IB DIPLOMA PROGRAMME
PROGRAMME DU DIPLÔME DU BI
PROGRAMA DEL DIPLOMA DEL BI

M02/841/H(2)

CHEMICAL AND PHYSICAL SYSTEMS
HIGHER LEVEL
PAPER 2

May 2002

2 hours 15 minutes

Name

Number

INSTRUCTIONS TO CANDIDATES

- Write your candidate name and number in the boxes above.
- Do not open this examination paper until instructed to do so.
- Section A: Answer all of Section A in the spaces provided.
- Section B: Answer two questions from Section B. Answer one of questions 3 or 4 and one of questions 5 or 6. You may continue your answers in a continuation answer booklet, indicate the number of booklets used in the box below. Write your name and candidate number on the front cover of the continuation answer booklets, and attach them to this question paper using the tag provided.
- At the end of the examination, indicate the numbers of the Section B questions answered in the boxes below.

QUESTIONS ANSWERED		EXAMINER	TEAM LEADER	IBCA
SECTION A	ALL	/40	/40	/40
SECTION B				
QUESTION	. . . . .	/25	/25	/25
QUESTION	. . . . .	/25	/25	/25
NUMBER OF CONTINUATION BOOKLETS USED	. . . . .	TOTAL /90	TOTAL /90	TOTAL /90

SECTION A

*Candidates must answer **all** questions in the spaces provided.*

In order to receive full credit in Section A, the method used and the steps involved in arriving at your answer must be shown clearly. It is possible to receive partial credit but, without your supporting work, you may receive little credit. For numerical calculations, you are expected to pay proper attention to significant figures.

1. (a) Research has now determined that nicotine is an addictive component of tobacco used in cigarettes. Chemical analysis showed that nicotine contained 74.07 % carbon, 8.64 % hydrogen and 17.28 % nitrogen. The molecular mass of nicotine is 162.

(i) Determine the empirical formula of nicotine. *[3]*

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(ii) Calculate the molecular formula of nicotine. *[3]*

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(iii) Predict whether nicotine would be a polar **or** non-polar molecule. *[1]*

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(b) Bromine exists in nature as isotopes Br-79 and Br-81. Given that the relative atomic mass of bromine is 79.9, what percentage of each isotope is present in nature? *[3]*

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(This question continues on the following page)

(Question 1 continued)

(c) In an experiment, copper was converted into a series of different compounds. Write balanced chemical equations for the following reactions.

(i) Copper is reacted with 8 M nitric acid to produce a solution of copper(II) nitrate and a brown pungent gas. No copper metal remains. *[2]*

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(ii) The copper nitrate is reacted with 2 M sodium hydroxide to form a light blue precipitate of copper hydroxide. *[2]*

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(iii) 100 dm^3 of water is added to the precipitate, and the solution is heated to form a black copper(II) oxide precipitate due to a decomposition reaction occurring. *[2]*

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(iv) The copper (II) oxide precipitate is decanted from the solution and washed with water to remove any excess reactants. The precipitate is added to 50 dm^3 of 2 M sulfuric acid. An aqua-blue solution is formed. *[2]*

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(v) Some pieces of zinc are added to the aqua-blue solution. *[2]*

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2. This is a data-based question concerning an oscillating spring undergoing simple harmonic motion. If a spring has negligible mass, the period of the oscillation is given by

$$T = 2\pi\sqrt{\left(\frac{m}{k}\right)}$$

where m is the mass attached to the spring and k is the spring constant.
For any real spring, the mass of the spring is not negligible, and the period of oscillation is given by

$$T = 2\pi\sqrt{\left[\frac{(m + m_0)}{k}\right]}$$ where m_0 is the effective mass of the spring.

A student sets up a spring attached to the clamp on a retort stand. For various masses given by m, the time for 10 oscillations was recorded. The following data was obtained.

$\frac{m}{\text{kg}}$	$\frac{\text{Time for 10 oscillations}}{\text{s}}$	$\frac{\text{Period}}{\text{s}}$	$\frac{\text{Period}^2}{\text{s}^2}$
0.030	4.74		
0.050	5.66		
0.060	6.12		
0.080	6.98		
0.100	7.76		

(a) Complete the last two columns of the table to determine the period and the period squared for the masses attached to the oscillating spring. *[3]*

(b) Plot a graph of the oscillating masses against the period squared on the grid paper on the next page. *[5]*

(c) From the graph obtained, what can be deduced about the relationship that exists between the period of the oscillation and the mass causing the oscillation. Justify your deduction. *[2]*

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(d) From the graph, determine the value for the spring constant of the spring. *[3]*

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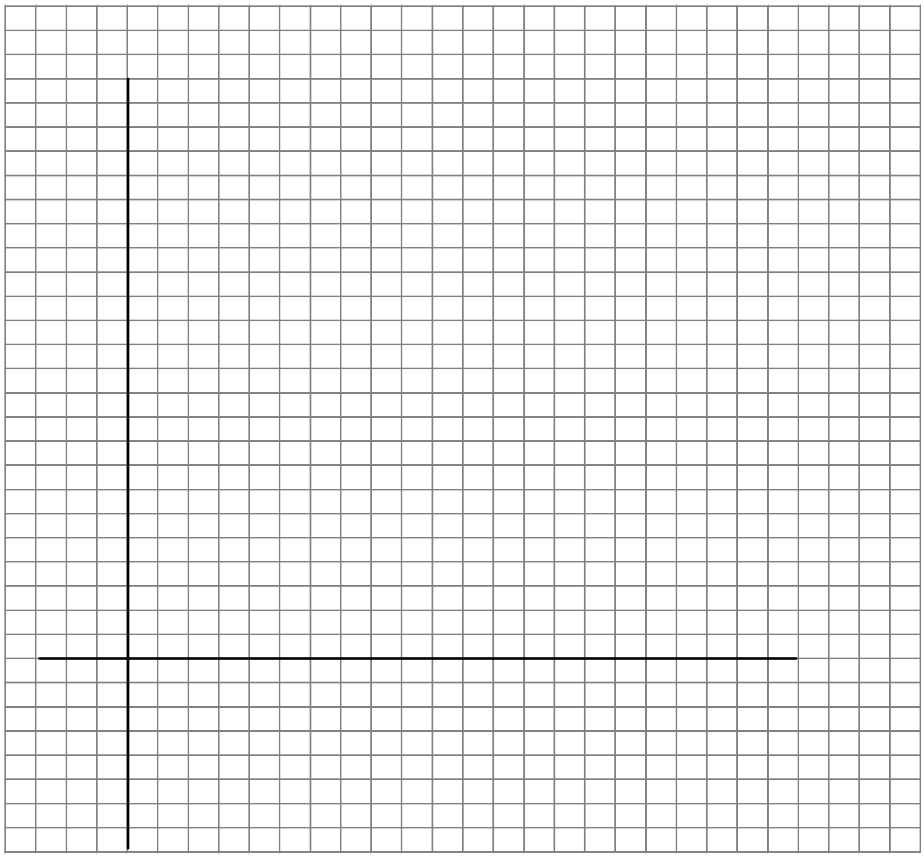
(Question 2 continued)



(e) From the graph determine the mass m_0 of the spring. *[3]*

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(f) In order to verify the value of the spring constant obtained from the graph, the student carried out an alternative investigation. Discuss an alternative investigation that would allow the spring constant to be obtained by another graphical means. *[4]*

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SECTION B

*Answer **one** of questions 3 **or** 4 **and one** of questions 5 **or** 6 in the spaces provided.*

3. (a) (i) Write the equilibrium expression for the reaction below.

$$I_{2(g)} + Cl_{2(g)} \rightleftharpoons 2ICl_{(g)}$$ *[1]*

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(ii) 0.50 mol of gaseous iodine molecules and 0.50 mol of gaseous chlorine molecules were mixed in a 1.0 dm^3 flask at a certain temperature and the mixture was allowed to reach equilibrium. When equilibrium was reached, 0.40 mol of gaseous iodine chloride was present. Find the equilibrium constant. *[2]*

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(iii) Explain whether an increase in pressure would affect the equilibrium. *[2]*

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(iv) If $\Delta H = 45$ kJ for the forward reaction, explain what would happen to the equilibrium expression if the equilibrium temperature was doubled. *[2]*

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(b) Why is the Haber process carried out at 450 °C when the forward reaction is exothermic? *[2]*

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(This question continues on the following page)

(Question 3 continued)

(c) (i) Using an example, state the Brønsted-Lowry definition of a base. *[2]*

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(ii) The molarity of an ethanoic acid solution is 1.0×10^{-3} and the K_a value at a certain temperature is 1.0×10^{-5}. Find the hydrogen ion concentration and the pH at this temperature. *[4]*

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(d) When aqueous solutions of ethanoic acid and sodium ethanoate are mixed, a buffer solution is produced.

(i) What is a buffer solution? *[1]*

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(ii) Using the above-mentioned buffer solution, explain in molecular terms how the buffer solution operates. *[2]*

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(iii) If a small amount of the ethanoic acid or sodium ethanoate was treated with a large amount of a concentrated base, would the pH of the final mixture be equal to, greater or less than 7? Explain your answer. *[2]*

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(This question continues on the following page)

(Question 3 continued)

(e) (i) Butanoic acid possesses a higher melting point and boiling point than almost all other organic compounds of a similar molecular mass. Why is this so? *[1]*

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(ii) Butanoic acid can be prepared from 1-butanol but not from 2-butanol. What is the name of the reaction used in the preparation of butanoic acid from 1-butanol, and what is the organic product of the reaction of 2-butanol with acidified potassium permanganate solution? *[2]*

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(iii) Write a molecular equation for the reaction of butanoic acid with ethanol, and name the organic product formed. *[2]*

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4. (a) The transition metal chromium can occur in several oxidation states.

(i) What are the oxidation number of chromium in the ions CrO_4^{2-}, $Cr_2O_7^{2-}$ and Cr^{3+}? *[3]*

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(ii) Which of the above ions would act as a reducing agent? *[1]*

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(b) Write the half-equation, and an overall balanced equation for the reaction that would occur between iron(II) nitrate and bromine in aqueous solution. *[4]*

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(Question 4 continued)

(c) (i) State Faraday's First Law of Electrolysis. *[2]*

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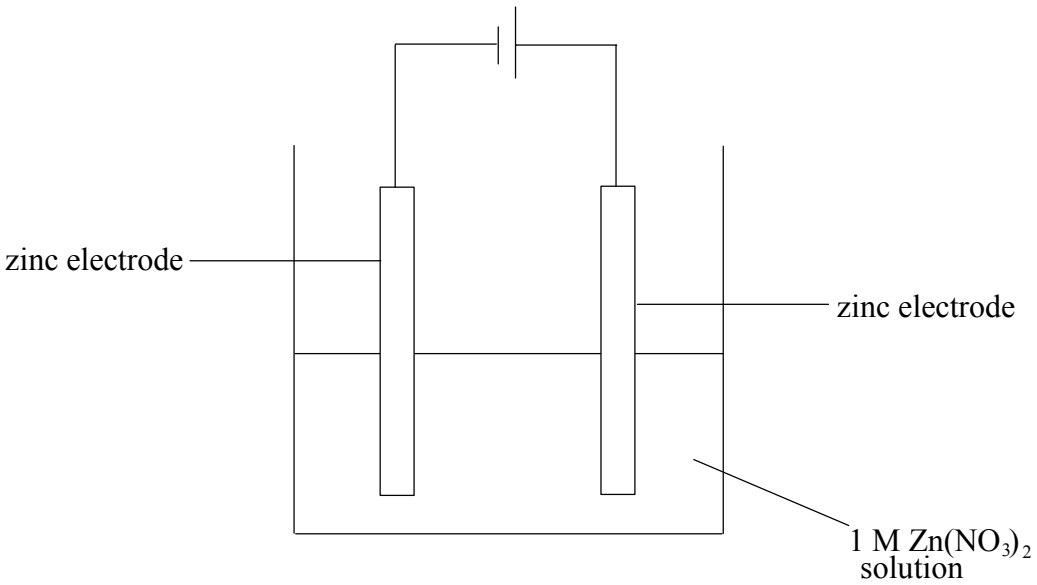
(ii) The following electrolytic cell can be used to produce zinc metal.



Calculate the mass of zinc deposited when a current of 0.500 A flows through the circuit for 120 minutes. (The Faraday constant is 9.65×10^4 C mol^{-1}.) *[4]*

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(Question 4 continued)

(d) Using a diagram, discuss the existence of optical isomers. *[2]*

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(e) Describe the condensation polymer formed when hexanedioic acid reacts with hexane-1,6-diamine to produce Nylon-66. *[3]*

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(f) Draw the structural formula, and name the **two** functional group isomers of $C_2H_4O_2$. *[2]*

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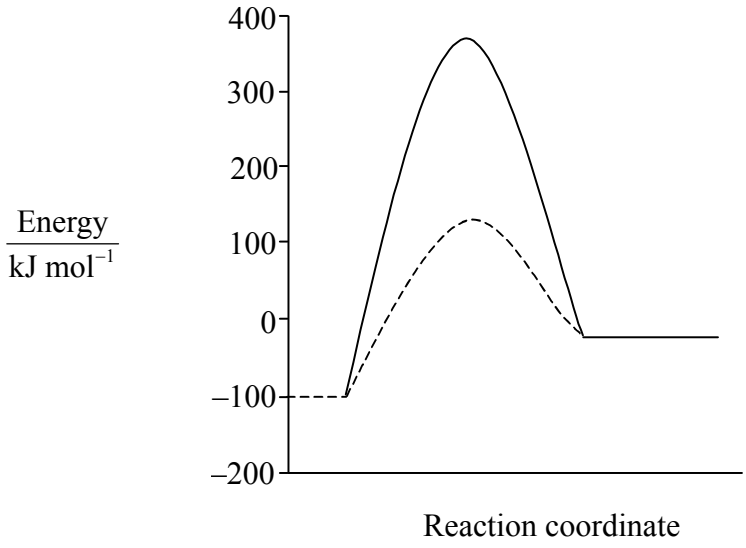
(Question 4 continued)

(g) The energy profile diagram below shows the decomposition of 1 mole of methane with and without the presence of a platinum catalyst.



(i) Estimate the enthalpy change for the reaction **with** and **without** the catalyst. *[2]*

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(ii) Estimate the activation energy **with** and **without** the catalyst. *[2]*

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5. This question deals with the production and transmission of electric power, electricity costs and efficiency, and fuse systems.

(a) Is it feasible to transmit power from a power station over long distances using direct current rather than alternating current? Justify your answer. *[2]*

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(b) An aluminum transmission cable has a resistance of 5.0 Ω when 10 kW of power is transmitted in the cable. Justify why it is better to transmit the power at 100 000 V rather than 1 000 V by comparing the power that would be wasted in the transmission at both of these voltages. *[4]*

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(c) Many step-up and step-down transformers are used in the electricity transmission from the power station to the home. In order to increase the efficiency of the transformers, eddy currents have to be minimised. How is this achieved in the transformer design? *[1]*

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(d) If the fuse controlling the maximum power for lighting in your house is rated at 8 A, what is the maximum number of 60 W light bulbs that can be operated in parallel with a 110 V power supply so as not to blow the fuse? *[2]*

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(Question 5 continued)

(e) A stainless steel calorimeter with a mass of 720 g was used to heat 1.5 kg of water. If the $\frac{\text{current}}{\text{voltage}}$ in a heating element supplying the power was $\frac{30.2\text{ A}}{110\text{ V}}$ and it took 2.5 minutes to heat the water from 25 °C to 98 °C, what is the specific heat capacity of the stainless steel? (Assume no heat loss to the surroundings. The specific heat capacity of water is $4.18\times10^{3}\text{ J kg}^{-1}\text{ K}^{-1}$.) *[5]*

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(f) How much does it cost to run the following appliances at the same time for one hour if electricity costs 10.5 cent per kilowatt-hour: a 6 kW oven, two 300 W colour televisions and five 100 W light globes? *[2]*

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(This question continues on the following page)

(Question 5 continued)

(g) In a nuclear fission reactor at a power station, uranium-235 is bombarded with a neutron to produce lanthanum-148 and bromine-85.

(i) Write a balanced equation for this reaction. *[2]*

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(ii) Calculate the energy released per fission given the following masses.

Uranium-235 = 235.044 u	Lanthanum-148 = 147.915 u
Bromine-85 = 84.911 u	Neutron = 1.008 u

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(iii) How many hours would it take a nuclear reactor producing heat at 0.5 MW to use 2.0 g of uranium-235 nuclei? *[4]*

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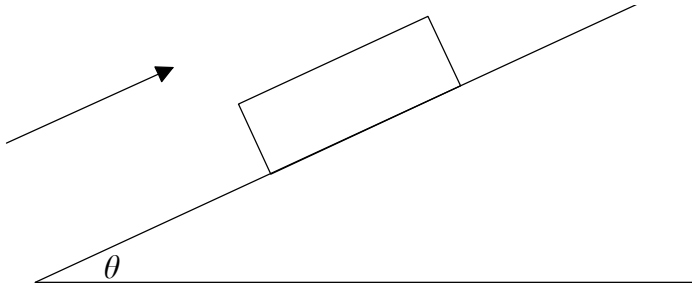
6. This question examines aspects of forces, uniform circular motion, satellites and space travel.

(a) A car is accelerating up a typical small hill as shown in the free body diagram below.



Label **all** the forces acting on the car to complete the free body diagram. *[3]*

(b) Explain the following situations with reference to Newton's Laws.

(i) A rocket moves forward by ejecting gases from the back of its propulsion system. *[2]*

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(ii) A car originally travelling in a straight line motion turns left around a corner. Objects on the dashboard of the car move to the right. *[2]*

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(iii) In recent years, air bags have been added to cars for increased safety. *[2]*

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(c) A 4.0 kg metal sphere is whirled by hand in a vertical circle of radius 1.0 m at a constant speed of 5.0 $m s^{-1}$. Determine the tension in the arm at the **top** and at the **bottom** of the motion. *[4]*

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(This question continues on the following page)

(Question 6 continued)

(d) The satellite moon Phobos moves in an approximately circular orbit around Mars with an orbital radius of 9.6×10^{6} m, a period of 2.75×10^{4} s. Calculate the mass of Mars. *[4]*

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(e) Explain what is meant by escape velocity and calculate the magnitude of the escape velocity from the surface of the Earth. *[4]*

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(f) Initially, the Space Shuttle is launched vertically. It is then tilted so that the path of its trajectory is parallel to the Earth's surface when the correct orbital speed is reached.

In which direction does the tilting take place? Explain your answer. *[2]*

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(g) A space vehicle of mass 5.0×10^{3} kg is in a "stationary" orbit alongside a space station. The space vehicle's rocket motor has an impulse of 10^{8} Ns. Its motor is fired for 5 seconds.

What is the acceleration given to the space vehicle relative to the space station? *[2]*

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