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VCE Specialist Mathematics ½
AOS 2 Revision [2.0]
Contour Check



Contour Check

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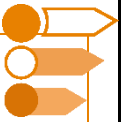
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Section A: [2.1] - Proofs I (Checkpoints)

Sub-Section [2.1.1]: Number Sets



Question 1



State all the number sets that the following are an element of:

a. $\sqrt{5}$

b. 5

c. $\pi + i$

d. $-\frac{3}{7}$

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Question 2

Express each of the following subsets of \mathbb{R} in interval notation.

a. $\{x: x > 3\}$

b. $\{x: -8 < x < 1\} \cap \{x: x \geq -3\}$

c. $\{x: x \neq 1\} \cup \{x: x \leq 5\}$

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Question 3

Rationalise the denominator and then simplify the following expressions.

a. $\frac{2}{\sqrt{3}}$

b. $\frac{5}{3+\sqrt{2}}$

c. $\frac{\sqrt{30}+7}{4+\sqrt{7}}$

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Question 4

Rationalise the denominator of the following expression and simplify

$$\frac{x+\sqrt{y}}{\sqrt{a}+\sqrt{b}}$$

Where $x, y, a, b > 0$ and $a \neq b$.

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Sub-Section [2.1.2]: Operations on Statements

Question 5



Consider the following statements:

A = It is hot outside.
 B = I go to the beach.

Write down the following:

a. $A \wedge B$.

b. $\neg B$.

c. $\neg A \vee \neg B$.

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Question 6

Use De Morgan's Law to write down the negation of the following statements:

- a.** The movie is entertaining and the popcorn is tasty.

- b.** The traffic is light or the weather is clear.

- c.** The phone is affordable and has a good camera.

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Question 7

Write the following as conditional statements.

- a.** People who recycle help the environment.

- b.** Employees who work overtime earn extra pay.

- c.** Athletes who practice regularly improve their performance.

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Question 8

Simplify the following logical expression using De Morgan's Laws:

$$\neg((P \wedge Q) \vee (\neg R \wedge S)).$$

Give your answer in the form:

$$(A \vee B) \wedge (C \vee D).$$

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Sub-Section [2.1.3]: Proofs Involving Even and Odd Numbers



Question 9



For an integer n , show that if n is even then n^3 is even.

Question 10



Show that $(4n + 2)^2 - (2n - 1)$ is always odd for any $n \in \mathbb{Z}$.

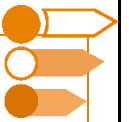
Question 11


Show that $n^2 + 7n + 10$ is even for all $n \in \mathbb{N}$.

Question 12


Prove that the product of any two odd integers minus the sum of the same two integers is always even.

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Sub-Section [2.1.4]: Proofs Involving Divisibility

Question 13



Show that if n is divisible by 7, then n^2 is also divisible by 7 for any $n \in \mathbb{N}$.

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Question 14


Show that if n is divisible by 2 and m is divisible by 3, then $3n + 4m$ is divisible by 3 for all $n, m \in \mathbb{N}$.

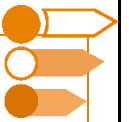
Question 15


Prove that if m and n are even integers, then $m^2 + n^2$ and $m^2 - n^2$ are both divisible by 4.

Question 16


Prove that the sum of any two consecutive odd numbers is divisible by 4.

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Sub-Section [2.1.5]: Proofs Involving Rational Numbers

Question 17



Show that if $\sqrt[3]{x}$ is rational, then x is rational for any $x \in \mathbb{R}$.

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Question 18


Show that if both x and y are rational, then $x^2 + y^2$ is rational.

Question 19


Prove that if x is rational and $x \neq 0$, then $\frac{1}{x}$ is also rational.


Question 20

Prove that if x and y are rational and $x, y \neq 0$ then,

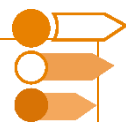
$$\frac{(x - 2y)^5 + x^2 + 3y}{x^2 + 2y^2}$$

is rational.

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Section B: [2.2] - Proofs II (Checkpoints)

Sub-Section [2.2.1]: Direct and Indirect Proofs



Question 21



Prove that all numbers of the form $n^3 - n$, where $n \in \mathbb{Z}$, are multiples of 6.

Question 22



Prove the following statement using a proof by contrapositive: If n^5 is odd, then n is odd.

Question 23


Prove the following statement using a proof by contradiction: $\sqrt{5} + \sqrt{7} < 5$.

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Question 24


Prove that for $a, b > 0$, we have $a + b \geq \left(\frac{1}{a} + \frac{1}{b}\right)^{-1}$.

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Sub-Section [2.2.2]: Proofs Involving Converse and Equivalent Statements

Question 25



Write the converse of the following statements.

- a. If a person exercises regularly, they stay healthy.

- b. If a car is fuel-efficient, it saves money on gas.

- c. If a student studies, they pass their exams.

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Question 26


Suppose $n \in \mathbb{Z}$. Prove that n is odd, if and only if $3n + 1$ is even.

Question 27


Prove the following statement: $\frac{n(n+1)}{2}$ is a natural number, if and only if n is a natural number.

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Question 28



Prove the following statement: For any integer n , n is divisible by 3, if and only if the sum of its digits is divisible by 3.

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Sub-Section [2.2.3]: Proofs involving the Universal and Existence Quantifiers

Question 29



Write the following statements in terms of the universal (\forall) and existential (\exists) quantifiers.

- a. All positive integers are greater than zero.

- b. There exists an integer that is a perfect square.

- c. For all real numbers x , if $x > 0$, then $\frac{1}{x} > 0$.

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Question 30

Negate the following statements involving universal and existential quantifiers.

a. $\forall n \in \mathbb{Z}, n + 0 = n$

b. $\exists x \in \mathbb{R}, x^3 = 8$

c. $\forall x \in \mathbb{R}, x^2 \geq 0$

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Question 31

Disprove the following statements by providing a counterexample.

- a. Disprove that for all integers n , $n^3 - n$ is always odd.

- b. Disprove that there exists an integer n such that, $2n + 1 = 0$.

- c. Disprove that for all real numbers x , $x^2 + x$ is greater than 1.

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Question 32

Prove that:

$$\forall a, b \in \mathbb{R}^+ \cup \{0\}, \frac{a+b}{2} \geq \sqrt{ab}$$

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Sub-Section [2.2.4]: Telescoping Series and Proofs by Induction

Question 33

Simplify the following telescoping series using partial fraction decomposition and simplification.

$$\sum_{k=1}^{n+1} \frac{1}{(k+1)(k+2)} = \frac{1}{6} + \frac{1}{12} + \frac{1}{20} + \cdots + \frac{1}{(n+1)(n+2)} + \frac{1}{(n+2)(n+3)}$$

[illegible]

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Question 34



Prove the following statement by induction:

$$2 + 4 + 6 + \cdots + 2n = n(n + 1) \text{ for all integers } n \geq 1.$$

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Question 35



Prove the following statement by induction:

$$a + ar + ar^2 + \cdots + ar^{n-1} = \frac{a(r^n - 1)}{r - 1} \text{ for all integers } n \geq 1.$$

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Question 36

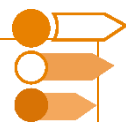
Prove the following statement by induction:

$$a + (a + d) + (a + 2d) + \cdots + (a + (n - 1)d) = \frac{n}{2}(2a + (n - 1)d), \text{ for all integers } n \geq 1.$$

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Section C: [2.3] - Proofs Exam Skills (Checkpoints)

Sub-Section [2.3.1]: Solve Problems Using AM-GM Inequalities



Question 37



Show using the AM-GM inequality that for $x > 0$ we have:

$$5x + \frac{5}{x} \geq 10$$

Question 38



Minimise $2x + \frac{2}{x}$ over $x > 0$ by applying the AM-GM inequality, and hence maximise $6 - 2x - \frac{2}{x}$.

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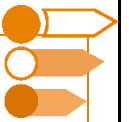
Question 39


Find an expression for the area of a rectangle that has a perimeter of 4 units and a width of x units, and hence use the AM-GM inequality to maximise the area of such a rectangle.

Question 40


Let $x, y > 0$. Furthermore, suppose that $xy = 4$. Find the minimum value of $xy^3 + x^3y$.

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Sub-Section [2.3.2]: Solve Arithmetic and Geometric Proofs

Question 41



Prove using induction that $2 + 7 + 12 + \cdots + (5n - 3) = \frac{n(5n-1)}{2}$.

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Question 42


Prove using induction that $1 \cdot 7 + 2 \cdot 8 + \cdots + n(n + 6) = \frac{n(n+1)(2n+19)}{6}$.

Question 43


Prove using induction that $2 \cdot 3 + 2 \cdot 3^2 + 2 \cdot 3^3 + \cdots + 2 \cdot 3^n = 3^{n+1} - 3$.


Question 44

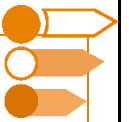
- a. Prove using induction that for all $n \in \mathbb{N}$, $1^3 + 2^3 + \dots + n^3 = \frac{n^2(n+1)^2}{4}$.

- b. Hence, write a rule for $2^3 + 4^3 + \dots + (2n)^3$.

Hint: $2^3 + 4^3 + \dots + (2n)^3$ is related to $1^3 + 2^3 + \dots + n^3$ in a reasonably simple way.

- c. Now, deduce a rule for $1^3 + 3^3 + \dots + (2n-1)^3$ using the rule you obtained above.

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Sub-Section [2.3.3]: Prove Divisibility With Induction

Question 45



Prove using induction that if $n \in \mathbb{N}$, then $8^n - 1$ is divisible by 7.

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Question 46

Prove using induction that if $n \in \mathbb{N}$, then $n^3 + 3n^2 + 2n$ is divisible by 3.

Note: If you want to make this question a bit harder, you can instead show that $n^3 + 3n^2 + 2n$ is also divisible by 6. You might need to use the fact that the product of two consecutive integers is always even.

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Question 47


Prove using induction that if $n \in \mathbb{N}$, then $10^{n+1} + 10^n + 1$ is divisible by 3.

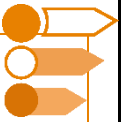
Note: The statement says that 111, 1101, 11001, etc., are all divisible by 3.

Question 48


Recall that $n! = 1 \cdot 2 \cdot 3 \cdots n$. For example, $3! = 1 \cdot 2 \cdot 3$. Prove using induction that if $n \in \mathbb{N}$, then $(2n)!$ is divisible by 2^n .

Section D: [2.4] - Logic & Algorithms I (Checkpoints)

Sub-Section [2.4.1]: Write and Understand Basic Algorithms



Question 49



Construct an algorithm that multiplies any input given by 10.

Question 50



Construct an algorithm that adds any input given by 5.

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Question 51



Construct an algorithm that subtracts any input given by 5 and multiplies by 2.

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Sub-Section [2.4.2]: Understanding and Evaluating Algorithms That Have Conditional Statements and Represent Hybrid Functions as Algorithms

Question 52



Using a flowchart, describe an algorithm of the following hybrid function.

$$f(x) = \begin{cases} 3x - 5 & x \geq 0 \\ x - 1 & x < 0 \end{cases}$$

Question 53



Using a flowchart, describe an algorithm of the following hybrid function.

$$f(x) = \begin{cases} 1 & x \geq 0 \\ 0 & x < 0 \end{cases}$$

Question 54


Turn the following function into an algorithm.

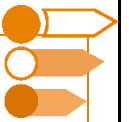
$$f(x) = \begin{cases} x^2 & x \geq 1 \\ -2x + 1 & x < 1 \end{cases}$$

Question 55


Turn the following function into an algorithm.

$$f(x) = \max\{n \in \mathbb{R} | n \leq x\}$$

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Sub-Section [2.4.3]: Understand and Evaluate Algorithms with Loops

Question 56



Check whether the following algorithm has any problems. If there is a problem, state the problem; if there is no problem, give the final output of the algorithm.

Step 1: $A \leftarrow 30$

Step 2: $A \leftarrow 3A - 20$

Step 3: Repeat 2 while $A > 65$.

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Question 57


Evaluate the following algorithm:

```

For  $a$  from 1 to 10
  if  $a = \text{even}$ , then
    print "yes"
  else
    print "no"
end for.

```

Question 58


Check whether the following algorithm has any problems. If there is a problem, state the problem; if there is no problem, give the final output of the algorithm.

```

Step 1:  $A \leftarrow 60$ 
Step 2:  $A \leftarrow 2A - 50$ 
Step 3: Repeat 2 while  $A \leq 130$ .

```


Question 59

Evaluate the following output:

```

 $a \leftarrow 5$ 
 $b \leftarrow 10$ 
if  $a - b < 5$ 
     $a \leftarrow a - 5$ 
     $b \leftarrow b - 10$ 
end if
print  $a, b$ .

```

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Sub-Section [2.4.4]: Write and Evaluate Functions using Pseudocode

Question 60



```

A ← [ ]
for n from 1 to 5
    append n to A.
    if n = 1, then
        return
    else
         $A = \sqrt{n^2 + A[n - 1]}$ 
        if A = integer
            print “A[n - 1], n, A is a perfect triangle.”
end for.

```

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Question 61

- a. Roger decided to invest \$1000 at an interest rate of 10% compounded monthly. Construct an algorithm that computes the number of years needed for Roger's investment to double.

- b. Jacob decided to invest \$500 at an interest rate of 15% compounded annually. Construct an algorithm that computes the number of years needed for Jacob's investment to increase by 50%.

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Question 62


Using pseudocode, write an algorithm to find all the primes less or equal to 100.

Question 63


Using pseudocode, construct an algorithm for the following:

Find the shortest distance between any 2 *different* coordinates from the list of coordinates.

Y coordinate = [1, 35, 5, 41, 5]
X coordinate = [123, 2, 74, 213, 2]

Section E: [2.5] - Logic & Algorithms II (Checkpoints)

Sub-Section [2.5.1]: Understand the Basics of Logic and Propositional Statements



Question 64



Translate the following to English:

P = I eat healthy.

Q = I exercise regularly.

R = I will lose weight.

$$P \wedge Q \Rightarrow R$$

Question 65



Translate the following to English:

A = I go jogging.

B = The weather is good.

C = I will feel energised.

$$\neg B \Rightarrow (\neg A \wedge \neg C)$$

Question 66


Translate into propositional logic using the correct syntax:

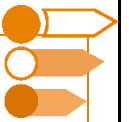
If the team wins the match, then the fans will celebrate and the opposing team will be disappointed.

Question 67


Translate into propositional logic using the correct syntax:

If the baker uses old flour, then the bread will not rise and the customers will complain.

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Sub-Section [2.5.2]: Construct Truth Tables and Recognise Equivalent Logical Expressions

Question 68



Write the truth table for:

$$\sim p \vee q$$

Question 69



Write the truth table for:

$$(p \wedge q) \vee (p \vee q)$$

Question 70



Construct a truth table for the statement $(p \oplus q) \Rightarrow r$, where \oplus is the exclusive or.

Question 71



Construct a truth table for the statement $\neg(p \wedge q) \oplus r$.

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Sub-Section [2.5.3]: Represent Logical Expressions using Switching Circuits and Logic Gates



Question 72



Use logic gates to represent the following expression and draw the corresponding truth table:

$$p \wedge \neg q$$

Question 73



Use logic gates to represent the following expression and draw the corresponding truth table:

$$\neg(p \wedge q)$$

Expression $\neg(p \wedge q)$:

p	q	$\neg(p \wedge q)$
1	1	0
1	0	1
0	1	1
0	0	1

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Question 74


Sketch a logic gate for the following expression:

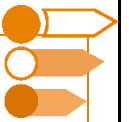
$$A(B + CD)$$

Question 75


Sketch a logic gate for the following expression:

$$[A(C + D)]' + BE$$

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Sub-Section [2.5.4]: Simplify and Evaluate Boolean Algebra Expressions using Algebraic Identities and Karnaugh Maps

Question 76



Simplify each expression by algebraic manipulation.

a. $\bar{a} \cdot 0 =$

b. $a + a =$

c. $a + \bar{a}b =$

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Question 77


Simplify each expression by algebraic manipulation.

a. $y + y\bar{y} =$

b. $xy + x\bar{y} =$

c. $\bar{x} + y\bar{x} =$

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Question 78


Simplify each expression by algebraic manipulation.

a. $(w + \bar{x} + y + \bar{z})y =$

b. $(x + \bar{y})(x + y) =$

c. $w + (w\bar{x}yz) =$

Question 79


Simplify the following expression by algebraic manipulation:

$$(x + z)(\bar{x} + y)(z + y) =$$

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Question 80

Using a Karnaugh map, identify the Boolean expression corresponding to each of the following truth tables:

a.

A	B	C	Result
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	1

b.

A	B	C	Result
0	0	0	0
0	0	1	0
0	1	0	1
0	1	1	0
1	0	0	1
1	0	1	0
1	1	0	1
1	1	1	0

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Section F: [2.1-2.5] - Exam 1 Overall (Checkpoints) (27 Marks)



Question 81 (3 marks)

Inspired from VCAA Specialist Mathematics Exam 1 2024

<https://www.vcaa.vic.edu.au/Documents/exams/mathematics/2024/2024specmaths1-w.pdf#page=3>

Prove that if x is an odd integer then $2x^2 - 3x - 7$ is even, using direct proof.

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Question 82 (4 marks)



Inspired from VCAA Specialist Mathematics Exam 1 2024

<https://www.vcaa.vic.edu.au/Documents/exams/mathematics/2024/NHT/2024SM1-nht-w.pdf#page=7>

Prove by mathematical induction that $1 \times 7 + 2 \times 15 + 3 \times 23 + \cdots + n(8n - 1) = \frac{1}{6}n(n + 1)(16n + 5)$ for all $n \in N$.

[illegible]

Question 83 (4 marks)

Prove using induction that for all $n \in \mathbb{N}$, $n < 2^n$.

Question 84 (3 marks)

Consider the statement below:

There cannot exist two integers m and n such that $5m + 10n = 3$.

- a.** Write down a statement to begin a proof by contradiction for the statement above. (1 mark)

- b.** Hence, obtain a contradiction and prove the original statement. (2 marks)

Question 85 (4 marks)

Prove using induction that $6^n + 4$ is divisible by 5 for all $n \in \mathbb{N}$.

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Question 86 (4 marks)

Prove using induction that for all $n \in \mathbb{N}$, it holds that $\left(1 + \frac{1}{1}\right)\left(2 + \frac{1}{2}\right) \cdots \left(1 + \frac{1}{n}\right) = n + 1$.

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Question 87 (5 marks)

Prove the following biconditional statement for $x, y \in \mathbb{Z}$:

$x + y$ is even, if and only if, $x^2 + y^2$ is even.

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Section G: [2.1-2.5] - Exam 2 Overall (Checkpoints) (7 Marks)



Question 88 (1 mark)

Inspired from VCAA Specialist Mathematics Exam 2 2024

<https://www.vcaa.vic.edu.au/Documents/exams/mathematics/2024/2024specmaths2-w.pdf#page=2>

Consider the statement:

'For any integers m and n , if $m + n \geq 9$ then $m \geq 5$ or $n \geq 5$ '.

The contrapositive of this statement is:

- A. If $m < 5$ or $n < 5$, then $m + n < 9$.
- B. If $m \geq 5$ or $n \geq 5$, then $m + n \geq 9$.
- C. If $m < 5$ and $n < 5$, then $m + n < 9$.
- D. If $m \leq 5$ and $n \leq 5$, then $m + n \leq 9$.

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Question 89 (1 mark)

Inspired from VCAA Specialist Mathematics Exam 2 2024

<https://www.vcaa.vic.edu.au/Documents/exams/mathematics/2024/NHT/2024SM2-nht-w.pdf#page=2>

Consider the following proof:

Prove that $\sqrt{15} + \sqrt{7} > \sqrt{19}$.

Assume $\sqrt{15} + \sqrt{7} \leq \sqrt{19}$.

Then $(\sqrt{15} + \sqrt{7})^2 \leq 19$

$15 + 2\sqrt{105} + 7 \leq 19$

$2\sqrt{105} \leq -3$

Hence, $\sqrt{15} + \sqrt{7} > \sqrt{19}$.

This proof can be best described as a:

- A. Direct proof.
- B. Proof by contrapositive.
- C. Proof by contradiction.
- D. Proof by counter-example.
- E. Proof by mathematical induction.

Question 90 (1 mark)

The contrapositive to the statement, “If n is even, then n^2 is even.” is:

- A. If n^2 is odd, then n is odd.
- B. If n^2 is even, then n is even.
- C. If n is odd, then n^2 is even.
- D. If n is odd, then n^2 is odd.

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Question 91 (1 mark)

Consider the following:

$$\text{For all } k > K, 1.5^k < (k - 1)!$$

What is the smallest value of $K \in \mathbb{N}$ such that the above holds?

- A. 2
- B. 3
- C. 4
- D. 5

Question 92 (1 mark)

The negation of the statement, “All the cars in the carpark are black.” is:

- A. All the vans in the carpark are black.
- B. There exists a car in the carpark that is not black.
- C. There exists a bus in the carpark without a mirror.
- D. All the cars in the carpark are yellow.

Question 93 (1 mark)

Find the minimum value of $6x^2 + \frac{6}{x^2}$.

- A. 6
- B. 25
- C. 15
- D. 12

Space for Personal Notes

Question 94 (1 mark)

Consider the following statement:

If a car in the carpark is black, then it costs a lot of money.

Which of the following is the converse of the above?

- A.** If a bus in the carpark costs a lot of money, then it is not black.
- B.** If a car costs a lot of money, then it is in the carpark.
- C.** If a car in the carpark is not black, then it costs a lot of money.
- D.** If a car in the carpark costs a lot of money, then it is black in colour.

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