exists a real number z such that $xy = z$. **3. a)** There is some student in your class who has sent a message to some student in your class. **b)** There is some student in your class who has sent a message to every student in your class. **c)** Every student in your class has sent a message to at least one student in your class. **d)** There is a student in your class who has been sent a message by every student in your class. **e)** Every student in your class has been sent a message from at least one student in your class. **f)** Every student in the class has sent a message to every student in the class. **5. a)** Sarah Smith

like it). **9. a)** $\forall x L(x, \text{Jerry})$ **b)** $\forall x \exists y L(x, y)$ **c)** $\exists y \forall x L(x, y)$ **d)** $\forall x \exists y \neg L(x, y)$ **e)** $\exists x \neg L(\text{Lydia}, x)$ **f)** $\exists x \forall y \neg L(y, x)$ **g)** $\exists x(\forall y L(y, x) \wedge \forall z((\forall w L(w, z)) \rightarrow z = x))$ **h)** $\exists x \exists y(x \neq y \wedge L(\text{Lynn}, x) \wedge L(\text{Lynn}, y) \wedge \forall z(L(\text{Lynn}, z) \rightarrow (z = x \vee z = y)))$ **i)** $\forall x L(x, x)$ **j)** $\exists x \forall y (L(x, y) \leftrightarrow x = y)$ **11. a)** $A(\text{Lois},$

i) $\forall x L(x, x)$ **j)** $\exists x \forall y (L(x, y) \leftrightarrow x = y)$ **11. a)** $A(\text{Lois},$ Professor Michaels) **b)** $\forall x(S(x) \rightarrow A(x,$ Professor Gross)) **c)** $\forall x(F(x) \rightarrow (A(x,$ Professor Miller) $\vee A($Professor Miller, $x))$) **d)** $\exists x(S(x) \wedge \forall y(F(y) \rightarrow \neg A(x, y)))$ **e)** $\exists x(F(x) \wedge \forall y(S(y) \rightarrow \neg A(y, x)))$ **f)** $\forall y(F(y) \rightarrow \exists x(S(x) \vee A(x, y)))$ **g)** $\exists x(F(x) \wedge \forall y((F(y) \wedge (y \neq x)) \rightarrow A(x, y)))$ **h)** $\exists x(S(x) \wedge \forall y(F(y) \rightarrow \neg A(y, x)))$ **13. a)** $\neg M$ (Chou, Koko) **b)** $\neg M(\text{Arlene, Sarah}) \wedge$

$c = b)))$ **d)** $\forall x((x < 0) \rightarrow \neg \exists y(x = y^2))$ **25. a)** There is a multiplicative identity for the real numbers. **b)** The product of two negative real numbers is always a positive real number. **c)** There exist real numbers x and y such that x^2 exceeds y but x is less than y. **d)** The real numbers are closed under the operation of addition. **27. a)** True **b)** True

closed under the operation of addition. **27. a)** True **b)** True **c)** True **d)** True **e)** True **f)** False **g)** False **h)** True **i)** False

$P(3, 2)) \wedge (P(1, 3) \vee P(2, 3) \vee P(3, 3))$ **31. a)** $\exists x \forall y \exists z \neg T(x, y, z)$ **b)** $\exists x \forall y \neg P(x, y) \wedge \exists x \forall y \neg Q(x, y)$ **c)** $\exists x \forall y (\neg P(x, y) \vee \forall z \neg R(x, y, z))$ **d)** $\exists x \forall y(P(x, y) \wedge \neg Q(x, y))$

Kevin Bacon. **39. a)** $x = 2, y = -2$ **b)** $x = -4$ **c)** $x = 17, y = -1$ **41.** $\forall x \forall y \forall z((x \cdot y) \cdot z = x \cdot (y \cdot z))$