

Wednesday 16 May 2012 – Morning

A2 GCE MATHEMATICS (MEI)

4758/01 Differential Equations

QUESTION PAPER

Candidates answer on the Printed Answer Book.

OCR supplied materials:

- Printed Answer Book 4758/01
- MEI Examination Formulae and Tables (MF2)

Other materials required:

- Scientific or graphical calculator

Duration: 1 hour 30 minutes



INSTRUCTIONS TO CANDIDATES

These instructions are the same on the Printed Answer Book and the Question Paper.

- The Question Paper will be found in the centre of the Printed Answer Book.
- Write your name, centre number and candidate number in the spaces provided on the Printed Answer Book. Please write clearly and in capital letters.
- **Write your answer to each question in the space provided in the Printed Answer Book.** Additional paper may be used if necessary but you must clearly show your candidate number, centre number and question number(s).
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Answer any **three** questions.
- Do **not** write in the bar codes.
- You are permitted to use a scientific or graphical calculator in this paper.
- Final answers should be given to a degree of accuracy appropriate to the context.
- The acceleration due to gravity is denoted by $g \text{ m s}^{-2}$. Unless otherwise instructed, when a numerical value is needed, use $g = 9.8$.

INFORMATION FOR CANDIDATES

This information is the same on the Printed Answer Book and the Question Paper.

- The number of marks is given in brackets [] at the end of each question or part question on the Question Paper.
- You are advised that an answer may receive **no marks** unless you show sufficient detail of the working to indicate that a correct method is being used.
- The total number of marks for this paper is **72**.
- The Printed Answer Book consists of **16** pages. The Question Paper consists of **4** pages. Any blank pages are indicated.

INSTRUCTION TO EXAMS OFFICER/INVIGILATOR

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1 Some differential equations of the form

$$\frac{d^2y}{dx^2} + 6 \frac{dy}{dx} + 9y = f(x)$$

are to be solved.

First consider the case $f(x) = x^2$.

(i) Find the general solution for y in terms of x . [9]

(ii) Find the particular solution subject to the conditions $y = 0$, $\frac{dy}{dx} = 0$ when $x = 0$. [5]

Now consider the case $f(x) = e^{-3x}$.

(iii) Explain why neither ae^{-3x} nor axe^{-3x} will be a particular integral for the differential equation. [1]

(iv) State an appropriate form for a particular integral and hence find the general solution. [7]

(v) State with reasons whether it is possible to have particular solutions for which

(A) y is positive for all values of x ,

(B) y is negative for all values of x . [2]

2 A parachutist of mass m kg falls vertically from rest. After she has fallen x m, her speed is v m s⁻¹. The forces acting on her are her weight and a resistance force of magnitude mkv^2 N, where k is a constant.

(i) Show that her motion is modelled by the differential equation

$$v \frac{dv}{dx} = g - kv^2$$

and solve this to show that $v^2 = \frac{g}{k} (1 - e^{-2kx})$. [8]

(ii) Given that her terminal speed is 55 m s⁻¹, calculate k . [1]

When her speed is 54 m s⁻¹, she opens her parachute. The motion is now modelled by assuming that the magnitude of the resistance force instantaneously changes to $0.1mgv$ N. The time from the parachute opening is t seconds.

(iii) Formulate and solve a differential equation to find v in terms of t . [8]

(iv) Calculate the time it takes for her speed to reduce to 12 m s⁻¹. [1]

(v) Calculate the distance she falls from the point at which she opens her parachute to the point at which her speed is 12 m s⁻¹. [6]

3 The differential equation $x \frac{dy}{dx} - 2y = x^3 \sin x$ is to be solved.

(i) Find the general solution for y in terms of x . [8]

(ii) Find the particular solution subject to the condition $y = 0$ when $x = \pi$. Sketch the solution curve for $0 \leq x \leq 4\pi$. [5]

Now consider the differential equation $x \frac{dy}{dx} - 2y^2 = 0$.

(iii) Find the general solution for y in terms of x . [5]

Now consider the differential equation $x \frac{dy}{dx} - 2y^2 = x^3 \sin x$.

This is to be solved numerically using Euler's method. The algorithm is given by $x_{r+1} = x_r + h$, $y_{r+1} = y_r + hy'_r$ with $(x_0, y_0) = (3.14, 0)$.

(iv) Use a step length of 0.01 to estimate y when $x = 3.16$. [5]

(v) How could this estimate be improved? [1]

4 The simultaneous differential equations

$$\frac{dx}{dt} = -2x - y + 6,$$

$$\frac{dy}{dt} = x - 2y + 7,$$

are to be solved.

(i) Eliminate y to obtain a second order differential equation for x in terms of t . Hence find the general solution for x . [12]

(ii) Find the corresponding general solution for y . [3]

Initially $x = 7$ and $y = 0$.

(iii) Find the particular solutions. [4]

As $t \rightarrow \infty$, $\frac{y}{x} \rightarrow k$.

(iv) State the value of k and show that $y = kx$ for infinitely many values of t . [5]

THERE ARE NO QUESTIONS WRITTEN ON THIS PAGE.



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