Directions: See Canvas. Scan this page to the front of your work.

(1) (3 points/3 points/2 points/2 points)

For the relation $R = \{(1,1),(1,3),(1,4),(2,3),(2,4),(3,1),(3,4),(4,1)\}$ on the set $A = \{1,2,3,4\}$, list **all** elements that are **missing** from the relation in order for R to satisfy the following properties: (a) reflexive, (b) symmetric, (c) transitive.
(d) Explain whether or not R is *antisymmetric*.

(2) (2 points each)

Let the sets be relations on the real numbers: $R_1 = \{(a,b) \in \mathbb{R}^2 \,|\, a \geq b\}$, the "greater than or equal to" relation & let $R_2 = \{(a,b) \in \mathbb{R}^2 \,|\, a \neq b\}$, the "unequal to" relation. Find:

(a) $R_1 \cap R_2$ (write out the relation in the *set notation*, as R_1 and R_2 were written)

(b) $R_1 \oplus R_2$ (write out the relation in the *set notation*, as R_1 and R_2 were written).

    Note: $\oplus$ is XOR (exclusive or).

(3) (3 points/3 points)

For the set $A = \{a,b,c\}$, answer the following:
(a) How many *elements* are in the set $A \times A$?
(b) *How many binary relations* are there on the set?

(4) (5 points)

If $R = \{(1,1),(1,2),(2,4),(3,1),(3,0)\}$, $S = \{(1,2),(2,0),(3,1),(0,0),(4,3)\}$ find $S \circ R$, with elements listed as above.

(5) (5 points each)

R is the relation represented by the matrix $\boldsymbol{M}_R = \begin{bmatrix} 1 & 0 & 0 \\ 1 & 1 & 1 \\ 0 & 1 & 0 \end{bmatrix}$, find the *matrix representations* for:

(a) R^{-1} (R inverse),
(b) $\bar{R}$ (R complement),
(c) $R \circ R$ (i.e., R^2, R composed with R).

(6) (4 points/2 points/4 points)

(a) The relation R is on $\{1,2,3\}$. Represent the relation

  $R = \{(1,1),(2,1),(2,2),(2,3),(3,2)\}$ with a *matrix*.

(b) By looking at the matrix, is the relation R *reflexive? Why or why not?*

(c) Draw the *directed graph* that represents the relation R**.**