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Mathematical Sciences Institute

EXAMINATION: Semester 2 - Mid-Semester, 2016

MATH1013 — Advanced Mathematics and Applications 1

Book A − Calculus

Exam Duration: 120 minutes. **Reading Time:** 15 minutes.

Materials Permitted In The Exam Venue:

- One A4 page with hand written notes on both sides. (This A4 page is to cover both Algebra and Calculus.)
- Unmarked English-to-foreign-language dictionary (no approval from MSI required).
- No electronic aids are permitted e.g. laptops, phones, calculators.

Materials To Be Supplied To Students:

• Scribble Paper.

Instructions To Students:

- Answer the Calculus questions in Book A, and the Algebra questions in Book B, in the spaces provided.
- The Algebra and Calculus sections are worth a total of 50 points each, with the value of each question as shown. It is recommended that you spend equal time on the Calculus and the Algebra papers.
- A good strategy is not to spend too much time on any question. Read them through first and attack them in the order that allows you to make the most progress.
- You must justify your answers. Please be neat.

Q1	Q2
10	10

Total / 20	

Question 1 10 pts

(a) Using the definition of sinh *x* in terms of exponentials, find the indefinite integral

$$\int \sinh x \, dx \, . \qquad 2 \, pts$$

Write your solution here

(b) Evaluate
$$\int_{1}^{\sqrt{3}} \frac{1}{(1+x^2)(\tan^{-1}x)^2} dx$$
.

Write your solution here

Answer Make the substitution $u = \tan^{-1} x$. Then $du = \frac{1}{1+x^2} dx$, so

$$\int_{1}^{\sqrt{3}} \frac{1}{(1+x^2)(\tan^{-1}x)^2} dx = \int_{\pi/4}^{\pi/3} \frac{du}{u^2}$$
$$= \left[-u^{-1} \right]_{\pi/4}^{\pi/3}$$
$$= -\frac{3}{\pi} + \frac{4}{\pi}$$
$$= \frac{1}{\pi}.$$

Grading Scheme:

- 1 point for trying a substitution
- 1 point for correctly performing the change of variables
- 1 point for computing the resulting integral
- 1 point for the right answer!

(c) Evaluate
$$\int_{1}^{2} (\ln x)^2 dx$$
.

Write your solution here

Answer

Let $U_1 = (\ln x)^2$ and $dV_1 = dx$. Then $dU_1 = \frac{2}{x} \ln x \, dx$ and $V_1 = x$, so integration by parts gives

$$\int_{1}^{2} (\ln x)^{2} dx = \left[x (\ln x)^{2} \right]_{1}^{2} - \int_{1}^{2} x \frac{2}{x} \ln x dx = 2 (\ln 2)^{2} - 2 \int_{1}^{2} \ln x dx.$$

Now let $U_2 = \ln x$ and $dV_2 = dx$. Then $dU_2 = \frac{1}{x} dx$ and $V_2 = x$, so integration by parts gives

$$\int_{1}^{2} \ln x \, dx = \left[x \ln x \right]_{1}^{2} - \int_{1}^{2} x \frac{1}{x} \, dx$$
$$= 2 \ln 2 - \int_{1}^{2} dx$$
$$= 2 \ln 2 - 1.$$

Hence

$$\int_{1}^{2} (\ln x)^{2} dx = 2(\ln 2)^{2} - 4 \ln 2 + 2.$$

Question 2 10 pts

Suppose $\alpha > 1$, $K \ge 0$, and that $f : \mathbb{R} \to \mathbb{R}$ has the property that, for all $x, y \in \mathbb{R}$,

$$|f(x) - f(y)| \le K|x - y|^{\alpha}.$$

Prove that f is constant.

Hints: for this question you may use the facts that

- for all r > 0, the mapping $t \mapsto t^r$ is continuous on $[0, \infty)$, and
- if $g : \mathbb{R} \setminus \{c\} \to \mathbb{R}$, then $\lim_{x \to c} g(x) = 0$ if and only if $\lim_{x \to c} |g(x)| = 0$.

Given $c \in \mathbb{R}$, consider $h : \mathbb{R} \setminus \{c\} \to \mathbb{R}$ defined by $h(x) = \frac{f(x) - f(c)}{x - c}$.

Finally, please note that $\alpha > 1$, NOT $\alpha > 0$.

Write your solution here

extra space for previous question