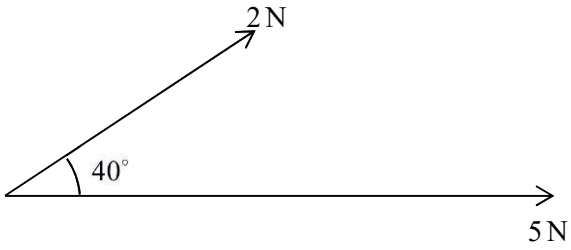
Section B: Mechanics
Answer **all** the questions

9 Two forces, of magnitudes 2 N and 5 N, act on a particle in the directions shown in the diagram below.



(i) Calculate the magnitude of the resultant force on the particle. **[3]**

(ii) Calculate the angle between this resultant force and the force of magnitude 5 N. **[1]**

10 A body of mass 20 kg is on a rough plane inclined at angle α to the horizontal. The body is held at rest on the plane by the action of a force of magnitude P N acting up the plane in a direction parallel to a line of greatest slope of the plane. The coefficient of friction between the body and the plane is μ.

(i) When $P = 100$, the body is on the point of sliding down the plane.
Show that $g\sin\alpha = g\mu\cos\alpha + 5$. **[4]**

(ii) When P is increased to 150, the body is on the point of sliding up the plane. Using this and your answer to part **(i)**, find an expression for α in terms of g. **[3]**

11 In this question the unit vectors **i** and **j** are in the directions east and north respectively.

A particle of mass 0.12 kg is moving so that its position vector **r** metres at time t seconds is given by $\mathbf{r} = 2t^3\mathbf{i} + \left(5t^2 - 4t\right)\mathbf{j}$.

(i) Show that when $t = 0.7$ the bearing on which the particle is moving is approximately 044°. **[3]**

(ii) Find the magnitude of the resultant force acting on the particle at the instant when $t = 0.7$. **[4]**

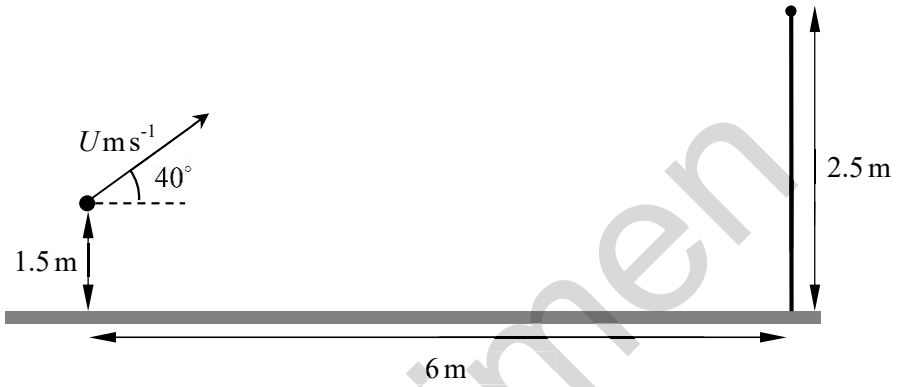
(iii) Determine the times at which the particle is moving on a bearing of 045°. **[2]**

12 A girl is practising netball. She throws the ball from a height of 1.5 m above horizontal ground and aims to get the ball through a hoop. The hoop is 2.5 m vertically above the ground and is 6 m horizontally from the point of projection.

The situation is modelled as follows.

- The initial velocity of the ball has magnitude $U\,\text{m s}^{-1}$.
- The angle of projection is 40°.
- The ball is modelled as a particle.
- The hoop is modelled as a point.

This is shown on the diagram below.



(i) For $U = 10$, find

(a) the greatest height above the ground reached by the ball, **[5]**

(b) the distance between the ball and the hoop when the ball is vertically above the hoop. **[4]**

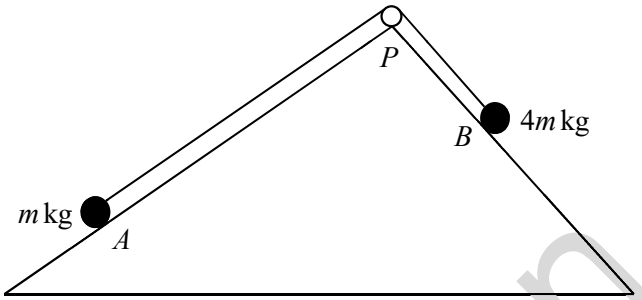
(ii) Calculate the value of U which allows her to hit the hoop. **[3]**

(iii) How appropriate is this model for predicting the path of the ball when it is thrown by the girl? **[1]**

(iv) Suggest one improvement that might be made to this model. **[1]**

13 Particle A, of mass m kg, lies on the plane Π_1 inclined at an angle of $\tan^{-1}\frac{3}{4}$ to the horizontal. Particle B, of $4m$ kg, lies on the plane Π_2 inclined at an angle of $\tan^{-1}\frac{4}{3}$ to the horizontal. The particles are attached to the ends of a light inextensible string which passes over a smooth pulley at P. The coefficient of friction between particle A and Π_1 is $\frac{1}{3}$ and plane Π_2 is smooth. Particle A is initially held at rest such that the string is taut and lies in a line of greatest slope of each plane.

This is shown on the diagram below.



(i) Show that when A is released it accelerates towards the pulley at $\frac{7g}{15}\,\text{m s}^{-2}$. **[6]**

(ii) Assuming that A does not reach the pulley, show that it has moved a distance of $\frac{1}{4}$ m when its speed is $\sqrt{\frac{7g}{30}}\,\text{m s}^{-1}$. **[2]**

14 A uniform ladder AB of mass 35 kg and length 7 m rests with its end A on rough horizontal ground and its end B against a rough vertical wall. The ladder is inclined at an angle of 45° to the horizontal. A man of mass 70 kg is standing on the ladder at a point C, which is x metres from A. The coefficient of friction between the ladder and the wall is $\frac{1}{3}$ and the coefficient of friction between the ladder and the ground is $\frac{1}{2}$. The system is in limiting equilibrium.

Find x. **[8]**

1 Express $\frac{8}{\sqrt{3}-1}$ in the form $a\sqrt{3}+b$, where a and b are integers. **[3]**

2 **(i)** Sketch the curve $y=-\frac{1}{x}$. **[2]**

(ii) The curve $y=-\frac{1}{x}$ is translated by 2 units parallel to the x-axis in the positive direction. State the equation of the transformed curve. **[2]**

(iii) Describe a transformation that transforms the curve $y=-\frac{1}{x}$ to the curve $y=-\frac{1}{3x}$. **[2]**

3 Express each of the following in the form 5^k.

(i) 25^4 **[1]**

(ii) $\frac{1}{\sqrt[4]{5}}$ **[2]**

(iii) $(5\sqrt{5})^3$ **[2]**

4 Solve the equation $x^{\frac{2}{3}}-x^{\frac{1}{3}}-6=0$. **[5]**

5 The points A and B have coordinates (2, 1) and (5, –3) respectively.

(i) Find the length of AB. **[2]**

(ii) Find an equation of the line through the mid-point of AB which is perpendicular to AB, giving your answer in the form $ax+by+c=0$ where a, b and c are integers. **[7]**

6 Solve the simultaneous equations

$$2x+y-5=0, \qquad x^2-y^2=3. \quad \textbf{[5]}$$

7 **(a)** Given that $\mathrm{f}(x)=(x^2+3)(5-x)$, find $\mathrm{f}'(x)$. **[4]**

(b) Find the gradient of the curve $y=x^{-\frac{1}{3}}$ at the point where $x=-8$. **[4]**

8 **(i)** Sketch the curve $y = 2x^2 - x - 3$, giving the coordinates of all points of intersection with the axes. **[4]**

(ii) Hence, or otherwise, solve the inequality $2x^2 - x - 3 > 0$. **[2]**

(iii) Given that the equation $2x^2 - x - 3 = k$ has no real roots, find the set of possible values of the constant k. **[3]**

9 The curve $y = 2x^3 - ax^2 + 8x + 2$ passes through the point B where $x = 4$.

(i) Given that B is a stationary point of the curve, find the value of the constant a. **[5]**

(ii) Determine whether the stationary point B is a maximum point or a minimum point. **[2]**

(iii) Find the x-coordinate of the other stationary point of the curve. **[3]**

10 A circle with centre C has equation $x^2 + y^2 - 10x + 4y + 4 = 0$.

(i) Find the coordinates of C and the radius of the circle. **[3]**

(ii) Show that the tangent to the circle at the point P (8, 2) has equation $3x + 4y = 32$. **[5]**

(iii) The circle meets the y-axis at Q and the tangent meets the y-axis at R. Find the area of triangle PQR. **[4]**

1. Balance the following chemical reactions:

   a. $CO + O_2 \rightarrow CO_2$

   b. $KNO_3 \rightarrow KNO_2 + O_2$

   c. $O_3 \rightarrow O_2$

   d. $NH_4NO_3 \rightarrow N_2O + H_2O$

   e. $CH_3NH_2 + O_2 \rightarrow CO_2 + H_2O + N_2$

   f. $Cr(OH)_3 + HClO_4 \rightarrow Cr(ClO_4)_3 + H_2O$

2. Write the balanced chemical equations of each reaction:

   a. Calcium carbide (CaC_2) reacts with water to form calcium hydroxide ($Ca(OH)_2$) and acetylene gas (C_2H_2).

   b. When potassium chlorate ($KClO_3$) is heated, it decomposes to form KCl and oxygen gas (O_2).

   c. C_6H_6 combusts in air.

   d. $C_5H_{12}O$ combusts in air.

3. Given the following reaction: $Na_2S_2O_3 + AgBr \rightarrow NaBr + Na_3[Ag(S_2O_3)_2]$

   a. How many moles of $Na_2S_2O_3$ are needed to react completely with 42.7 g of AgBr?

   b. What is the mass of NaBr that will be produced from 42.7 g of AgBr?

4. From the reaction: $B_2H_6 + O_2 \rightarrow HBO_2 + H_2O$

   a. What mass of O_2 will be needed to burn 36.1 g of B_2H_6?

   b. How many moles of water are produced from 19.2 g of B_2H_6?

5. Calculate the mass (in kg) of water produced from the combustion of 1.0 gallon (3.8 L) of gasoline (C_8H_{18}). The density of gasoline is 0.79 g/mL.

6. One mole of aspartame ($C_{14}H_{18}N_2O_5$) reacts with two moles of water to produce one mole of aspartic acid ($C_4H_7NO_4$), one mole of methanol (CH_3OH) and one mole of phenylalanine.

   a. What is the molecular formula of phenylalanine?

b. What mass of phenylalanine is produced from 378 g of aspartame?

7. KO_2 is used in a closed-system breathing apparatus. It removes carbon dioxide and water from exhaled air. The reaction for the removal of water is: $KO_2 + H_2O \rightarrow O_2 + KOH$. The KOH produced is used to remove carbon dioxide by the following reaction: $KOH + CO_2 \rightarrow KHCO_3$.

   a. What mass of KO_2 produces 235 g of O_2?

   b. What mass of CO_2 can be removed by 123 g of KO_2?

Thermal Reactions

8. How many kilojoules are given off when 17.8 mol of $CH_4(g)$ react?

   $CH_4(g) + 2\ O_2(g) \rightarrow CO_2(g) + 2\ H_2O(\ell)\ \Delta H = -890.1$ kJ

9. How many kilojoules are absorbed when 23.09 mol of $C_6H_6(\ell)$ are formed?

   $6\ C(s) + 3\ H_2(g) \rightarrow C_6H_6(\ell)\ \Delta H = 49.0$ kJ

Electrolysis

1 Faraday (F) = **96 500 Coulombs** (**C**) = **1 mole of electrons**.

10. A current was passed through an electrolysis circuit of silver nitrate solution and 0.54g of silver was formed.

    - $A_r(Ag)$= 108 and the electrode equation is $\mathbf{Ag^+ (aq) + e^- ==> Ag_{(s)}}$
    - $A_r(Ag)$= 64 and the electrode equation is $\mathbf{Cu^{2+}{}_{(aq)} + 2e^- ==> Cu_{(s)}}$
    - If in the same circuit a copper(II) sulphate and copper electrodes cell was connected, how much copper is deposited at the negative (-) cathode?

11. How long will it take to produce 2 dm^3 of chlorine gas by passing a 6A current through concentrated sodium chloride solution at 25C and 101kPa (1 atmosphere pressure)