

① a) If $X \rightarrow Y$ and $YW \rightarrow Z$, then $XW \rightarrow Z$

This expression can be broken down more into, if $X \rightarrow Y$ and $Y \rightarrow Z$ and $W \rightarrow Z$. Since $Y \subseteq X$ and $Z \subseteq Y$, we know $X \subseteq Z$ by transitivity. Since $Z \subseteq W$ and $X \rightarrow Z$, we know $Z \subseteq W$ and $Z \subseteq X$ by augmentation. This resulting expression can be rewritten $XW \rightarrow Z$ by reflexivity.

b) If $X \rightarrow YZ$, then $X \rightarrow Y$ & $X \rightarrow Z$

Since $YZ \subseteq X$, this can be expressed $Y \subseteq X$ and $Z \subseteq X$ by reversing augmentation. The resulting expression can be rewritten $X \rightarrow Y$ and $X \rightarrow Z$

c) If $X \rightarrow Y$ and $X \rightarrow Z$ then $X \rightarrow YZ$

Since $X \rightarrow Y$ can be expressed $Y \subseteq X$ through transitivity, $Y \subseteq X$ and $X \rightarrow Z$ is equal to $X \rightarrow YZ$ according to the definition of augmentation

② a) minimal

b) $\{ab \rightarrow cd, c \rightarrow d, d \rightarrow a, db \rightarrow ac\} = \{ab \rightarrow c, b \rightarrow d\}$

$a \rightarrow c, b \rightarrow d, c \rightarrow d, d \rightarrow a, d \rightarrow a, b \rightarrow c$
 $ab \rightarrow c, b \rightarrow d$

c) $\{ab \rightarrow c, c \rightarrow de, c \rightarrow a\} = \{b \rightarrow acde\}$

$a \rightarrow c, b \rightarrow c, c \rightarrow d, c \rightarrow e, c \rightarrow a$
 $b \rightarrow acde$

③ a) $\{a\}$

b) $\{b, d\}$

c) $\{a\}$

d) $\{c\}$

$c \rightarrow b, bd \rightarrow e, a \rightarrow d, e \rightarrow a$

$c \rightarrow b, b \rightarrow e, d \rightarrow e, a \rightarrow d$

$c \rightarrow b, b \rightarrow e, a \rightarrow e$

$c \rightarrow e$

④ Stock (broker, office, investor, stock, quantity, dividend)

FDs: $\{broker \rightarrow office, investor; investor \rightarrow stock, quantity, dividend\}$

candidate key: $\{broker\}$

- 5)
- a) $CK: \{ \text{director} \}$ 1NF
 - b) $CK: \{ \text{title} \}$ 1NF
 - c) $CK: \{ \text{award-type}, \text{award-year} \}$ 3NF
 - d) $CK: \{ \text{award-type}, \text{award-year} \}$ 2NF
 - e) $CK: \{ \text{director} \}$ 3NF

6)

Movie_info(title, director, studio, studio_loc, award-type, award-year)

/

Movie(title, director, studio, award-type, award-year) Studio(studio, studio_loc)

/

Movie(title, director, studio, award-year) studio(studio, studio_loc) award(award-year, type)

- 7)
- a) $CK: \{ \text{Student}, \text{course} \}$ 2NF
 - b) $CK: \{ \text{Student}, \text{course} \}$ 3NF
 - c) $CK: \{ \text{Student} \}$ 1NF

8)

Based on the current functional dependencies, the highest normal form the relation can be in is 2NF because the prime key in Student, Course \rightarrow grade, instructor, time violates the expectation that there be no prime FDs. Course \rightarrow grade creates a prime FD

9)

steam-games (title, game-file, year, publisher, game-assets)

title, year, publisher \rightarrow game-file, game-assets

game-file \rightarrow game-assets

$\{ \text{game-file}, \text{game-assets} \} \cap \{ \text{game-assets} \} = \{ \text{game-assets} \}$

Game asset is not a key in $\{ \text{title}, \text{year}, \text{publisher} \}$ or $\{ \text{game-file} \}$, so it is not lossless, & therefore not in BCNF

See included schema At end

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Bricks

elem-id, design-id → name, color, price

Theme

name → description, license

license → description, year-start, year-end

Sets

item-number → name, theme, category, age-range, price, part-list, minifig-count, vip-points

theme → category, age-range

part-list → minifig-count

item-number

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a Bricks (elem-id, design-id, name, color, price)

brickID (elem-id, design-id, name) brickDesc (name, color, price)

Theme (name, description, year-start, year-end, license)

ThemeDesc (name, description, license) LicenseInfo (license, description, year-start, year-end)

Sets (item-number, name, theme, category, age-range, price, part-list, minifig-count, vip-points, height, width, depth)

SetID (item-number, name, theme, part-list, vip-pts, height, width, depth)

SetTheme (theme, category, age-range)

Parts (part-list, minifig-count)

Bricks	
PK	elem_id
	design_id
	name
	color
	price

Theme	
PK	name
	description
	year_start
	year_end
	license

Category	
PK	Name

Sets	
PK	item_number
	name
FK	theme
FK	category
	age_range
	price
	part_list
	minifig_count
	vip_points
	height
	width
	depth