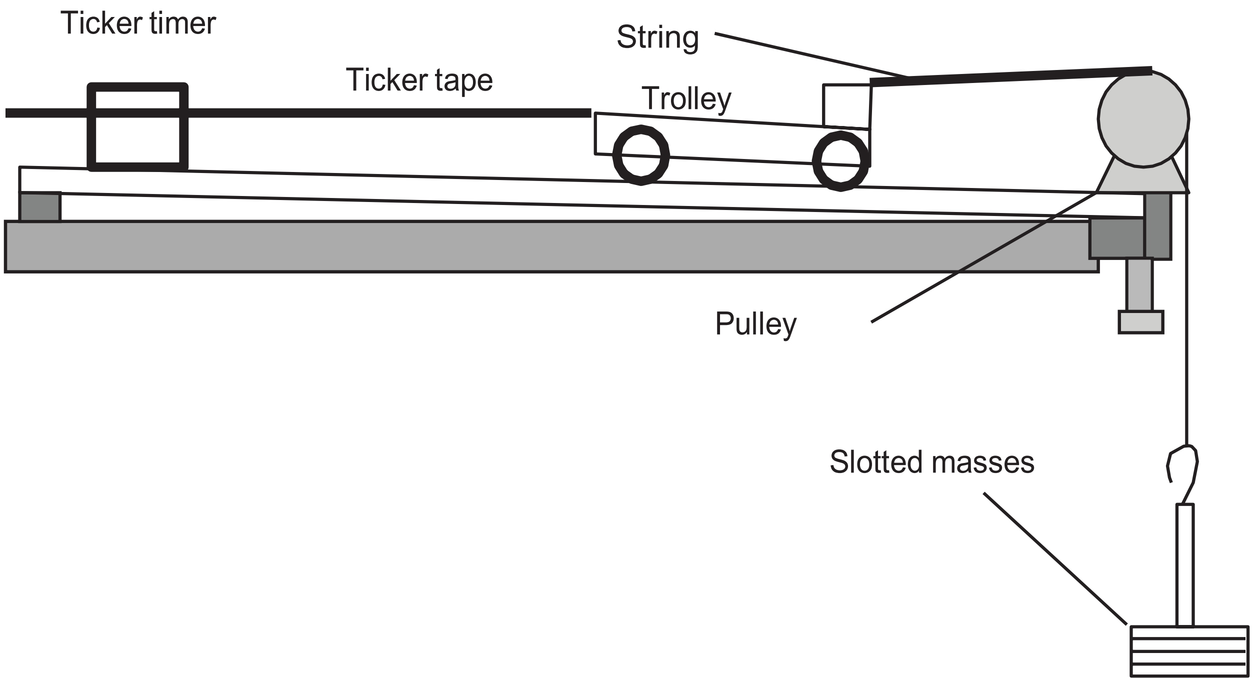
AIM: To verify the relationship between acceleration and net force of the system of constant mass.

60 marks

APPARATUS

12 V AC power supply
Conducting leads
Ticker timer
Ticker tape
Trolley track
Trolley
10 g slotted mass holder with 4 × 10 g mass pieces
Light inextensible string
Clamp (to hold the pulley on the track)
Freely running (almost frictionless) pulley
Books (to raise one end of the trolley track)
Mass meter
Prestik

METHOD



A. Setting up a friction compensated track

1. Clamp a pulley to the one end of the track.
2. Place a stopper on the track in front of the pulley to stop the trolley before it bumps into the pulley.
3. Position the track at the edge of a table so that when a weight is hung from the pulley it can fall freely to the ground.
4. Connect the ticker timer to the AC power pack with the two connecting leads.
5. Position the ticker timer on the other end of the track. Ensure it is firmly in place by attaching it to the track with some Prestik.
6. Raise the end of the track which has the ticker timer unt on it by placing a few books under it.
7. Measure a length of ticker tape equal to the length of the track + 10 cm. Run the ticker tape through the ticker timer and attach the tape to one end of the trolley.
8. Place the trolley on the raised end on the track and hold it in a position which will allow it to run down the track to the other end.
9. Start the ticker timer and release the trolley, allowing it to run freely down the track while it pulls the tape through the timer.
10. Stop the timer when the trolley reaches the stopper at the other end.
11. Examine the ticker tape as follows:

EXPERIMENT

11.1 If the gaps between the dots on the tape increase gradually along the length of the tape, the trolley is accelerating. Lower the height of the track a little (by removing a book or two). Repeat the procedure from step 6.

11.2 If the gaps between the dots on the tape are of equal length, the trolley is running at constant velocity. Move on to Part B of the procedure.

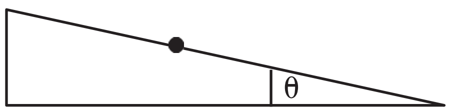
B. Investigating the relationship between acceleration and net force on a system with constant mass.

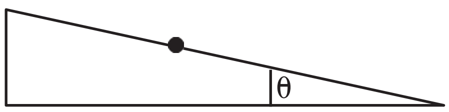
1. Measure the mass of the trolley.
2. Ensure that the track is stable and secure.
3. Cut a length of string which extends from the trolley at its maximum height and for about 5 cm over the pulley.
4. Attach one end of the string to the trolley and the other end to the hook of the slotted mass holder.
5. Place four of the slotted mass pieces on the trolley.
6. Feed a new length of ticker tape through the ticker timer and attach it to the trolley. Label the tape with the mass of the slotted mass holder (and the mass pieces on it).
7. Hold the trolley on the track while you position the string over the pulley. Hook the slotted mass holder onto the other end of the string and allow it to hang freely over the edge of the table.
8. Start the timer and release the trolley and the mass holder so that the trolley accelerates down the track as the mass holder falls to the ground.
9. Repeat steps 6 to 8 four more times, by moving one of the four slotted mass pieces from the trolley to the mass holder each time.

OBSERVATIONS AND RESULTS

1. Draw and label the forces acting on the trolley when it is a) running at constant velocity on the track and b) accelerating down the track.

   a. At constant velocity on the track **b.** Accelerating on the track





(7)

EXPERIMENT

2. Name the independent variable: ________________________________ (1)

3. Name the dependent variable: ________________________________ (1)

4. Name two control variables: ________________________________ (2)

5. Analyse each ticker tape as follows:

   5.1 Choose a section of tape where the gaps between the dots are easy to see.

   5.2 Mark off consecutive segments of five gaps between dots until you have three consecutive segments of five gaps on each tape.

   5.3 Record the length of each of the segments for each tape in the table below.

   5.4 Calculate the average speed in the first and last segment.

   5.5 Calculate the acceleration of the trolley.

Mass on holder (m) (kg)	Force of holder (mg) ( )	Segment 1 (m)	Segment 2 ( )	Segment 3 (m)	Average Speed 1 (v_1) $\frac{Segment\ 1}{0,1}$ ( )	Average Speed 3 (v_3) $\frac{Segment\ 3}{0,1}$ ( )	Acceleration $\frac{v_3 - v_1}{0,2}$ ( )

(17)

ANALYSIS AND INTERPRETATION

6. Plot a graph of acceleration against force using the graph paper provided. (7)

7. Extend the graph so that it cuts the y-axis.

8. Comment on the shape of the graph. (2)

Deduce the relationship between the acceleration of the trolley and the net force acting on the trolley. (5)

9. Calculate the gradient of the graph. Show the coordinates that you use for this calculation on the graph. (4)

10. What quantity does the gradient of the graph represent? Explain briefly. (4)

11. Compare the value of the gradient of the graph with the total mass of the accelerating system. Calculate the % error. (Total mass = 300 g) (6)

CONCLUSION

12. (2)

EXPERIMENT

13. Comment on the experimental procedure:

Give a suggestion of how to take more reliable results. (1)

PART C 50 MARKS

AIM: To verify the relationship between acceleration and mass of the system when a constant net force acts on it.

VARIABLES

Independent variable: ______________________________ (2)

Dependent variable: ______________________________ (2)

Control variable: ______________________________ (2)

METHOD

Write down the method for this part of the investigation. (5)

OBSERVATIONS AND RESULTS

1. Table of results: Acceleration of the system vs mass for a constant net force

Calculate and complete the values missing from the table of results. (20)

Total mass of system (m) (kg)	Inverse of total mass $\left(\frac{1}{m}\right)$ (kg^{-1})	Segment 1 (m)	Segment 2 (m)	Segment 3 (m)	Average Speed 1 (v_1) $\frac{Segment\ 1}{0,1}$ (m.s^{-1})	Average Speed 3 (v_3) $\frac{Segment\ 3}{0,1}$ (m.s^{-1})	Acceleration $\frac{v_3 - v_1}{0,2}$ (m.s^{-2})
0,300		0,012	0,029	0,045			
0,290		0,031	0,048	0,065			
0,280		0,045	0,063	0,080			
0,270		0,021	0,039	0,057			
0,260		0,056	0,075	0,094			

ANALYSIS AND INTERPRETATION

4. Plot a graph of acceleration against the inverse of mass (on the graph paper which is available on the next page). (7)

5. Describe the shape of the graph. (2)

____

____

____

____

6. Describe the relationship between acceleration and the inverse of mass. (2)

____

____

____

____

EXPERIMENT

6. Give a reason why it is much more useful to plot a graph of acceleration against the inverse of mass, than it is to plot a graph of acceleration against mass. (5)

CONCLUSION

7. (3)

Formal Experiment

MARKING GUIDELINES

110 MARKS

Newton's Second Law of Motion: When a net force, F_{net}, is applied to an object of mass, m, it accelerates in the direction of the net force. The acceleration, a, is directly proportional to the net force and inversely proportional to the mass.

$$F_{net} = ma$$

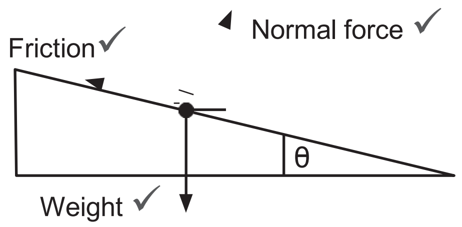
PART B **50 MARKS**

AIM: To verify the relationship between acceleration an net force on a system of constant mass.

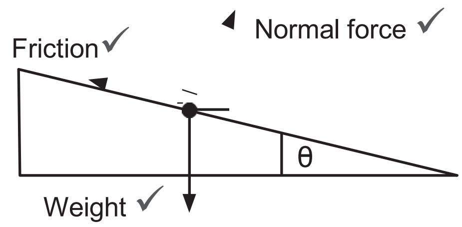
OBSERVATIONS AND RESULTS

1. Draw and label the forces acting on the trolley when it is a) running at constant velocity on the track and b) accelerating down the track.

   a. At constant velocity on the track



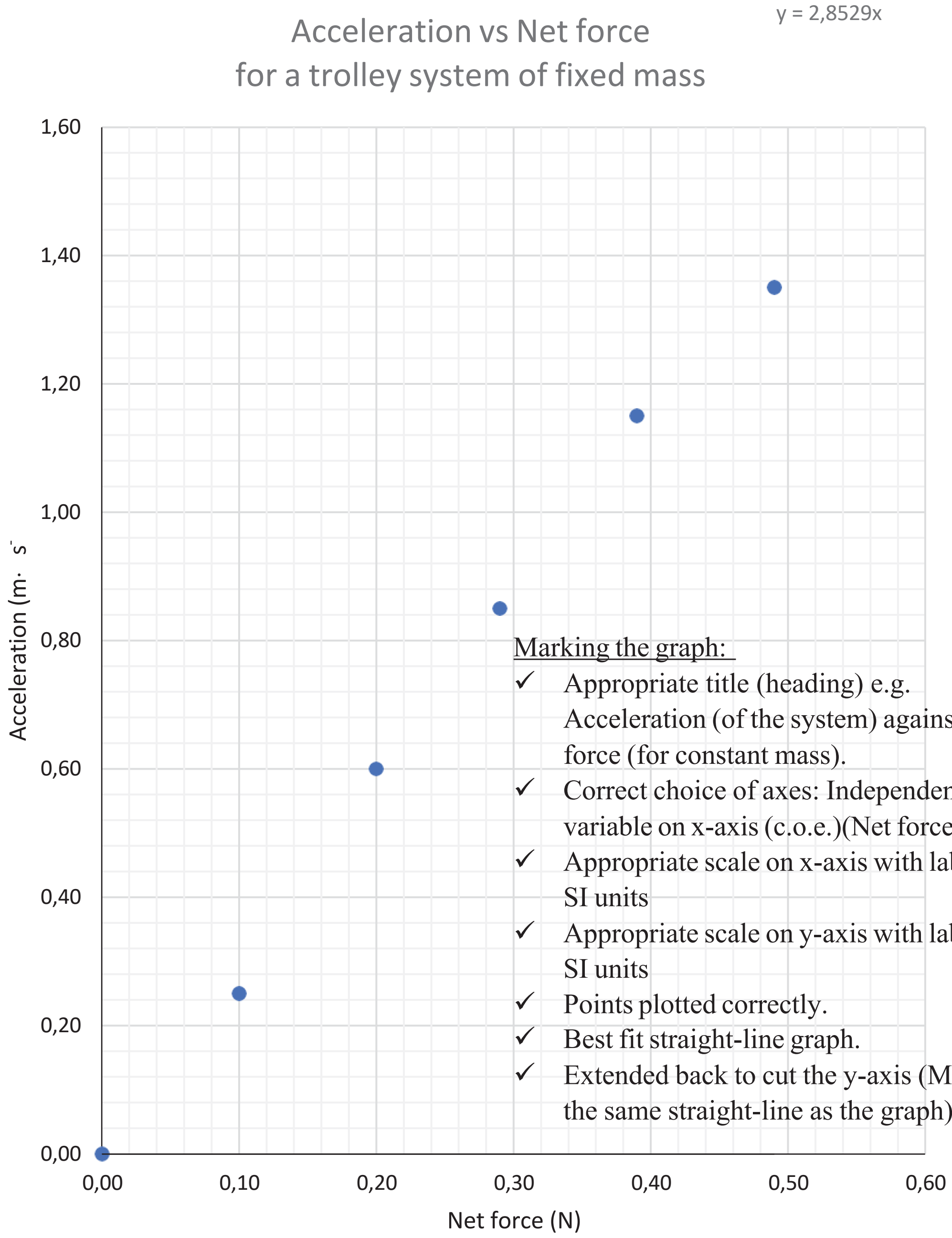
   b. Accelerating on the track



No net force ✓ Net force > 0 (7)

2. Name the independent variable: *Net force* ✓ (1)
3. Name the dependent variable: *Acceleration* ✓ (1)
4. Name two control variables: *Mass of the system* ✓ (2)
   Angle of the inclined plane (friction compensated plane) ✓
5. Analyse each ticker tape as follows:
   - 5.1 Choose a section of tape where the gaps between the dots are easy to see.
   - 5.2 Mark off consecutive segments of five gaps between dots until you have three consecutive segments of five gaps on each tape.
   - 5.3 Record the length of each of the segments for each tape in the table below.
   - 5.4 Calculate the average speed in the first and last segment.
   - 5.5 Calculate the acceleration of the trolley. (18)

Mass on holder (m) (kg)	Force of holder (mg) (N) ✓	Segment 1 Values ✓ (m)	Segment 2 SI units (m) ✓	Segment 3 Values ✓ (m)	Average Speed 1 (v_1) $\frac{Segment\ 1}{0,1}$ (m.s−1) ✓	Average Speed 3 (v_3) $\frac{Segment\ 3}{0,1}$ (m.s−1) ✓	Acceleration $\frac{v_3 - v_1}{0,2}$ (m.s−2) ✓
0,010	0,10 ✓	39,0	41,0	44,0	0,39 ✓	0,44 ✓	0,25 ✓
0,20	0,20	54,0	61,0	66,0	0,54	0,66	0,60 ✓
0,030	0,29 ✓	62,0	68,0	79,0	0,62 ✓	0,79 ✓	0,85 ✓
0,040	0,39	86,0	98,0	109,0	0,86	1,09	1,15 ✓
0,050	0,49	90,5	105,0	118,0	0.91	1,18	1,35 ✓



Marking the graph: (7)

- ✓ Appropriate title (heading) e.g. Acceleration (of the system) against net force (for constant mass).
- ✓ Correct choice of axes: Independent variable on x-axis (c.o.e.)(Net force)
- ✓ Appropriate scale on x-axis with label and SI units
- ✓ Appropriate scale on y-axis with label and SI units
- ✓ Points plotted correctly.
- ✓ Best fit straight-line graph.
- ✓ Extended back to cut the y-axis (Must be the same straight-line as the graph)

EXPERIMENT

8. Comment on the shape of the graph.

A straight-line graph ✓ *cuts the y-axis at the origin.*✓ (2)

Deduce the relationship between the acceleration of the trolley and the net force acting on the trolley.

The equation of the graph is y = mx✓ *where m is the gradient of the graph* ✓

Y-values represent acceleration of the trolley. ✓

X-values represent the net force. ✓

Since the graph passes through the origin, the acceleration is directly proportional to the net force acting on it. ✓ (5)

9. Calculate the gradient of the graph. Show the coordinates that you use on the graph.

$gradient = \frac{\Delta a}{\Delta F}$ or $\frac{\Delta y}{\Delta x}$ method✓

$= \frac{1,40 - 0,0}{0,49 - 0,0}$ Using the appropriate values of the two coordinates✓ shown on the graph✓

$= \approx 2,86$ accurate calculation ✓ SI units not required. (4)

10. What quantity does the gradient of the graph represent? Explain briefly.

$F = ma$ ✓ therefore $a = \frac{F}{m}$ ✓ (Newton's second law)

From the graph: $a = kF$ where k is the gradient of the graph.✓

Therefore $k = \frac{1}{m}$ ✓ OR The gradient equals the inverse of the mass of the system. (4)

11. Compare the value of the gradient of the graph with the total mass of the accelerating system. Calculate the % error.

Find the inverse of the gradient ✓ *(0,350)*

Compare inverse of gradient with the total mass of the accelerating system.✓

Comment on % error

$\% \ error = \frac{\text{Total mass of system - inverse of gradient}}{\text{Total mass of system}} \times 100\%$ ✓ *method*

$= \frac{0,300 - 0,350}{0,300} \times 100\%$ (for example)✓

= 16,7 %✓

Fairly low percentage error (therefore results are reasonably reliable.) ✓ (6)

CONCLUSION

12. *The acceleration is directly proportional to the net force* ✓ *provided the mass of the system remains constant.* ✓ (2)

13. Comment on the experimental procedure:

ANY VALID SUGGESTION ✓ *e.g.*
The results would be more reliable if for each set of readings three ticker tapes were run through.
The average of the acceleration could be calculated. This would give a more reliable result. (1)

PART C — 50 MARKS

AIM: To verify the relationship between acceleration and mass of the system when a constant net force acts on it.

1. VARIABLES

Independent variable: *Mass (of the system)* ✓✓ (2)
Dependent variable: *Acceleration (of the system)* ✓✓ (2)
Control variable: *Constant net force* ✓✓ (2)

2. METHOD

Write down the method for this part of the investigation.

Learners will use their own words – they must essentially plan in a similar way. (5)

1. *Hang one slotted mass on the mass hanger.* ✓
2. *Place the remainder of the slotted mass pieces on the trolley.* ✓
3. *Attach the ticker tape and the mass hanger to the trolley.* ✓
4. *Allow the trolley to accelerate down the track.* ✓
5. *Repeat steps 3 and 4 four more times, removing one mass piece from the trolley each time, until the trolley runs down the track without any mass pieces on it.* ✓

OBSERVATIONS AND RESULTS

3. (20)

Total mass of system (m) (kg)	Inverse of total mass $\left(\frac{1}{m}\right)$ (kg^{-1})	Segment 1 (m)	Segment 2 (m)	Segment 3 (m)	Average Speed 1 (v_1) $\frac{Segment\ 1}{0,1}$ (m.s^{-1})	Average Speed 3 (v_3) $\frac{Segment\ 3}{0,1}$ (m.s^{-1})	Accelera-tion $\frac{v_3 - v_1}{0,2}$ (m.s^{-2})
0,300	3,33✓	0,012	0,029	0,045	0,12✓	0,45✓	1,64✓
0,290	3,45✓	0,031	0,048	0,065	0,31✓	0,65✓	1,70✓
0,280	3,57✓	0,045	0,063	0,080	0,45✓	0,80✓	1,75✓
0,270	3,70✓	0,021	0,039	0,057	0,21✓	0,57✓	1,80✓
0,260	3,85✓	0,056	0,075	0,094	0,56✓	0,94✓	1,90✓

ANALYSIS AND INTERPRETATION

4. Plot a graph of acceleration against the inverse of mass (on the graph paper which is available on the next page.

Marking the graph: (7)

✓Appropriate title (heading) e.g. Graph of acceleration (of the system) against net force (for constant mass).

✓Correct choice of axes: Independent variable on x-axis (c.o.e.)

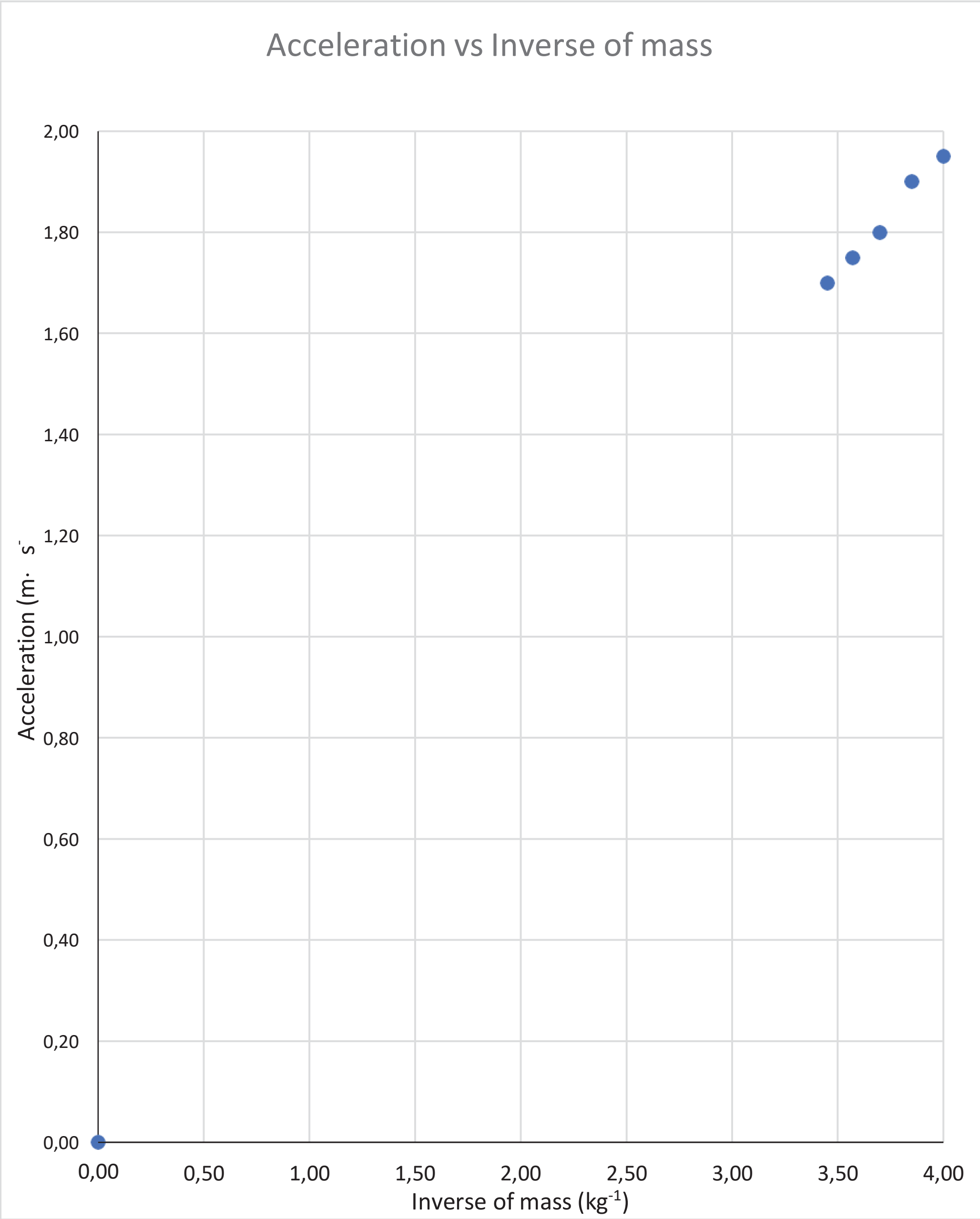
✓Appropriate scale on x-axis with label and SI units

✓Appropriate scale on y-axis with label and SI units

✓Points plotted correctly

✓Best fit straight-line graph

✓Extended back to cut the y-axis (Must be the same straight-line as the graph)



5. Describe the shape of the graph.

The graph is a straight-line graph✓ passing through the origin.✓ (2)

6. Describe the relationship between acceleration and the inverse of mass.

The acceleration of the system is directly proportional ✓ to the inverse of its mass ✓ (provided the force remains constant). Remains constant.)

OR The acceleration of the system is inversely✓ proportional to its mass ✓ (provided the force remains constant). (2)

Give a reason why it is much more useful to plot a graph of acceleration against the inverse of mass, than to plot a graph of acceleration against mass.

The straight-line graph through the origin confirms that $y = mx$ ✓ therefore we know that acceleration and mass are inversely proportional to each other. ✓

If we had plotted acceleration against mass the graph would have been a hyperbola✓

However to confirm the inverse relationship we should then plot the graph of acceleration against the inverse of mass. ✓
By plotting it in the first place we have saved time and effort. ✓ (5)

7. CONCLUSION:

The acceleration of the system is inversely✓ *proportional to its mass*✓
provided the net force remains constant. ✓ (3)

ASSESSMENTS

Gr11_Physical_Science_Term1_Resource_Book.indb 81 2018/12/24 8:24:51 AM

Topic 1: Vectors in two dimensions

QUESTIONS

MULTIPLE CHOICE

1. The following three forces act on an object in the horizontal plane. A 30 N force acts to the right, a 50 N force acts to the left and a 40 N force acts to the right. The resultant force acting on the object is ...

   A 120 N.

   B 20 N.

   C 20 N to the right.

   D 60 N to the left. (2)

2. Two forces of magnitude 50 N and 80 N act on an object. Which of the following forces cannot be the magnitude of the resultant of these two forces?

   A 30 N

   B 50 N

   C 130 N

   D 20 N (2)

3. The following two forces act on an object: A 180 N horizontal force acts to the right and a 100 N force acts upwards in the vertical plane. The magnitude of the resultant force acting on the object is ...

   A 280 N.

   B 80 N.

   C 205,91 N.

   D 0 N. (2)

4. A man hikes 8 km east and 6 km north. The direction of his resultant displacement is:

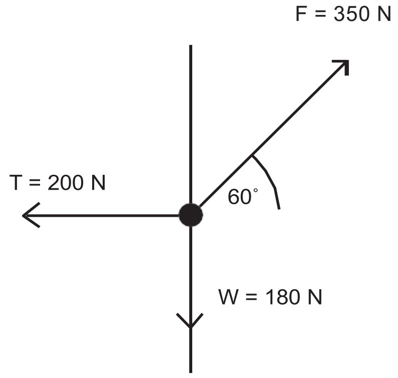
   A on a bearing of 036,9°.

   B on a bearing of 053,1°.

   C 53,1° north of east.

   D 36,9° east of north. (2)

5. Three forces F, T and W act on an object as shown in the diagram below.



The magnitude and direction of the resultant force in the <u>horizontal plane</u> is ...

A 150 N to the right.
B 200 N to the left.
C 175 N to the right.
D 25 N to the left. (2)

6. Refer to question 1.5. The magnitude and direction of the resultant force in the <u>vertical plane</u> is ...

A 180 N down.
B 123,11 N upwards.
C 170 N upwards.
D 123,11 N downwards. (2)

LONG QUESTIONS

1. A horizontal force of 300 N is applied to an object to the right while an upward vertical force of 400 N is applied at the same time.
   1.1 Define a vector. (2)
   1.2 Define a resultant vector. (2)
   1.3 Draw a neat, fully labelled vector diagram of these forces in the Cartesian plane, using the tail-to-head method. (2)
   1.4 Determine the magnitude and direction of the resultant force acting on the object. (4)

[10]

2. The following four forces act on an object. A 40 N force acts vertically upwards, a 30 N force acts horizontally to the right, a 90 N force acts at 45° below the horizontal and to the left and a 50 N force acts horizontally to the left.
   2.1 Draw a neat, fully labelled vector diagram of the four forces in the Cartesian plane (not necessarily to scale). (4)
   2.2 Determine the magnitude and direction of the horizontal and vertical components of the 90 N force. (6)
   2.3 Determine the magnitude and direction of the resultant force acting on the object. (5)

[15]

ASSESSMENTS

3. An aircraft flies 30 km north, then 40 km east, then 60 km south and then 60 km west.
   3.1 Define displacement. (2)
   3.2 Draw a neat, fully labelled vector diagram (tail-to-head method) of these displacements. Draw in the resultant displacement (R). (5)
   3.3 Draw a neat, fully labelled vector diagram (tail-to-tail method) of the resultant horizontal (R_x) and vertical (R_y) components of these displacements. Draw in the resultant displacement (R). (5)
   3.4 Calculate the magnitude and direction of the resultant displacement of the aircraft. State the direction as a bearing. (4)

[16]

4. A large crate is pulled along horizontal ground by a chain which makes an angle of 30° above the ground. The chain applies a force of 500 N.
   4.1 Draw a neat, fully labelled vector diagram of the force applied by the chain as well as the horizontal and vertical components of the 500 N force. (3)
   4.2 Calculate the magnitude of the force with which the crate is pulled along the ground by the chain. (2)
   4.3 Calculate the magnitude of the force with which the crate is lifted by means of the chain. (2)
   4.4 List any other forces which act on the crate in the horizontal and vertical planes. (3)

[10]

5. Three forces act on an object. F_1 = 35 N acts vertically upwards, F_2 = 65 N acts at 45° above the horizontal and to the right, F_3 = 50 N acts 30° below the horizontal and to the right.
   5.1 Distinguish between a vector and a scalar quantity. (3)
   5.2 Draw a neat, fully labelled vector diagram of the three forces in the Cartesian plane (acting at the origin). (3)
   5.3 Determine the magnitude and direction of the resultant force acting on the object. Draw any relevant vector diagrams to support your answer. (9)

[15]

6. Consider the following three forces which act simultaneously on the same object: F_1 = 600 N acts on a bearing of 330°, F_2 = 400 N acts on a bearing of 270°, F_3 = 400 N acts on a bearing of 190°.
   6.1 Use a ruler, pencil, protractor and a scale of **1 cm : 100 N** to find the magnitude and direction of the resultant force (using the tail-to-head method). Label your vector diagram clearly. (10)
   6.2 State the magnitude and direction of a fourth force F_4 which could be applied to the object so that the resultant force on the object becomes zero. (2)

[12]

MARKING GUIDELINES

MULTIPLE CHOICE

1. C ✓✓ $R = (+30) + (-50) + (+40) = +20\text{ N}$ to the right [CL2] (2)

2. D ✓✓ The maximum resultant force is achieved when the two forces act in the same direction:

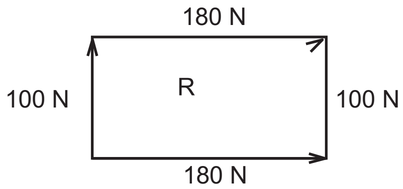
$$R = (+50) + (+80) = +130\text{ N}$$

The minimum resultant force is achieved when the two forces act in opposite directions:

$$R = (+80) + (-50) = +30\text{ N}$$

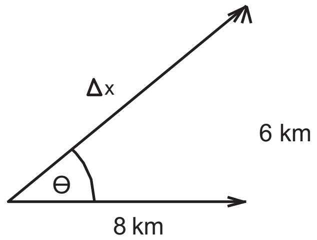
Any resultant force between 30 N and 130 N can be achieved by increasing the angle between the two forces, from 0° to 180°.
It is impossible to obtain a resultant of 20 N from these two forces. [CL2] (2)

3. C ✓✓



$R^2 = 100^2 + 180^2$
$R^2 = 42\ 400$
$R = \sqrt{42\ 400} = 205,91\text{ N}$ [CL2] (2)

4. B ✓✓



$\theta = \tan^{-1}\left(\frac{6}{8}\right) = 36,9°$
Bearing is measured clockwise from north, therefore the bearing is
90° – 36,9° = 053,1° [CL3] (2)

5. D ✓✓ $F_x = F\cos\theta = 350\cos 60° = 175\text{ N}$ to the right
$R_x = +175 - 200 = -25\text{ N}$ therefore $R_x = 25\text{ N}$ to the left [CL2] (2)

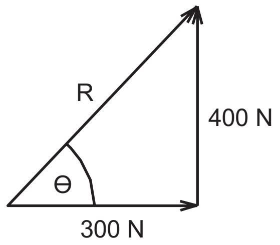
6. B ✓✓ $F_y = F\sin\theta = 350\sin 60° = 303,11\text{ N}$ upwards
$R_y = +303,11 - 180 = +123,11\text{ N}$ upwards [CL2] (2)

LONG QUESTIONS

1.1 A physical quantity which has magnitude ✓ (size) and direction ✓. [CL1] (2)

1.2 The sum of two or more vectors. ✓✓ [CL1] (2)

1.3



✓Correct vectors placed tail-to-head.
✓Correct resultant.

[CL2] (2)

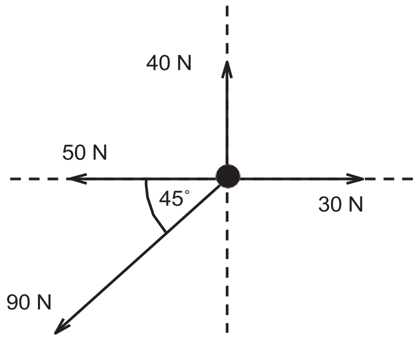
1.4 $R^2 = 300^2 + 400^2$ ✓

$R = \sqrt{250\ 000} = 500\ \text{N}$ ✓

$\theta = \tan^{-1}\left(\frac{400}{300}\right) = 53{,}1°$ ✓

$R = 500\ \text{N}$ at 53,1° above the horizontal axis ✓ [CL2] (4)

2.1 One TICK for each of the forces shown in their correct places and if the 45° is not shown take off one mark.



[CL2] (4)

2.2 $F_x = F\cos\theta = 90\cos 45°$ ✓ $= 63{,}64\ \text{N}$ ✓ to the left ✓

$F_y = F\sin\theta = 90\sin 45°$ ✓ $= 63{,}64\ \text{N}$ ✓ downwards ✓ [CL2] (6)

2.3 $R_x = +30 - 50 - 63{,}64 = -83{,}64\ \text{N}$ therefore $R_x = 83{,}64\ \text{N}$ ✓to the left

$R_y = +40 - 63{,}64 = -23{,}64\ \text{N}$ therefore $R_y = 23{,}64\ \text{N}$ ✓downwards

$R^2 = 83{,}64^2 + 23{,}64^2$

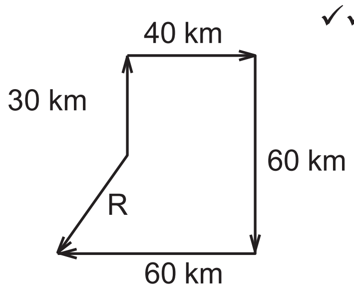
$R = 86{,}92\ \text{N}$ ✓

$\theta = \tan^{-1}\left(\frac{23{,}64}{83{,}64}\right) = 15{,}8°$ ✓

$R = 86{,}92\ \text{N}$ at 15,8° below the horizontal axis and to the left ✓ [CL3] (5)

3.1 The change in position of a body ✓✓ [CL1] (2)

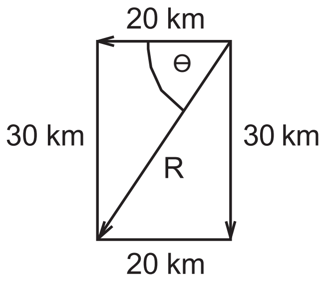
3.2



✓✓✓✓ One mark for each correct vector
✓ Correct resultant (−1 any error)

[CL2] (5)

3.3 $R_x = +40 - 60 = -20$ km therefore $R_x = 20$ km west ✓
$R_y = +30 - 60 = -30$ km therefore $R_y = 30$ km south ✓

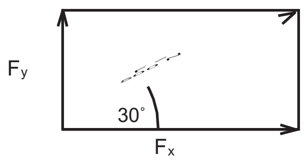


✓✓One mark for each correct vector
✓ Correct resultant (−1 any error)

[CL3] (5)

3.4 $R^2 = 20^2 + 30^2$ ✓
$R = 36{,}06$ km ✓
$\theta = \tan^{-1}\left(\frac{30}{20}\right) = 56{,}3°$ ✓
$R = 36{,}06$ km on a bearing $213{,}7°$ ✓ [CL3] (4)

4.1



✓ correct force F
✓✓ correctly labelled components F_x, F_y

[CL2] (3)

4.2 $F_x = F\cos\theta = 500\cos 30°$ ✓ $= 433{,}01$ N ✓ [CL2] (2)

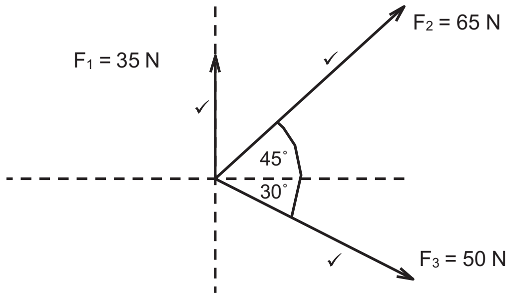
4.3 $F_y = F\sin\theta = 500\sin 30°$ ✓ $= 250$ N ✓ [CL2] (2)

4.4 Friction in the horizontal plane ✓
Weight ✓ and the normal force ✓ in the vertical plane [CL4] (3)

5.1 A vector has both magnitude ✓ and direction ✓, whereas a scalar has magnitude only ✓ [CL1] (3)

ASSESSMENTS

5.2



[CL2] (3)

5.3 $F_{2x} = F_2 \cos 65 \cos 45° = 45,96$ N right ✓

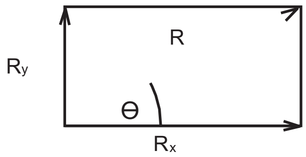
$F_{2y} = F_2 \sin\theta = 65 \sin 45° = 45,96$ N up ✓

$F_{3x} = F_3 \cos\theta = 50 \cos 30° = 43,30$ N right ✓

$F_{3y} = F_3 \sin\theta = 50 \sin 30° = 25$ N down ✓

$R_x = +45,96 + 43,30 = 89,26$ N right ✓

$R_y = +35 + 45,96 - 25 = 55,96$ N up ✓



(−1 No diagram OR incorrect diagram)

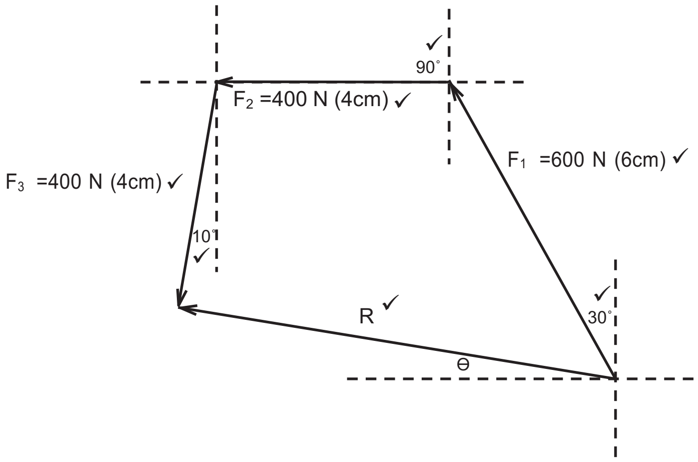
$R^2 = 89,26^2 + 55,96^2$

$R = 105,35$ N ✓

$\theta = \tan^{-1}\left(\frac{55,96}{89,26}\right) = 32,1°$ ✓

$R = 105,35$ N at $32,1°$ above the horizontal and to the right ✓ [CL3] (9)

6.1



$R = 7,8$ cm ✓

$\theta = 9°$

$R = 780$ N ✓ bearing 279° ✓ [CL3] (10)

6.2 $F_4 = 780$ N ✓ bearing 099° ✓

F_4 should be equal in magnitude to R but opposite in direction. [CL4] (2)

Topic 2: Newton's Laws and Application of Newton's Laws

QUESTIONS

MULTIPLE CHOICE

1. Which ONE of the following physical quantities is a measure of the inertia of a body?
   A Mass
   B Energy
   C Velocity
   D Acceleration (2)

2. The magnitude of the gravitational force exerted by one body on another body is F. When the distance between the centres of the two bodies is doubled, the magnitude of the gravitational force, in terms of F, will now be …
   A $\frac{1}{4}F$
   B $\frac{1}{2}F$
   C $2F$
   D $4F$ (2)

3. Two forces, F and T, are applied on a crate lying on a frictionless, horizontal surface, as shown in the diagram below. The magnitude of force T is greater than that of force T.

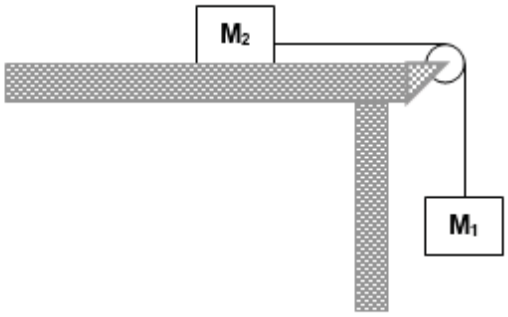
   The crate will …
   A accelerate towards the right.
   B accelerate towards the left.
   C move at a constant speed towards the right.
   D move at a constant speed towards the left. (2)

4. A person stands on a bathroom scale that is calibrated in newton, in a stationary elevator. The reading on the bathroom scale is w. The elevator now moves with a constant upward acceleration of $\frac{1}{3}g$, where g is the gravitational acceleration. What will the reading on the bathroom scale be now?
   A $\frac{1}{3}w$
   B $\frac{3}{4}w$
   C $\frac{4}{3}w$
   D w (2)

5. A laptop rests on a table. According to Newton's 3rd law, what is the reaction force to the weight of the laptop?
   A The upward force of the table on the laptop.
   B The upward force of the laptop on the Earth.
   C The downward force of the Earth on the laptop.
   D The normal force on the laptop. (2)

6. A person stands on a scale in an elevator. He notices that the scale reading is lower than his usual weight. Which of the following could possibly describe the motion of the elevator?
   A It is moving down at constant speed.
   B It is moving down and slowing down.
   C It is moving up and slowing down.
   D It is moving up and speeding up. (2)

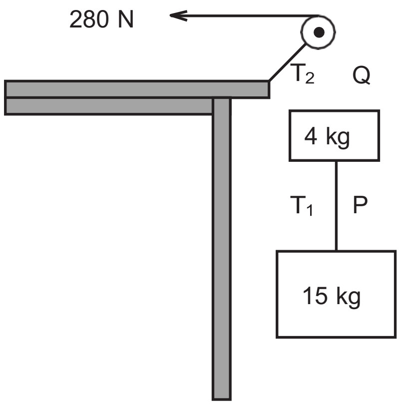
7. The diagram below shows a block of mass M_2 initially at rest on a smooth, horizontal table. Another block of mass M_1 is attached to it by a light inextensible cord that passes over a frictionless pulley. When the block M_2 is released, it accelerates with an acceleration *a*. What will be the acceleration of block M_2 if the mass of block M_1 is doubled?
   The acceleration is:
   A equal to *a*.
   B greater than *a* and less than 2*a*.
   C equal to 2*a*.
   D greater than 2*a*.



(2)

LONG QUESTIONS

1. Two blocks of masses 15 kg and 4 kg respectively are connected by a light inextensible string, P. A second light inextensible string, Q, attached to the 4 kg block, runs over a light frictionless pulley. A constant horizontal force of 280 N pulls the second string as shown in the diagram below. The magnitudes of the tensions in P and Q are T_1 and T_2 respectively. Ignore the effects of air resistance.



1.1 State Newton's Second Law of Motion in words. (2)

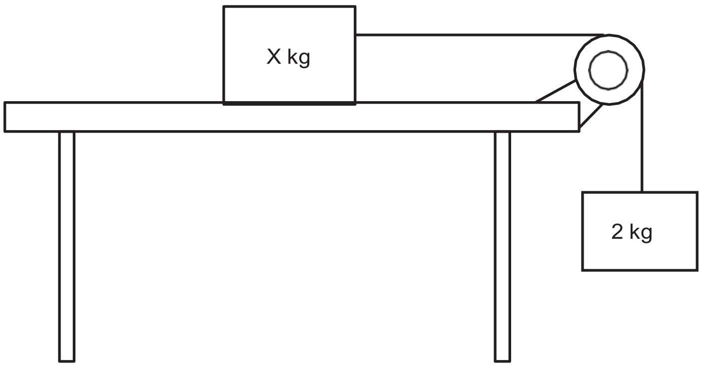
1.2 Draw a labelled free-body diagram indicating ALL the forces acting on the 4 kg block. (3)

1.3 Calculate the magnitude of the tension T_1 in string P. (6)

1.4 When the 280 N force is replaced by a sharp pull on the string, one of the two strings break. Which ONE of the two strings, P or Q, will break? Explain briefly. (2)

[13]

2.1 Two blocks of mass X kg and 2 kg respectively are connected by a light, inextensible string. The string runs over a light, frictionless pulley, as shown in the diagram below. The blocks are stationary.



2.1.1 State Newton's THIRD law in words. (2)

2.1.2 Calculate the tension in the string. (3)

The coefficient of static friction (μ_s) between the unknown mass X and the surface of the table is 0,15.

2.1.3 Calculate the minimum value of mass X that will prevent the blocks from moving. (5)

The block of unknown mass X is now replaced with a block of mass 4,5 kg. The 2 kg block now accelerates downwards. The coefficient of kinetic friction (μ_k) between the 4,5 kg block and the surface of the table is 0,10.

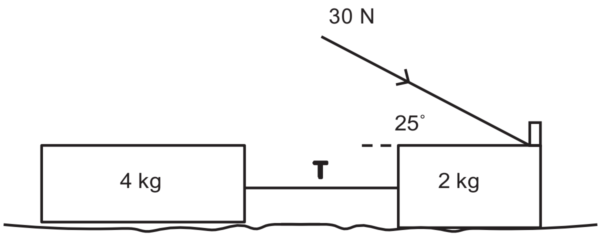
2.1.4 Calculate the magnitude of the acceleration of the 4,5 kg block. (5)

2.2 A small hypothetical planet A has a mass of $4,5 \times 10^{20}$ kg and a radius of 450 km. Calculate the gravitational force (weight) that planet A exerts on a 800 kg car on this planet's surface. (4)

[19]

ASSESSMENTS

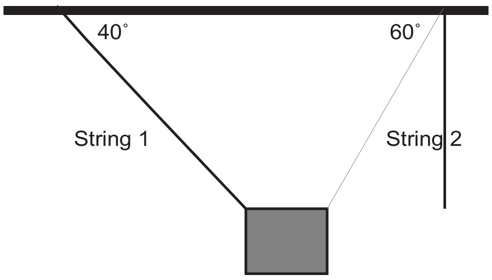
3. A learner constructs a push toy using two blocks with masses 2 kg and 4 kg respectively. The blocks are connected by a massless, inextensible cord.
The learner then applies a force of 30 N at an angle of 25° to the 2 kg block by means of a light rigid rod, causing the toy to move across a flat, rough, horizontal surface, as shown in the diagram below.



The coefficient of kinetic friction (μ_k) between the surface and each block is 0,20.

3.1 State Newton's Second Law of Motion in words. (2)
3.2 Calculate the magnitude of the kinetic frictional force acting on the 4 kg block. (3)
3.3 Draw a labelled free-body diagram showing ALL the forces acting on the 2 kg block. (5)
3.4 Calculate the magnitude of the:
3.4.1 kinetic frictional force acting on the 2 kg block. (3)
3.4.2 tension in the cord connecting the two blocks. (5)
[21]

4. A block of unknown mass hangs stationary from the ceiling by means of two strings as shown in the diagram below.



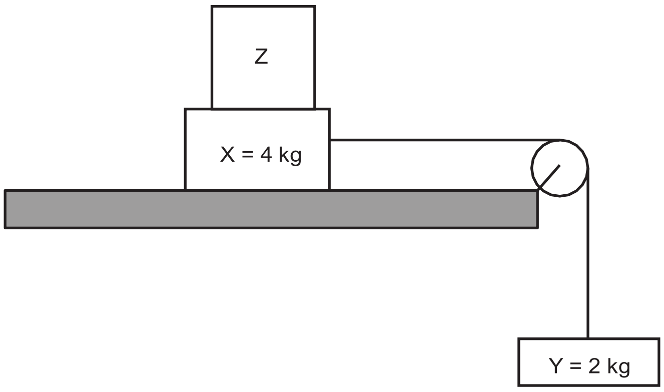
The tension in string 1 is 450 N.

4.1 Are the forces acting on the block in equilibrium? Explain your answer. (3)
4.2 Determine the magnitude of the horizontal component of the tension in string 1. (2)
4.3 Calculate the magnitude of the tension in string 2. (3)
4.4 Calculate the mass of the block. (5)
[13]

5. An empty lift of mass 800 kg is accelerated upwards at 2 $m.s^{-2}$ from the ground floor of an office building.
   5.1 Draw a labelled free-body diagram of the accelerating lift, showing the forces acting on the lift. Your diagram should reflect the relative sizes of the forces. (3)
   5.2 State Newton's second law. (2)
   5.3 Calculate the tension in the lift cable while the empty lift is accelerated upwards. (4)
   5.4 The lift cable is able to withstand a maximum tension of 18 kN. Determine the maximum cargo mass that the lift can carry while accelerating upwards at 2 $m.s^{-2}$. (5)

[14]

6. Block **X** has a mass of 4 kg and Block Y has a mass of 2 kg. Block **X** is placed on a rough table that has a coefficient of static friction of 0,18. Block **X** and Block **Y** are joined by a light, inextensible string over a frictionless pulley and Block **Z** is placed on top of Block **X** as shown in the diagram below.



The system, as shown in the diagram, is only just at rest and on the limit of sliding.
   6.1 Determine the tension in the rope joining Block X and Block Y while the system is at rest. (2)
   6.2 Define frictional force. (2)
   6.3 State the magnitude of the frictional force required for Block X to be at rest. (2)
   6.4 Calculate the minimum mass of Block Z to stop Block X from sliding. (5)

Block Z is removed and the system starts accelerating.
   6.5 State Newton's second law. (2)
   6.6 Draw a labelled, free-body diagram for Block Y while it is accelerating. (2)

The magnitude of the acceleration of the system is 2,5 $m.s^{-2}$.
   6.7 Calculate the tension in the rope joining the blocks. (3)
   6.8 Calculate the frictional force acting on Block X while it is accelerating. (3)
   6.9 State two reasons why the frictional force between Block X and the surface is smaller than the value stated in Question 6.3. Briefly explain your answer. (4)

[25]

ASSESSMENTS

7. The photograph shows the result of an incident of emergency braking carried out by a truck driver. He was driving a truck (mass 10 800 kg) at 80 $km \cdot h^{-1}$ while carrying a granite block (mass 160 000 kg) in the trailer. He braked suddenly to avoid hitting a child who crossed the road in front of him. It was agreed after the incident that the driver was in no way to blame. (He was completely innocent of any wrong doing).

7.1 With reference to one of Newton's Laws, explain the behaviour of the granite block. (4)

7.2 Convert 80 $km \cdot h^{-1}$ to $m \cdot s^{-1}$. (3)

The skid marks of the truck on the road were 38,2 m in length from the time the driver slammed on the brakes to when the truck stopped.

7.3 Calculate the acceleration of the truck. (4)

7.4 Calculate the magnitude of the braking force exerted on the truck while it was brought to a standstill. (3)

7.5 Suggest a way in which the trucking company can prevent accidents of this kind from happening when the trucks carry a heavy load, such as blocks of granite, in the future. (1)

[15]

8. While an astronaut (mass 75 kg) works in Space at a distance of 15 m from his spaceship, his power pack fails to work. The pack has a mass 25 kg. The astronaut knows that now his only way of getting back to his spaceship is to push his pack away from him.

8.1 State an appropriate law of physics, and <u>use it</u> to **explain** how the astronaut is able to return to his spaceship by pushing his pack away from him. (6)

8.2. State Newton's Law of Universal Gravitation. (3)

8.3. When the astronaut gets to Mars he feels much lighter than he did on Earth because the acceleration due to gravity on Mars is 3,5 $m.s^{-2}$. The mass of Mars is $6,4 \times 10^{23}$ kg. Calculate the radius of Mars in m. (5)

8.4 The astronaut, wearing his spacesuit and life support systems, jumps vertically upwards from the surface of Mars. Will the astronaut be able to jump higher, from the same initial velocity (while wearing the same kit) on Mars than on Earth? Justify your answer, by considering an appropriate formula. (5)

[19]

MARKING GUIDELINES

MULTIPLE CHOICE

1. A ✓✓ (Related to the definition) [CL1] (2)

2. A ✓✓ $F = G\frac{m_1 m_2}{r^2}$

   $F_{new} = G\frac{m_1 m_2}{(2r)^2} = G\frac{m_1 m_2}{4r^2} = \frac{1}{4}\left[G\frac{m_1 m_2}{r^2}\right] = \frac{1}{4}F$ [CL3] (2)

3. B ✓✓ Since F is greater than T, the net force acts to the left, therefore the acceleration is also left. [CL2] (2)

4. C ✓✓ $F_{net} = ma$

   $F - w = ma$

   $F - mg = m\left(\frac{1}{3}g\right)$

   $F = mg + m\left(\frac{1}{3}g\right)$

   $F = \frac{4}{3}mg = \frac{4}{3}w$ [CL4] (2)

5. B ✓✓ Weight of laptop = Downward force of Earth on laptop.
   Reaction force = Upward force of laptop on Earth. [CL2] (2)

6. C ✓✓ If the reading on scale (the upward force) is less than his weight (the downward force), the net force on him acts downwards. The direction of his acceleration is also down. [CL3] (2)

7. B ✓✓ Initially $a = \frac{M_1}{M_1 + M_2}g$

   When M_1 is doubled, $a' = \frac{2M}{2M_1 + M_2}g$

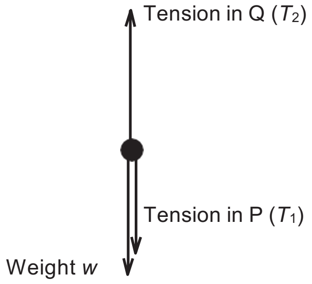
   Therefore $\frac{a'}{a} = \frac{2M_1 g}{2M_1 + M_2} \times \frac{M_1 + M_2}{M_1 g} = \frac{2(M_1 + M_2)}{2M_1 + M_2}$

   This value is greater than 1 and less than 2. [CL 4] (2)

LONG QUESTIONS

1.1 When a net force is applied to an object of mass, *m*, it accelerates in the direction of the net force. ✓ The acceleration, *a*, is directly proportional to the net force and inversely proportional to the mass. ✓ [CL1] (2)

1.2



One mark for each correct force which is correctly labelled.

[CL3] (3)

1.3 Choose up as positive:

<u>4 kg:</u>

$F_{net} = ma$

$T_2 - W_{4kg} - T_1 = (4)a$ ✓

$280 - 39,2 - T_1 = 4a$

$240,8 - T_1 = 4a$

$T_1 = 240,8 - 4a$ ✓ (i)

<u>15 kg:</u>

$F_{net} = ma$

$T_1 - W_{15kg} = (15)a$ ✓

$T_1 - 147 = 15a$

$T_1 = 147 + 15a$ ✓ (ii)

Set equation (i) equal to equation (ii)

$240,8 - 4a = 147 + 15a$

$93,8 = 19a$

$\therefore\ a = 4,94\ \text{m·s}^{-2}$ ✓

$T_1 = 240,8 - 4a = 240,8 - 4(4,94) = 221,04\ \text{N}$ ✓ [CL3] (6)

1.4 P ✓ Since the 15 kg mass has the greater inertia ✓ [CL4] (2)

2. 2.1.1 When object A exerts a force on object B, object B simultaneously exerts an oppositely directed force of equal magnitude on object A. ✓✓ [CL1] (2)

2.1.2 $T = w_{2kg}$ ✓ $= 2 \times 9,8$ ✓ $= 19,6\ \text{N}$ ✓ up [CL2] (3)

2.1.3 $f_s^{max} = 19,6\ \text{N}$ ✓ to the left

$f_s^{max} = \mu_s N = \mu_s(mg) = (0,15$ ✓$)(X)(9,8$ ✓$) = 1,47X$ ✓

$19,6 = 1,47X$

$X = 13,33\ \text{kg}$ ✓ [CL3] (5)

2.1.4 Choose right and down as positive:

4,5 kg:

$F_{net} = ma$

$T - f_k = 4,5a$ ✓

$T - (0,1)(44,1) = 4,5a$

$T - 4,41 = 4,5a$

$T = 4,41 + 4,5a$ ✓ (i)

2 kg:

$F_{net} = ma$

$W_{2kg} - T = 2a$ ✓

$19,6 - T = 2a$

$T = 19,6 - 2a$ ✓ (ii)

Set equation (i) equal to equation (ii)

$4,41 + 4,5a = 19,6 - 2a$

$6,5a = 15,19$

$a = 2,34\ \text{m·s}^{-2}$ ✓ [CL3] (5)

2.2 $F = G\dfrac{m_1 m_2}{r^2}$

$F = (6,67 \times 10^{-11})\dfrac{(4,5 \times 10^{20})(800)\checkmark}{(450 \times 10^3\checkmark)^2}$

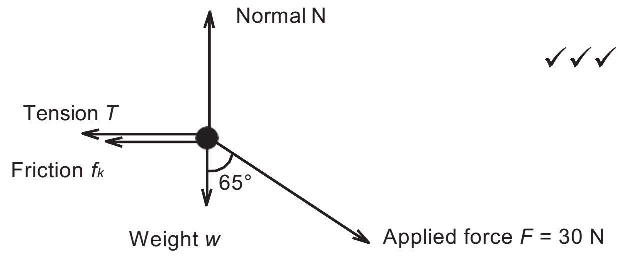
$F = 118,58$ N ✓ towards the centre of the planet. ✓ [CL3] (4)

"Force of attraction" does not specify the direction of the force. The direction of the force is towards the centre of the planet. Attraction describes the type of force that acts on the car.

3.1 When a net force is applied to an object of mass, m, it accelerates in the direction of the net force. ✓ The acceleration, a, is directly proportional to the net force and inversely proportional to the mass. ✓ [CL1] (2)

3.2 $f_k = \mu_k.N = (0,20\checkmark)(4)(9,8\checkmark) = 7,84$ N ✓ [CL2] (3)

3.3



✓✓✓✓✓ For each correctly labelled force.

−1 If the angle is not shown.

[CL2] (5)

3.4.1 $F_y = F\sin 25° = 30\sin 25° = 12,68$ N ✓ downwards

$F_{down} = F_y + W = 12,68 + 19,6 = 32,28$ N ✓ downwards

Therefore: $N = 32,28$ N upwards

$f_k = \mu_k.N = (0,20)(32,28) = 6,46$ N ✓ [CL3] (3)

3.4.2 $F_x = F\cos 25° = (30)\cos 25° = 27,19$ N ✓ to the right

Choose right as positive:

2 kg:	4 kg:
$F_{net} = ma$	$F_{net} = ma$
$F_x - T - f_k = (2)a$	$T - f_k = (4)a$
$27,19 - T - 6,46 = 2a$ ✓	$T - 7,84 = 4a$ ✓
$20,73 - T = 2a$	$T = 7,84 + 4a$ (ii)
$T = 20,73 - 2a$ ✓ (i)	

Set equation (i) equal to equation (ii)

$20,73 - 2a = 7,84 + 4a$

$12,89 = 6a$

$a = 2,14\ \text{m}\cdot\text{s}^{-2}$

$T = 20,73 - 2a = 20,73 - 2(2,14) = 16,45$ N ✓ [CL3] (5)

4.1 Yes ✓. The block remains at rest, ✓ therefore the net force is zero. ✓ [CL2] (3)

4.2 $T_{1x} = T_1\cos 40° = 450\cos 40°$ ✓ $= 344,72$ N ✓ [CL2] (2)

ASSESSMENTS

4.3 $T_{2x} = T_2 \cos 60° = T_2 \cos 60°$

$T_{1x} = T_{2x}$ (net force in horizontal plane is zero)

$344,72 \{= T_2 \cos 60° \{$

$T_2 = \dfrac{344,72}{\cos 60°} = 689,44 \text{ N} \{$ [CL3] (3)

4.4 $T_{1y} = T_1 \sin 40° = 450 \sin 40° = 289,25 \text{ N} \{$ upwards

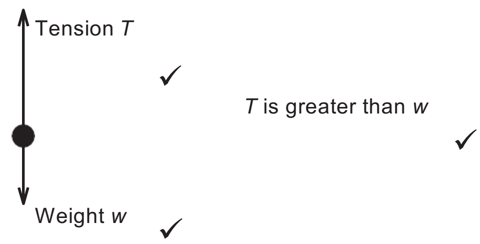
$T_{2y} = T_2 \sin 60° = 689,44 \sin 60° = 597,07 \text{ N} \{$ upwards

$w = T_{1y} + T_{2y}$

$w = 289,25 + 597,07 = 886,32 \text{ N} \{$ [CL3] (5)

$m = \dfrac{w}{g} = \dfrac{886,32}{9,8 \{} = 90,44 \text{ kg} \{$

5.1



[CL2] (3)

5.2 When a net force is applied to an object of mass, m, it accelerates in the direction of the net force. ✓ The acceleration, a, is directly proportional to the net force and inversely proportional to the mass. ✓ [CL1] (2)

5.3 Choose up as positive.

$F_{net} = ma$

$T - w = \hat{}800h(2 \{)$

$T - 7\ 840 \{= 1\ 600$

$T = 9\ 440 \text{ N} \{$ upwards ✓ [CL3] (4)

5.4 Choose up as positive

$F_{net} = ma$

$T - w = m2$

$18\ 000 \{ - (mg) \{= 2m \{$

$18\ 000 - 9,8m = 2m$

$18\ 000 = 11,8m$

$m = 1\ 525,42 \text{ kg} \{$

Cargo mass = 1525,42 – 800 = 725,42 kg ✓ [CL4] (5)

6.1 $w_{2kg} = \hat{}2h\hat{}9,8h = 19,6 \text{ N}$

Therefore: $T = 19,6 \text{ N} \{\{$ [CL2] (2)

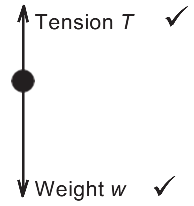
6.2 The force that opposes the motion of an object ✓ and acts parallel to the surface the object is in contact with ✓ [CL1] (2)

6.3 $f = 19,6 \text{ N} \{\{$ [CL2] (2)

6.4 $f_s^{max} = n_s N$
19,6 {= ^0,18 {h^*m*h(9,8 {)
m = 11,11 kg {
m_z = 11,11 - 4 = 7,11 kg { [CL3] (5)

6.5 When a net force is applied to an object of mass, m, it accelerates in the direction of the net force. ✓ The acceleration, a, is directly proportional to the net force and inversely proportional to the mass. ✓ [CL1] (2)

6.6



[CL2] (2)

6.7 Choose down as positive. Working with the net force on Y:
$F_{net} = ma$
w - *T*{= ^2h(2, 5){
19,6 - *T* = 5
T = 14,6 N { upwards on the 2 kg block [CL3] (3)

6.8 $F_{net} = ma$
T - *f* = ^4h(2, 5)
14,6 - *f* = 10
f = 4,6 N { to the left { [CL3] (3)

6.9 The coefficient of kinetic friction is always less than ✓✓ the coefficient of static friction.
The weight of the block has decreased, therefore the normal force has decreased. ✓
f is directly proportional to the normal force N. ✓ [CL4] (4)

7.1 The granite block continues to move at its initial speed✓ (of 80 $km.h^{-1}$) when the truck stops because there is no net force acting on the block. ✓According to Newton's First Law, ✓the block continues in its state of constant velocity until it crashes into the cab of the truck (until a net force acts on it). ✓ [CL 3] (4)

7.2 80 $km.h^{-1}$ = $\frac{80 \# 1000\{}{60 \# 60\{}$ = 22,22 $m.s^{-1}$ ✓ [CL 2] (3)

7.3 $v_i = 22{,}22\ m.s^{-1}$ $v_f = 0\ m.s^{-1}$ $\Delta x = 38{,}2\ m$
$v_f^2 = v_i^2 + 2a\Delta x$✓
0 = $(22{,}22)^2 + 2a(38{,}2)$ ✓
a = − 6,46 $m.s^{-2}$ ✓ = 6,46 $m.s^{-2}$ backwards✓ [CL 3] (4)

7.4 F_{net} = *ma*✓
= (10 800 + 160 000) × 6,46✓
= 1 103 368 N (or 1,10 × 10^6 N)✓ [CL 4] (3)

ASSESSMENTS

7.5 The block of granite should be held firmly in place in the trailer (restrained by straps to prevent it from moving forwards or backwards while the truck is in motion. ✓ [CL 3] (1)

8.1 When a body A exerts a force on body B, body B simultaneously exerts a force of the same magnitude but in the opposite direction on body A. ✓✓ (Newton's 3rd Law. ONLY 1 MARK IF IT IS JUST STATED AS THE LAW (WITHOUT THE LAW STATED IN WORDS).
The astronaut exerts force on the power pack, pushing it away from him. ✓The power pack exerts force on the astronaut pushing him in the opposite direction. ✓This push will help him reach the spaceship because there is no air resistance (or frictional forces) acting on him in Space. ✓ Once he starts moving towards the spaceship he will continue to move at constant velocity. ✓ [CL 4] (6)

8.2 There exists a force of attraction between any two objects in the universe. ✓The force is directly proportional to the product of their masses ✓and inversely proportional to the square of the distance between their centres.✓ [CL 1] (3)

8.3 $g = \frac{Gm}{r^2}$ ✓

$$3,8 = \frac{(6,67 \times 10^{-11})\ ✓\ (6,4 \times 10^{22})}{r^2}\ ✓$$

$$r = \sqrt{1,1234 \times 10^{12}}\ ✓ = 1,06 \times 10^{6}\ \text{m·s}^{-2}\ ✓$$

[CL 3] (5)

8.4 He will jump higher on Mars ✓ [because $g_{earthg} > g_{moon}$ ✓]
$v_f^2 = v_i^2 + 2a\Delta y$ ✓
On the Mars $0 = v_i^2 + 2(3,8)\,\Delta y$ therefore $\Delta y = v_i^2 / (7,6)$✓
On the Earth $0 = v_i^2 + 2(9,8)\,\Delta y$ therefore $\Delta y = v_i^2 / (19,6)$ ✓

Therefore for the same launch speed (v_i) he jumps higher on Mars. [CL 4] (5)

Topic 3: Atomic Combinations (Molecular Structure)

QUESTIONS

MULTIPLE CHOICE

1. Which chlorine compound has bonding that can be described as ionic with some covalent character?
   A $NaC\ell$
   B $MgC\ell_2$
   C $A\ell C\ell_3$
   D $SiC\ell_4$ (2)

2. Which molecule has only six bonding electrons?
   A C_2H_4
   B C_2F_6
   C H_2O
   D NF_3 (2)

3. What set of data would hydrogen sulfide, H_2S, be expected to have?

	Number of bonding pairs	Shape
A	1	Trigonal planar
B	2	Pyramidal
C	2	Angular
D	3	Pyramidal

(2)

4. Which ONE of the following best describes the bond formed between an H^+ ion and the NH_3 molecule to form an NH_4^+ ion?
   A covalent bond
   B dative covalent bond
   C ionic bond
   D hydrogen bond (2)

ASSESSMENTS

5. Refer to the following list of substances and the electronegativities provided on the Periodic Table.

   CO_2 NH_3 H_2O N_2 HF

   Which of the following lists all the non-polar molecules from the above list?

   A N_2
   B N_2 and NH_3
   C N_2 and CO_2
   D N_2, CO_2 and NH_3 (2)

6. Which of the following pure substances will conduct electric current when molten (in the liquid phase)?

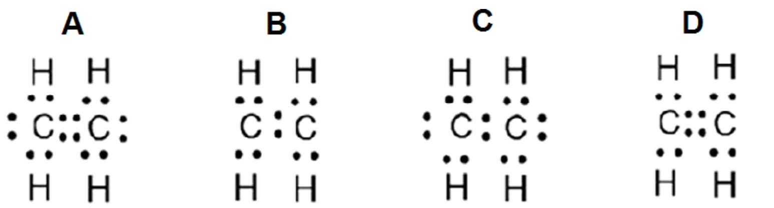
   Pb $PbBr_2$ $C_6H_{12}O_6$ (glucose) CH_3CH_2OH (alcohol)

   A Pb and $PbBr_2$
   B Pb and CH_3CH_2OH (alcohol)
   C Pb, $PbBr_2$ and CH_3CH_2OH (alcohol)
   D All of these substances (2)

7. A dative covalent bond forms when…

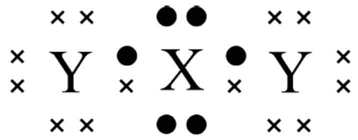
   A water decomposes.
   B ionic compounds dissociate in water.
   C hydronium ions are produced.
   D hydroxide ions are produced. (2)

8. Which of one of the following Lewis structures correctly represents a molecule of C_2H_4?



(2)

9. Consider the Lewis structure of a compound shown below:



Which ONE of the following is correct?

	Name of element X	Name of element Y	Molecular shape of compound
A	chlorine	sulfur	angular
B	oxygen	chlorine	angular
C	chlorine	oxygen	linear
D	sulfur	chlorine	linear

(2)

10. Which of the following substances has polar covalent bonds between its atoms, but its molecule is non-polar?

A H_2O
B H
C HCℓ
D CCℓ4 (2)

LONG QUESTIONS

1.1 Study the following list of substances:

Hg I_2 SF_6 KI PCℓ$_3$ Ne C H_2O

For each statement below choose a substance that displays those properties. You can choose a substance once, more than once or not at all.

1.1.1 A substance that conducts electricity when molten but not when solid. (1)
1.1.2 A substance that forms a covalent crystal lattice. (1)
1.1.3 A substance that consists of non-polar molecules containing polar bonds. (1)
1.1.4 Its molecules have two lone pairs on the central atom. (1)
1.1.5 A substance which has delocalised electrons. (1)
1.1.6 Its molecules have a non-ideal shape. (1)
1.1.7 A substance which consists of monatomic molecules. (1)

1.2 Refer to the bond energies supplied below:

A	B
C−C	**C=C**
346 $kJ.mol^{-1}$	602 $kJ.mol^{-1}$

1.2.1 What information does the bond energy provide? (1)

1.2.2 Which of A or B will have the shorter bond length? (1)

1.2.3 Explain why the bond energy in B is not double the bond energy in A. (2)

[11]

2.1 South Africa has comparable greenhouse gas emissions to many industrialised countries. The main air pollutants generated by South African industries are carbon dioxide (CO_2), methane (CH_4), carbon monoxide (CO), sulfur dioxide (SO_2), the oxides of nitrogen (NO_2, NO and N_2O) and ammonia (NH_3).

2.1.1 Draw Lewis structures to represent:

a) carbon dioxide. (2)

b) methane. (2)

2.1.2 Define the term "electronegativity". (2)

2.1.3 By means of a suitable calculation describe the type of bonding that occurs in a molecule of sulfur dioxide. (2)

2.1.4 The chemical bonds within the methane molecule are polar covalent and yet methane is known to be a non-polar molecule. Explain how this phenomenon comes about. Show the polarity of the molecule with the use of a Lewis diagram. (4)

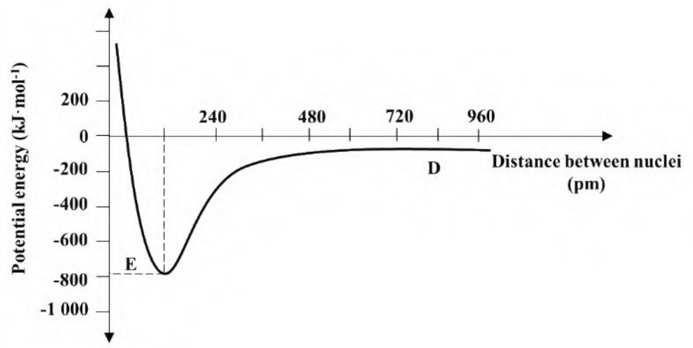
2.1.5 Of the pollutants listed above, choose

a) one trigonal pyramidal

b) one tetrahedral and

c) one linear molecule. (3)

2.2 The graph below shows the change in energy that takes place when an oxygen atom approaches a carbon atom during the formation of a C=O bond.



2.2.1 Define the term 'bond length'. (2)

2.2.2 From the graph, write down the:

(a) bond length, in pm, of the C=O bond. (1)

(b) bond energy, in $kJ \cdot mol^{-1}$ needed to break the C=O bond. (2)

(c) Name the potential energy represented by E. (1)

2.2.3 How will the bond length of an S=O bond compare to that of the C=O bond? Write down EQUAL TO, SHORTER THAN or LONGER THAN. Give a reason for your answer. (2)

2.2.4 What can be said about the forces between the two atoms at point D? (2)

[25]

3. 3.1 $CO_2(g)$, SO_2 and $CO(g)$ are some of the air pollutants in the South African atmosphere.

3.1.1 CO has a dative covalent bond. Draw the Lewis structure for a carbon monoxide molecule and use it to help explain the idea of a dative covalent bond. (3)

3.1.2 Explain why you would expect the CO molecule to be polar. (2)

3.1.3 What is the nature of the partial charges on (i.e. the polarity of) the C and O atoms in the CO molecule? Explain your answer. (2)

3.2 Consider the gases CO_2 and SO_2.

3.2.1 Refer to Lewis Diagrams and the VSEPR theory. Compare the shapes of a CO_2 molecule and a SO_2 molecule, both of which contain two oxygen atoms bonded to one other atom. (4)

3.2.2 Comment on the polarity of both the CO_2 and SO_2 molecules. In each instance, explain your answer with reference to the molecular shape. (4)

[15]

4. Sulfur forms many compounds by reacting with other elements.

4.1 Three of these compounds are sodium sulfide, $SOC\ell_2$, SF_2 and two other fluorides.

4.1.1 Draw Lewis diagrams to show the bonding in:

a) sodium sulfide (3)

b) SF_2 (2)

4.1.2 There are two possible ways of drawing the Lewis diagram of $SOC\ell_2$. Draw the two possible Lewis structures. Explain how you arrived at each of the structures. (5)

4.1.3 Use the valence shell electron pair repulsion (VSEPR) theory to deduce the shapes of the following molecules:

a) SF_2 (2)

b) $BeC\ell_2$ (2)

4.2 Sulfur is in group 16 and period 3 of the Periodic Table.

4.2.1 Define the terms:

a) Electronegativity (2)

b) Bond polarity (2)

4.2.2 Give reasons for your answers to the next two questions. Identify the type of bonds that form in

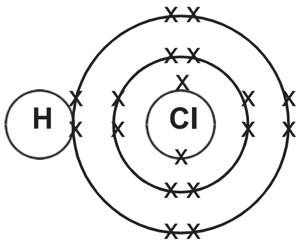
a) SF_2 (3)

b) H_2S (3)

[24]

ASSESSMENTS

5. 5.1 The hydrogen halides (hydrogen fluoride, hydrogen chloride, hydrogen bromide and hydrogen iodide) are important chemicals.
The diagram below represents a molecule of hydrogen chloride.



5.1.1 What type of particles are represented by the crosses (X)? (1)
5.1.2 What type of chemical bond holds the atoms in this molecule together? (1)

5.2 The relative amount of energy (in $kJ.mol^{-1}$) required to break the bond in each of the hydrogen halide molecules is shown below.

H – F	569
H – Cℓ	432
H – Br	366
H – I	298

One of the important properties of the hydrogen halides is that they dissolve in water to form acids. For example, hydrogen chloride reacts with water to form hydrochloric acid.
To form an acid the bond between the hydrogen and the halogen atoms must be broken and ions are formed. The stronger the acid the more molecules that split up to form ions.

5.2.1 Which ion must be formed to make a solution acidic? (1)
5.2.2 Which of the hydrogen halides would you expect to react with water to form the strongest acid? Explain your answer. (3)
[6]

6. A learner studies fluorine and carbon and the bonds that atoms of each can form with other atoms. Fluorine is a reactive element that can react with water and with many metals. Carbon is a very special element because it is one of the elements in the food we eat, the clothes we wear and the fuel in our cars.

6.1 Write down the number of electrons in the valence energy level of an atom of:
6.1.1 fluorine. (1)
6.1.2 carbon. (1)

6.2 Describe what is meant by the term ‘covalent bond’. (2)

6.3 Write down the Lewis structure for:
6.3.1 F_2 (2)
6.3.2 HCN (2)

6.4 Write down the name of the type of bond between particles in molecules of:
6.4.1 F_2 (1)
6.4.2 HF (1)

6.5 Write down the molecular shape as predicted by the VSEPR model of:

6.5.1 BF_3 (2)

6.5.2 CH_4 (2)

6.5.3 HF (2)

6.6 The table below shows bond lengths and bond energies for different bonds between two carbon atoms.

	Bond	Length (pm)	Energy (kJ·mol^{-1})
A	C – C	154	348
B	C = C	134	614
C	C / C	120	839

6.6.1 Describe the relationship between bond length and bond energy as shown in the above table. (2)

6.6.2 Which one of the bonds (A, B or C) will be the weakest? Explain. (3)

[20]

MARKING GUIDELINES

MULTIPLE CHOICE

1. B ✓✓ Δ electronegativity = 3,0 – 1,2 = 1,8 which implies that the bond is polar covalent. However, Mg is a metal bonding with the non-metal Cℓ, therefore the bond is ionic. This is the compound which is ionic with some covalent character. [CL3] (2)

2. D ✓✓ Nitrogen has three unpaired electrons which it is able to share with the three fluorine atoms. There are three bonds around each nitrogen atoms. Each bond consists of a shared pair of electrons. Therefore, this compound has 6 bonding electrons (six electrons involved in chemical bonds). [CL2] (2)

3. C ✓✓ There are two bonding pairs because two hydrogen atoms are attached to the sulfur atoms. The two lone pairs of sulfur repel each other strongly so the shape of H_2S is similar to that of water. It is angular (or bent). [CL2] (2)

4. B ✓✓ The hydrogen ion bonds with the ammonia molecule by attaching to the lone pair of electrons. This type of covalent bond where one atom donates both electrons to form the bond is called a dative covalent bond. [CL3] (2)

5. C ✓✓ Nitrogen is non-polar because it consists of three non-polar covalent bonds. CO_2 is non-polar because its molecule is linear, with the effect of the two polar covalent bonds directed in opposite directions, resulting in an overall non-polar molecule. [CL2] (2)

6. A ✓✓ Pb is a metal with delocalised electrons to carry charge through the substance. $PbBr_2$ in molten form dissociates into its ions (cations and anions). These ions are free to carry charge throughout the molten liquid. [CL2] (2)

7. C ✓✓ Hydronium ions are formed when a hydrogen ion (H^+ ion) attaches itself to one of the lone pairs of electrons of a water molecule. This kind of bond is called a dative covalent bond. [CL3] (2)

8. D ✓✓ Carbon has four electrons in the outermost energy level of its atoms. This Lewis structure is the only one which correctly shows carbon atoms with four valence electrons. [CL4] (2)

9. B ✓✓ The element X has six valence electrons therefore it is either a sulfur or an oxygen atom. The element Y must belong to the halogens because it has seven valence shell electrons. The only possible choices are narrowed to choices B and D. However, there are two lone pairs on atom X, so the shape of the molecule will be angular. [CL4] (2)

10. D ✓✓ This molecule has a symmetrical shape (tetrahedral). Even though it has polar covalent bonds between the atoms, the overall electron distribution is symmetrical, therefore its molecule is non-polar. [CL3] (2)

LONG QUESTIONS

1.1.1 KI ✓ An ionic solid conducts electric current ONLY when molten or dissolve in water. (1)

1.1.2 C✓ Carbon as diamond is a covalent crystal lattice. (1)

1.1.3 SF_6✓ The six fluorine atoms are arranged symmetrically around the sulfur atom therefore the overall charge distribution in the molecule is symmetrical – a non-polar molecule. (1)

1.1.4 H_2O✓ The oxygen atom has two lone pairs on it in a water molecule. (1)

1.1.5 Hg✓ Mercury is a metal therefore it has delocalised electrons. (1)

1.1.6 H_2O✓ or $PC\ell_3$✓ Shapes are angular (bent) and trigonal pyramidal (each of these shapes has lone pairs around the central atom, therefore it has a non-ideal shape). (1)

1.1.7 Ne✓ Neon is a noble (inert) gas. Its molecules consist of one atom only (therefore monatomic). (1)

Because of the choices that learners must make from the list of substances, the overall cognitive level of this question is Level 3. It requires learners to have a good understanding and knowledge of molecular geometry and bonding. [CL3]

1.2.1 The bond energy is the amount of energy required to break all the chemical bonds in one mole of the substance.✓ [CL1] (1)

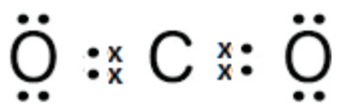
1.2.2 B✓ [CL2] (1)

The greater the bond energy the shorter the bond length.

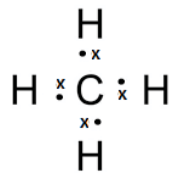
1.2.3 The first bond that forms in a double bond has the same bond energy as a single bond. It is a non-polar covalent bond between the two carbon atoms. ✓ The second bond that forms has slightly less bond energy as it is a less stable bond.✓ OR It breaks more easily than the first single bond. (This is a result of the orientation of the electron orbitals when the bond is formed.) [CL4] (2)

[11]

2.1.1 a)



b)



[CL2] (4)

✓ Correct number of electrons around each atom.
✓ Correct positioning of chemical bonds.
(2 marks for each Lewis diagram)

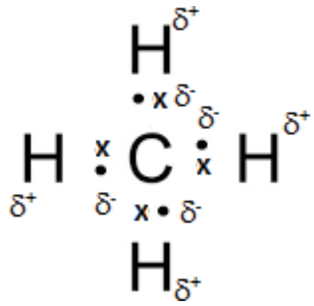
2.1.2 The electronegativity is a measure of the tendency of an atom in a molecule to attract the bonding electrons.✓✓ [CL1] (2)

2.1.3 S: EN = 2,5 O: EN = 3,5

Δ electronegativity = 3,5 – 2,5 = 1,0✓

Polar covalent bond ✓ [CL2] (2)

2.1.4 The methane molecule has a tetrahedral shape.✓ Its polar covalent bonds are arranged symmetrically within the molecule✓ therefore the overall electron distribution within the molecule is symmetrical ✓– and the molecule is non-polar.
✓ Lewis diagram with dipoles shown



[CL3] (4)

2.1.5 a) NH_3 ✓
b) CH_4 ✓
c) CO_2 or CO or NO ✓ [CL3] (3)

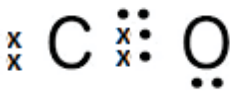
2.2.1 The bond length is the average distance between the nuclei of two bonded atoms.✓✓ [CL1] (2)

2.2.2 a) 120 pm✓ [CL3] (1)
b) 800✓✓ $kJ.mol^{-1}$ [CL2] (2)
c) Bond energy: the amount of energy per mole of the substance required to break the double bond between the carbon and oxygen atoms.✓ [CL2] (1)

2.2.3 LONGER THAN ✓ The sulfur atom is larger than the carbon atom✓ therefore the bond length will be longer (the attraction between the two atoms will be less). [CL4] (2)

2.2.4 At point D there is very little (or no) force ✓between the two atoms because the atoms are fairly far apart from one another. ✓ [CL3] (2)

[25]

3.1.1  ✓✓

Dative covalent bond occurs when one atom contributes both electrons (from a lone pair of electrons) to the bond. ✓ In this case oxygen donates the electrons to the dative covalent bond.✓ [CL4] (4)

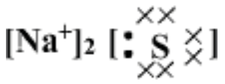
3.1.2 Δ electronegativity = 3,5 – 2,5 = 1,0✓
Polar covalent bond
The molecule is linear therefore it is a dipole (polar molecule). ✓ [CL2] (2)

3.1.3 Oxygen is more electronegative than carbon therefore the shared pairs of electrons will be more strongly attracted to oxygen ✓ making it slight negative (δ^-). Carbon will be δ^+. ✓ [CL3] (2)

3.2.1 The CO_2 molecule is linear.✓ It's shape is ideal since there are no lone pairs in the molecule.✓
The SO_2 molecule is angular (bent) ✓since there are two lone pairs on the central atom (S).✓ [CL4] (4)

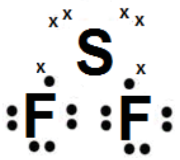
3.2.2 The CO_2 molecule is non-polar✓ because although the bonds are polar covalent, they are arranged symmetrically in the molecule, so the overall electron distribution is also symmetrical.✓ The SO_2 molecule has a bent structure since the lone pairs repel each other strongly. Oxygen is more electronegative than sulfur,✓ therefore the oxygen atoms will be slightly negative (δ^-) and the sulfur atom will be slightly positive (δ^+)✓ (a polar molecule). [CL3] (4)

4.1.1 a)



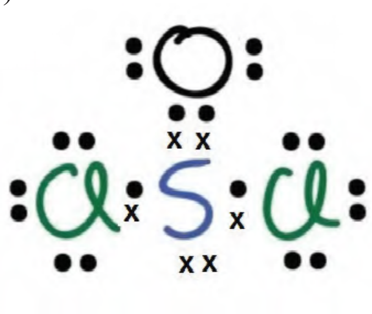
✓Correct sodium ion
✓Two sodium ions
✓Correct sulfide ion [CL3] (3)

b)

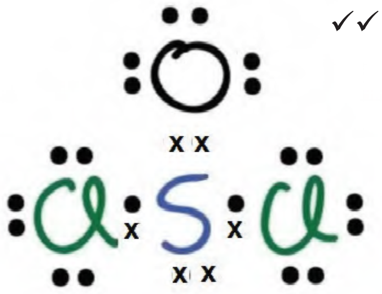


✓Correct number of electrons sulfur atom
✓Correct fluoride ions
[CL3] (2)

4.1.2 a)



b)



✓✓ One mark for each

Sulfur is the central atom with its six valence electrons.✓ Oxygen also has six valence electrons and chlorine has seven valence electrons.✓ In the first molecule sulfur and oxygen form a double bond between them; in the second molecule there is a dative covalent bond between sulfur and oxygen.✓ [CL4] (5)

4.1.3 a) SF_2 Angular ✓ Two lone pairs on sulfur atom repel each other ✓causing the shape to be bent (angular). [CL3] (2)

b) $BeC\ell_2$ Linear ✓ An ideal shape as there are no lone pairs on Be.✓
[CL2] (2)

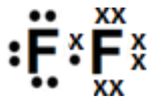
4.2.1 a) Electronegativity: a measure of the tendency of an atom in a molecule to attract the bonding electrons.✓✓ [CL1] (2)

b) Bond polarity: A non-polar covalent bond is one in which the electron density is shared equally between the bonding atoms, ✓ and a polar covalent bond is one in which the electron density is shared unequally between the bonding atoms.✓ [CL1] (2)

4.2.2 a) SF_2 Polar covalent bonds✓
Δ electronegativity ✓ (method) = 4,0 – 2,5 = 1,5✓ [CL2] (3)

b) H_2S Polar covalent bonds✓
Δ electronegativity = 2,5 – 2,1 = 0,4✓ [CL2] (2)
[21]

5.1.1 electrons✓ [CL2] (1)
5.1.2 polar covalent bonds✓ [CL2] (1)
5.2.1 H^+ ion (or H_3O^+ ion or hydrogen ion or hydronium ion) [CL3] (1)
5.2.2 HI ✓
It requires the lowest amount of energy to break the bond between H and I✓
therefore it will react most readily with water✓ to release $H^=$ ions. [CL4] (3)
[6]

6.1.1 7✓ [CL2] (1)
6.1.2 4✓ [CL2] (1)
6.2 A covalent bond is the sharing of electrons to form a chemical bond between two atoms. [CL!] (2)
6.3.1

✓correct number of valence electrons in each atom
✓covalent bond shown clearly [CL2] (2)
6.3.2

✓correct number of valence electrons in each atom
✓covalent bonds shown clearly [CL2] (2)
6.4.1 covalent bond ✓(non-polar) [CL2] (1)
6.4.2 polar covalent bond✓ [CL2] (1)
6.5.1 trigonal planar✓ [CL2] (2)
6.5.2 tetrahedral✓ [CL2] (2)
6.5.3 linear✓ [CL2] (2)
6.6.1 The shorter the bond length the higher the bond energy.✓✓ [CL3] (2)
6.6.2 C✓ C can break to form B losing 839 – 614 = 225 $kJ.mol^{-1}$ ✓ which is less than the energy required to break a single covalent bond between the carbon atoms.✓
[CL4] (3)
[20]

Topic 4: Intermolecular Forces

QUESTIONS

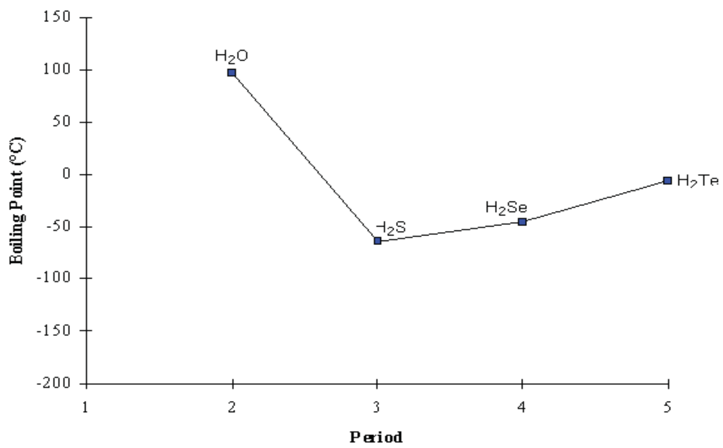
MULITPLE-CHOICE QUESTIONS

1. Between which particles can hydrogen bonds occur?
   A Small molecules that contain hydrogen.
   B Molecules in which hydrogen is bonded to small atoms with high electronegativity.
   C Small atoms with very high electronegativity.
   D Molecules in which hydrogen is bonded to small atoms with low electronegativity. (2)

2. The gecko is a small lizard that can climb up a smooth glass window. The gecko has millions of microscopic hairs on its toes and each hair has thousands of pads on its tip. The result is that the molecules in the pads are extremely close to the glass surface on which the gecko is climbing.
   What is the attraction between the gecko's toe pads and the glass surface?
   A dative covalent bonds
   B covalent bonds
   C ionic bonds
   D van der Waals forces (2)

ASSESSMENTS

Questions 3. and 4. refer to the graph below.



3. Water has a higher boiling point than expected because it…
   A is a liquid.
   B has strong hydrogen bonding intermolecular forces.
   C is a polar covalent molecule.
   D has small polar molecules.

4. The tendency for boiling point to increase from H_2S to H_2Te is due to…
   A stronger London intermolecular forces.
   B stronger polar covalent bonds.
   C increasing molecular polarity.
   D stronger dipole-dipole intermolecular forces.

5. Which one of the following combinations is correct?

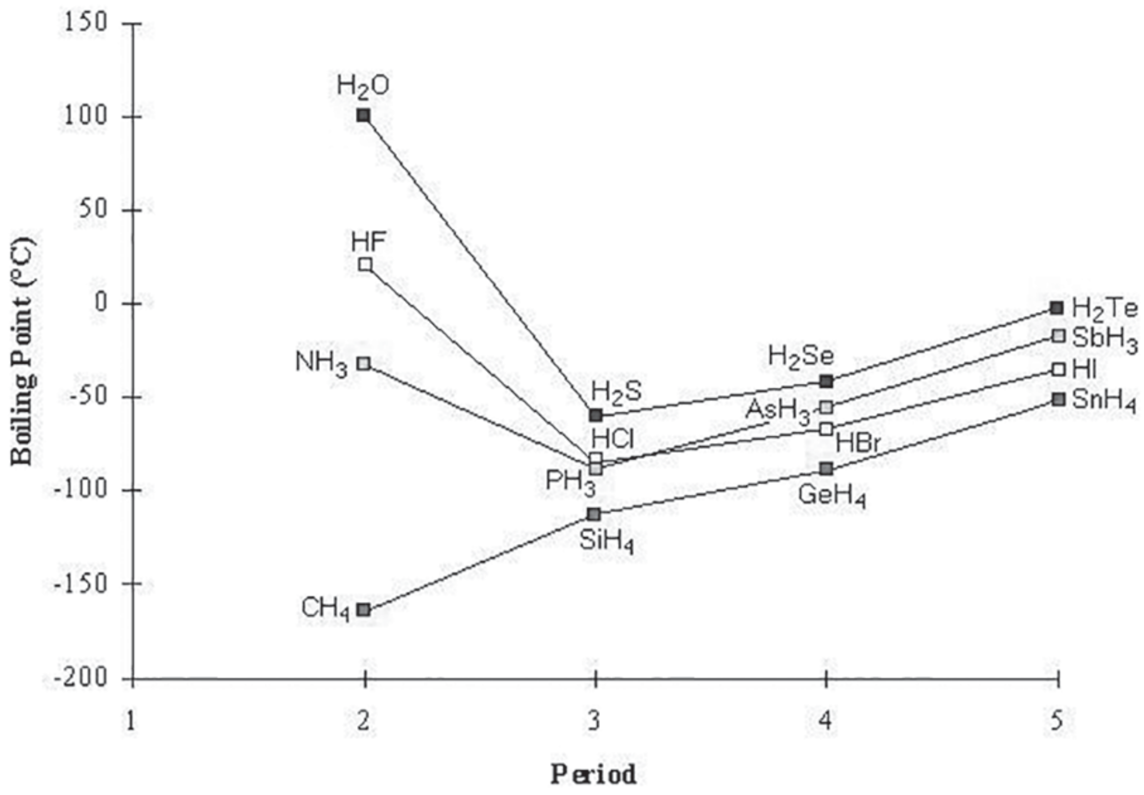
	Compound	Strongest Intermolecular force
A	CH_3F	Hydrogen bonding
B	$HC\ell$	Hydrogen bonding
C	CH_3OH	Dipole-dipole forces
D	$CC\ell_4$	London forces

(2)

6. The fact that noble gases liquefy can be given as evidence for the existence of …
   A covalent bonds.
   B dipole-dipole forces.
   C hydrogen bonds.
   D London forces. (2)

7. Crude oil consists of a mixture of different compounds called hydrocarbons. The molecular formula of some of these compounds is given below. Which one of these compounds will have the highest boiling point?
   A C_4H_{10}
   B C_6H_{14}
   C C_8H_{18}
   D $C_{10}H_{22}$ (2)

8. The graph shown below gives the boiling points of the hydrides of group 14, 15, 16 and 17 elements.



Water, hydrogen fluoride and ammonia have higher boiling points than expected, which suggests that these substances have stronger intermolecular forces between their molecules.

Which of the following does not contribute to the unexpectedly high boiling points of these three substances?

Nitrogen, oxygen and fluorine ……

A have small atoms.

B are non-metals.

C have high electronegativities.

D are bonded to hydrogen atoms. (2)

9. Hydrogen chloride occurs naturally as a gas at room temperature. When the temperature is reduced, hydrogen chloride liquefies and eventually solidifies. Which of the following pairs correctly names the bonds and the intermolecular forces found in hydrogen chloride?

	Bond	Intermolecular force
A	Non-polar covalent	Hydrogen bond force
B	Polar covalent	Hydrogen bond force
C	Non-polar covalent	London force
D	Polar covalent	Dipole-dipole force

(2)

10. In which one of the following compounds will hydrogen bonds be present? (All these compounds are in the liquid phase).
A $HC\ell$
B HF
C H_2
D H_2S (2)

LONG QUESTIONS

1. Water exists as a liquid at room temperature, but methane exists as a gas at this temperature. The molar mass of water is 18 $g.mol^{-1}$ and that of methane is 16 $g.mol^{-1}$. Explain, by discussing their intra- and intermolecular forces, why these two substances of similar molar mass exist in different phases at room temperature. [6]

2. H_2O and $CC\ell_4$ are both liquids that also act as solvents for other substances. $CC\ell_4$ has been used in the dry-cleaning business, but because it is toxic, it is no longer used for this commercially.
The table below gives information about these two substances.

Substance	Viscosity ($kg.m^{-1}.s$)	Surface tension ($J.m^{-2}$)
H_2O	1×10^{-3}	$7{,}3 \times 10^{-2}$
$CC\ell_4$	$9{,}7 \times 10^{-4}$	$2{,}7 \times 10^{-2}$

2.1 Determine the types of bonds in each of these substances. Justify your answer. (3)
2.2 Draw Lewis dot diagrams for:
a) H_2O
b) $CC\ell_4$ (4)
2.3 Identify the specific type of intermolecular forces in each compound. (2)
2.4 Explain the differences in viscosity and the surface tension of these two substances as shown in the data in the table above. (5)
2.5 $KC\ell$ and I_2 are both solids at room temperature. Which of these substances will dissolve most readily in $CC\ell_4$? Explain briefly. (3)
[17]

3.1 Consider the following information for the compounds CF_4 and NH_3 at standard pressure.

Compound	Melting Point (˚C)	Boiling Point (˚C)	Solubility in Water at 20 ˚C
CF_4	−183,6	−127,8	insoluble
NH_3	−77,7	−33,3	soluble

3.1.1 What evidence is there in the table that suggests that NH_3 molecules experience stronger intermolecular forces than CF_4? (1)

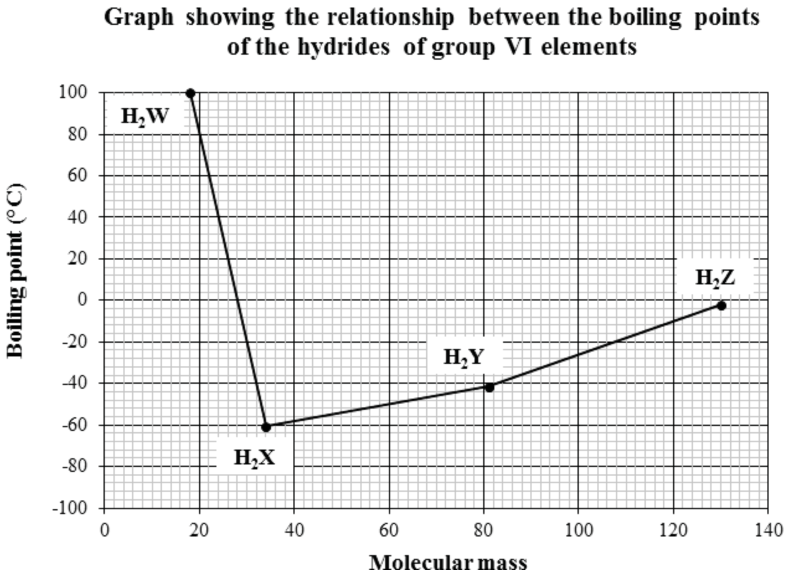
3.1.2 Explain fully why CF_4 is insoluble in water but NH_3 is soluble. (5)

3.1.3 Ammonia dissolves in water to form the ammonium anion.

(a) Write down the ionic equation for the reaction. (1)

(b) Explain the formation of a dative covalent bond in ammonia. (2)

3.2 The graph below shows the relationship between the boiling points of the hydrides of group VI elements, namely H_2W, H_2X, H_2Y and H_2Z, and molecular mass.



3.2.1 What unexpected result do you observe on the graph? (2)

3.2.2 Identify H_2W. (2)

3.2.3 Explain the phenomenon referred to in question 3.2.1. (4)

[17]

4. The equation for the combustion reaction of ethanol is given below.
   $C_2H_5OH(\ell) + 3\ O_2(g) \rightarrow 2\ CO_2(g) + 3\ H_2O(\ell)$ $\Delta H < 0$
   4.1 Draw the Lewis electron dot diagram for the ethanol molecule (CH_3CH_2OH). Use dots and crosses or different colours to show which electrons come from which atoms. (3)
   4.2 Name and define the specific type of intramolecular bond that forms between the C atom and the O atom in the ethanol molecule. (3)
   4.3 Name/state the molecular geometry (shape) around…
   (a) each C atom in the ethanol molecule. (1)
   (b) the O atom in the ethanol molecule. (1)
   4.4 Explain clearly why ethanol is a versatile (very useful) solvent. (4)
   [12]

5. The table below shows the boiling points of four alcohols.

Alcohol	Molecular formula	Boiling point (°C)
Methanol	CH_3OH	65
Ethanol	C_2H_5OH	79
Propanol	C_3H_7OH	97
Butanol	C_4H_9OH	117

   5.1 Draw a graph of the boiling points (on the y-axis) against the number of carbon atoms in the molecule (on the x-axis). Start with the temperatures from 60°C. Draw the line of best fit for the data. (5)
   5.2 Describe the trend in the boiling points of the alcohols. (2)
   5.3 Name the strongest intermolecular forces in these substances. (1)
   5.4 Explain the trend that this data shows about boiling points of alcohols, with reference to the intermolecular forces. (2)
   5.5 Methanol (CH_3OH) has a boiling point of 65°C whereas ethane (C_2H_6) boils at – 164°C. Explain why these two substances have such wide differences in their boiling points even though they have the same molecular mass. (4)
   [14]

6. The boiling points of four compounds of hydrogen at standard pressure are given in the table below.

Formula	Boiling point (°C)
CH_4	-164
NH_3	–33
H_2O	100
SiH_4	–112

   6.1 Define the term 'boiling point'. (2)

6.2 Fully explain the difference in boiling points between CH_4 and
6.2.1 NH_3. (3)
6.2.2 SiH_4. (3)

6.3 Explain why the boiling points of NH_3 and H_2O differ by referring to electronegativity, the molecular shapes and the intermolecular forces in these substances. (4)

6.4 Select a substance from the table above which has
6.4.1 polar molecules. (1)
6.4.2 non-polar molecules. (1)
[14]

7. The properties of water play an important role for survival on Earth.
7.1 Explain why the density of water decreases when it freezes. (3)
7.2 Give ONE reason why this decrease in the density of water is important for life on Earth. (2)
7.3 Briefly explain, by referring to the unique property of water involved, how water regulates temperatures on Earth. (2)
7.4 Which ONE of intermolecular forces or intramolecular forces is stronger? Explain your answer using water as an example. (3)
7.5 Water evaporates slower than eucalyptus oil. Explain this statement in terms of intermolecular forces. (3)
[13]

MARKING GUIDELINES

MULTIPLE CHOICE

1. B ✓✓ It is the small atom with high electronegativity that is bonded to a hydrogen atom that allows hydrogen bonds to form between molecules of a substance. [CL2] (2)

2. D ✓✓ It is the force between the molecules of glass and the molecules in the pads of gecko's toes that allows it climb the smooth glass surface. The other choices here concern intramolecular forces (chemical bonds). The gecko does not bond permanently with the glass! [CL3] (2)

3. B ✓✓ The other substances do not have hydrogen bonds between their molecules. It must therefore be the strong hydrogen bonds between water molecules that accounts for its high boiling point. [CL2] (2)

4. D ✓✓ The molecules of H_2S, H_2Se and H_2Te are polar, therefore the intermolecular forces between them are dipole-dipole forces. The forces become stronger as the size of the molecules increases. [CL2] (2)

5. D ✓✓ CH_3F does not have hydrogen bonding because the fluorine atom is attached to the carbon atom (not to a hydrogen atom). $HC\ell$ has dipole-dipole forces (not hydrogen bonds). CH_3OH has dipole-dipole forces, but its strongest intermolecular forces are hydrogen bonds. The only correct answer is therefore $CC\ell_4$ which does have London forces between its molecules. [CL3] (2)

6. D ✓✓ The noble gases are non-polar substances. The fact that they liquefy gives evidence that forces exist between their molecules in the liquid phase. These forces are London forces. [CL2] (2)

7. D ✓✓ These compounds are all the same type of substance; therefore, they will have the same type of intermolecular forces between their molecules. The intermolecular forces will increase in strength as the size of the molecules increases because there will be more points of contact available for the forces to hold the molecules closer together. [CL2] (2)

8. B✓✓ It is the small atom with high electronegativity that is bonded to a hydrogen atom that allows hydrogen bonds to form between molecules of a substance. Therefore, the fact that these elements are non-metals does not contribute directly to the hydrogen bonding. [CL 4] (2)

9. D ✓✓ Hydrogen chloride has one polar covalent bond between its atoms. It has dipole-dipole intermolecular forces between its molecules. [CL 3] (2)

10. B ✓✓ F is a small atom with high electronegativity bonded to H. It is these types of molecules that can form hydrogen bonds between them. [CL2] (2)

LONG QUESTIONS

1. Both methane and water have polar covalent bonds between their atoms.✓

   Δ electronegativity C-H = 2,5 – 2,1 = 0,4

   Δ electronegativity H-0 = 3,5 – 2,1 = 1,4

   (for calculating Δ electronegativity correctly) ✓

   The bond between oxygen and hydrogen is more polar than that between carbon and hydrogen.

   Water has an angular structure, whereas methane is tetrahedral. The electron distribution in the water molecule is asymmetrical, but it is symmetrical in the methane molecule.✓

   Water molecules are polar; methane molecules are non-polar.✓

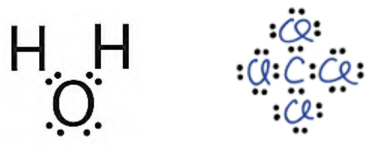
   The intermolecular forces between water molecules are hydrogen bond (dipole-dipole) forces which are much stronger✓ than the London forces (induced dipole-induced dipole forces) that exist between methane molecules,✓ therefore water is a liquid and methane is a gas at room temperature. [CL 4] [6]

2.1 Water: polar covalent bond✓

$CC\ell 4$: polar covalent bond✓

The differences in electronegativity in each of these bonds is greater than 0. [CL 2] (3)

2.2



2 marks for each correct diagram.

-1 any mistake. [CL 3] (4)

2.3 Water: hydrogen bond ✓ (dipole-dipole) forces $CC\ell_4$: London forces ✓ [CL 2] (2)

2.4 The viscosity of water is about 10 times that of $CC\ell_4$, and its surface tension is just a little more than twice as high.✓ The hydrogen bonds ✓between molecules in water are much stronger ✓than the dispersion (London) forces in $CC\ell_4$. ✓ Therefore, it makes sense that water molecules will cling to one another more tightly than $CC\ell_4$ molecules – and therefore have stronger forces in the surface of the liquid (surface tension) and greater viscosity than $CC\ell_4$.✓ [CL 4] (4)

2.5 Iodine is a non-polar substance, whereas $KC\ell$ is an ionic substance. ✓ Substances with similar strength of intermolecular forces are able to dissolve in one another. ✓ Therefore, iodine will dissolve in $CC\ell_4$ (but $KC\ell$ will not).✓ [CL 3] (3)

[17]

3.1.1 The melting and boiling points of NH_3 are much higher than those of CF_4 therefore it takes more energy to overcome the intermolecular forces in NH_3. [CL2] (2)

3.1.2 CF_4 molecules are non-polar molecules; they have London forces between them. ✓ Water molecules are polar molecules with stronger hydrogen bonds between them. ✓ If CF_4 is added to water, the water molecules are so strongly attracted to each other that they will not move apart to allow CF_4 molecules to mix in with them. ✓ Therefore CF_4 is insoluble in water.
NH₃ molecules are polar molecules with hydrogen bonding force between them. ✓Because these forces are of comparable strength to the forces between water molecules, ammonia molecules will mix with water molecules ✓– ammonia will dissolve in water. [CL3] (5)

3.1.3 a) $NH_3(g) + H_2O(\ell) \rightarrow NH_4^+(aq) + OH^-(aq)$ ✓ [CL3] (1)
b) The lone pair of electrons on the NH_3 molecule is donated to form the bond ✓ with the H^+ ion that is removed from the water molecule. ✓ [CL3] (2)

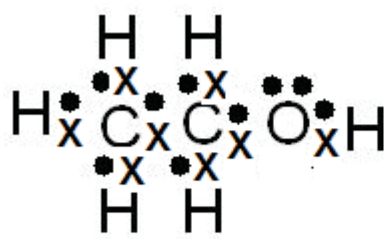
3.2.1 The boiling point of H_2W is much higher that expected. ✓✓ [CL2] (2)

3.2.2 Water (or H_2O) ✓✓ [CL2] (2)

3.2.3 Water molecules have much stronger intermolecular forces between their molecules than the other hydrides of group VI elements do. ✓ This occurs because hydrogen is bonded to oxygen which is a very small atom ✓ with high electronegativity ✓. Hydrogen bonds exist between water molecules; dipole-dipole forces exist between the molecules of the other substances. ✓ [CL3] (4)

[17]

4.1.



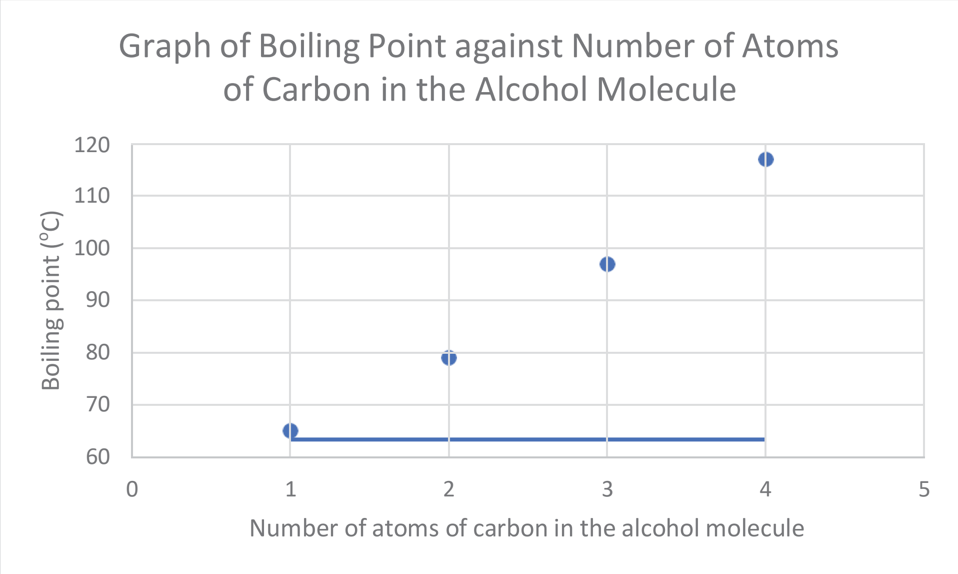
✓ 4 electrons on each carbon atom
✓ 1 electron on each hydrogen atom
✓ 6 electrons on oxygen atoms (1 lone pair)
[CL3] (3)

4.2 polar covalent bond✓
The bonded pair of shared electrons✓ is more strongly attracted to the more electronegative atom (oxygen). ✓ [CL2] (3)

4.3 a) tetrahedral ✓ [CL2] (1)
b) angular ✓ [CL3] (1)

4.4 Ethanol molecules have a non-polar side and a polar side to them✓✓ therefore they are able to dissolve polar ✓and non-polar substances. ✓ [CL4] (4)

5.1



✓Appropriate title for the graph
✓Axes labelled correctly with SI unit (y-axis)
✓Appropriate scales on axes
✓Points plotted correctly
✓Line of best fit (straight line) [CL2] (5)

5.2 The boiling point increases at a steady rate ✓as the number of carbon atoms in the alcohol molecule increases.✓ [CL3] (2)

5.3 Hydrogen bonds ✓ [CL2] (1)

5.4 As the number of carbon atoms in the molecules increases, the size of the molecules also increases.✓ The intermolecular forces between the molecules become stronger because there are more points of contact available on the bigger molecules.✓ [CL3] (2)

5.5 Methanol has hydrogen bonding between its molecules whereas ethane which is a non-polar substance ✓ has weaker London forces between its molecules.✓ Hydrogen bonding forces are the strongest type of intermolecular force; ✓ London forces are the weakest forces between molecules✓ therefore there is a wide difference between their boiling points. [CL3] (4)

6.1 The boiling point is the temperature at which the vapour pressure of a liquid is equal to the atmospheric pressure.✓✓ [CL1] (2)

6.2 NH_3 is a polar molecule which has strong hydrogen bonds between its molecules.✓ CH_4 is a non-polar molecule with weaker London forces between its molecules.✓ It takes much more energy to overcome the forces between the molecules of NH_3 ✓ therefore its boiling point is much higher than that of CH_4.
[CL3] (3)

ASSESSMENTS

6.3 NH_3 and H_2O both have polar molecules with hydrogen bonds between them. ✓ The electronegativity difference between N and H is 3,0 – 2,1 = 0,9 whereas the electronegativity difference between H and O is 3,5 – 2,1 = 1,4.✓ The covalent bonds inside the water molecule are more polar than those in the NH_3 molecule.✓ Water molecules have an angular shape, whereas NH_3 molecules are trigonal pyramidal.✓ This allows each water molecule to form two hydrogen bonds with two other water molecules making the intermolecular forces in water much stronger than those in NH_3. ✓ [CL4] (4)

6.4.1 NH_3 or H_2O ✓ [CL2] (1)

6.4.2 CH_4 or SiH_4 ✓ [CL2] (1)

[14]

7.1 Hydrogen bonds between water molecules act in particular directions.✓ When ice crystallises, this directional property of hydrogen causes the molecules to align next to each in a more open structure than they do when water is liquid.✓ Water's volume increases as the molecules move into their positions in the crystal, therefore its density decreases.✓ [CL3] (3)

7.2 Water freezes from the top down so, ice forms on the surface of water first while the bottom of the lake, dam, river or ocean remains liquid. ✓The sheet of ice over the top of a frozen lake insulates the water below it from the colder air in the atmosphere. In this way plants and animals that live in water are able to do so under the sheet of ice.✓ [CL2] (2)

7.3 Water has a very high specific heat capacity. (It takes a large amount of energy to be absorbed per kg of water to raise the temperature of water by 1°C).✓ Water also releases a large amount of energy per kg when its temperature drops by 1°C. In this way water acts as a heat reservoir – and regulates the temperatures on Earth.✓ [CL3] (2)

7.4 Intramolecular forces are stronger than intermolecular forces. ✓ In water the polar covalent bond between hydrogen atoms and oxygen atoms requires more energy to break✓, that the energy required to overcome the hydrogen bonding forces that keep the molecules together in liquids and solids.✓ [CL3] (3)

7.5 Eucalyptus oil molecules are non-polar molecules with weaker London forces between them.✓ Water molecules have stronger hydrogen bonds between their molecules.✓ It takes more energy to release a water molecule from the surface than it does to release molecules of eucalyptus oil.✓ [CL3] (3)