

MATH 271 DISCRETE MATHEMATICS

PRACTICE PROBLEMS 6: RELATIONS – HINTS & SOLUTIONS

Exercise 1. Consider the relation R on $\mathbb{Z}^+$ defined by: $\forall a, b \in \mathbb{Z}^+, aRb$ if and only if $\gcd(a, b) = 1$. Is R reflexive? symmetric? antisymmetric? transitive?

Solution 1.

- R is not reflexive. Choose $2 \in \mathbb{Z}^+$, and $\gcd(2, 2) = 2 \neq 1$; therefore, 2 is not related to 2.
- R is symmetric. Suppose $a, b \in \mathbb{Z}^+$, then by definition $\gcd(a, b) = \gcd(b, a)$ and so bRa .
- R is not antisymmetric; for instance $\gcd(2, 3) = 1 = \gcd(3, 2)$ so $2R3$ and $3R2$, but $2 \neq 3$.
- R is not transitive; for instance, $2, 3, 4 \in \mathbb{Z}^+$, $2R3$ because $\gcd(2, 3) = 1$ and $3R4$ because $\gcd(3, 4) = 1$, but 2 is not related to 4 because $\gcd(2, 4) = 2 \neq 1$.

Exercise 2. Consider the relation T on $\mathbb{Z}$ defined by: $\forall x, y \in \mathbb{Z}, xTy$ if and only if $3 \mid 2x + y$. Is T reflexive? symmetric? antisymmetric? transitive?

Solution 2.

- T is reflexive. Suppose $a \in \mathbb{Z}$, then $2a + a = 3a$ is divisible by 3 (because $a \in \mathbb{Z}$); therefore, by definition aTa .
- T is symmetric. Suppose $a, b \in \mathbb{Z}$, and suppose aTb . Then by definition of T , 3 divides $2a + b$, so there exists $k \in \mathbb{Z}$ so that $2a + b = 3k$. Now, we see that

$$2b + a = 2b + b - b + a + 2a - 2a = 3b + 3a - (2a + b) = 3b + 3a - 3k = 3(a + b - k),$$

therefore, since $a + b - k \in \mathbb{Z}$, 3 divides $2b + a$ and bTa .

- T is reflexive. Suppose $a, b, c \in \mathbb{Z}$. Suppose that aTb and bTc . Then by definition of T , $3 \mid 2a + b$ and $3 \mid 2b + c$. Then there exists $k, \ell \in \mathbb{Z}$ so that $2a + b = 3k$ and $2b + c = 3\ell$. Now it follows that

$$2a + c = 2a + b - b + 2b - 2b + c = 3k + 3\ell - 3b = 3(k + \ell - b),$$

therefore, since $k + \ell - b \in \mathbb{Z}$, 3 divides $2a + c$ and aTc .

Thus, T is an equivalence relation, i.e., T is reflexive, symmetric and transitive.

Now you show that T is not antisymmetric.

Exercise 3. Recall that for any finite set S , $|S|$ denotes the number of elements in S .

Let $A = \{0, 1, 2, 3, 4, 5, 6, 7, 8, 9\}$ and let $B = \{1, 3, 5, 7, 9\}$. Let R be the relation on $\mathcal{P}(A)$ (the power set of A) defined by: for all $X, Y \in \mathcal{P}(A)$, XRY if and only if $|X \cap B| = |Y \cap B|$.

Is R reflexive? symmetric? antisymmetric? transitive?

Solution 3.

Claim: R is reflexive: Suppose that $X \in \mathcal{P}(A)$. Since $|X \cap B| = |X \cap B|$, it follows from the definition of R that $XR X$. Thus, R is reflexive.

Claim: R is symmetric: Suppose that $X, Y \in \mathcal{P}(A)$. Suppose that XRY . By definition of R , $|X \cap B| = |Y \cap B|$. Moreover, $|Y \cap B| = |X \cap B|$ and so YRX , that is R is symmetric.

Claim: R is not antisymmetric: Indeed, $X = \{1\}$ and $Y = \{3\}$ are elements of $\mathcal{P}(A)$ that satisfy XRY and YRX (you can check!), but $X \neq Y$ since $1 \in X$ but $1 \notin Y$.

Claim: R is transitive: Suppose that $X, Y, Z \in \mathcal{P}(A)$. Suppose that XRY and YRZ . Since XRY , we have $|X \cap B| = |Y \cap B|$. Since YRZ , it follows that $|Y \cap B| = |Z \cap B|$. Therefore,

$$|X \cap B| = |Y \cap B| = |Z \cap B|$$

and so XRZ . Thus, R is transitive.

Exercise 4. Let $S = \{1, 2, 3, 4\}$. If possible, define a relation R on S so that:

Practice Problems In Discrete Mathematics

**Milan Randic, Marjana Novic, Dejan
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Two Thousand Solved Problems in Discrete Mathematics Seymour Lipschutz, Marc Lipson, 1992 [Art And Practice Of Mathematics, The: Interviews At The Institute For Mathematical Sciences, National University Of Singapore, 2010-2020](#) Yu Kiang Leong, 2021-06-23 This book constitutes the second volume of interviews with prominent mathematicians and mathematical scientists who visited the Institute for Mathematical Sciences National University of Singapore First published in the Institute's newsletter Imprints during the period 2010-2020 they offer glimpses of an esoteric universe as viewed and

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