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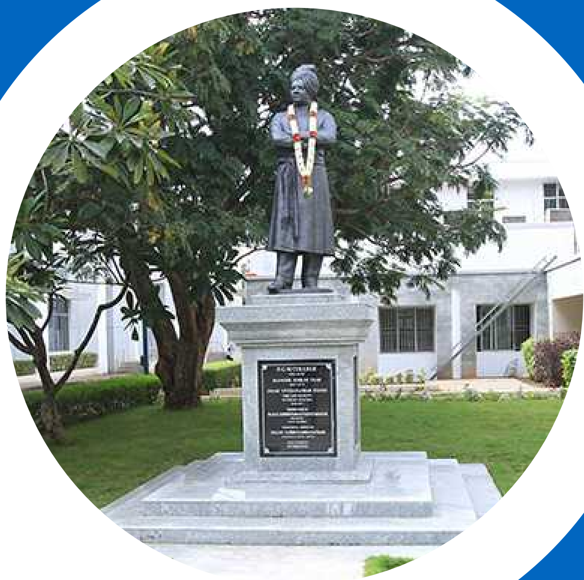

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27th October 2021

Jointly Organized by

Department of Biological Science, Physical Science and Computational Science

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ABOUT THE INSTITUTION

A nations's growth is in proportion to education and intelligence spread among the masses. Having this idealistic vision, two great philanthropists late. S.P. Nallamuthu Gounder and Late. Arutchelver Padmabhushan Dr.N.Mahalingam formed an organization called Pollachi Kalvi Kazhagam, which started NGM College in 1957, to impart holistic education with an objective to cater to the higher educational needs of those who wish to aspire for excellence in knowledge and values. The College has achieved greater academic distinctions with the introduction of autonomous system from the academic year 1987-88. The college has been Re-Accredited by NAAC and it is ISO 9001 : 2015 Certified Institution. The total student strength is around 6000. Having celebrated its Diamond Jubilee in 2017, the college has blossomed into a premier Post-Graduate and Research Institution, offering 26 UG, 12 PG, 13 M.Phil and 10 Ph.D Programmes, apart from Diploma and Certificate Courses. The college has been ranked within Top 100 (72nd Rank) in India by NIRF 2021.

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The International conference on “Emerging Trends in Science and Technology (ETIST-2021)” is being jointly organized by Departments of Biological Science, Physical Science and Computational Science - Nallamuthu Gounder Mahalingam College, Pollachi along with ISTE, CSI, IETE, IEE & RIYASA LABS on 27th OCT 2021. The Conference will provide common platform for faculties, research scholars, industrialists to exchange and discus the innovative ideas and will promote to work in interdisciplinary mode.

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Contra $\delta_{\mathcal{I}}$-semi-continuous functions in ideal topological spaces

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Abstract - In this paper, we apply the notion of $\delta_{\mathcal{I}}$-semi-open sets in ideal topological spaces and a new class of functions namely contra $\delta_{\mathcal{I}}$-semi-continuous and contra $\delta_{\mathcal{I}}$-semi-irresolute functions are introduced and investigated in ideal topological spaces. Also, relationships between this new class and other classes of functions are established.

Keywords *Ideal topological spaces, $\delta_{\mathcal{I}}$-semi-open sets, $\delta_{\mathcal{I}}$-semi-closed sets, Contra $\delta_{\mathcal{I}}$-semi-continuous functions and Contra $\delta_{\mathcal{I}}$-semi-irresolute functions.*
2010 Subject classification: *54A05*

1 Introduction

A new class of functions called contra-continuous functions is introduced by Dontchev [5] in 1996. He defined a function $f : X \to Y$ to be *contra-continuous* if the preimage of every open set of Y is closed in X. Dontchev and Noiri [6] introduced and investigated a new weaker form of this class of functions called *contra-semi-continuous* functions. In this direction, the concept of *contra semi-$\mathcal{I}$-continuous* functions via the notion of semi-I-open sets, is introduced by Jamal M. Mustafa [9] in 2010.Throughout this paper, $(X, \tau, \mathcal{I})$ and $(Y, \sigma, \mathcal{I})$ (or simply X and Y), always mean ideal topological spaces on which no separation axiom is assumed. For a subset A of a space $(X, \tau, \mathcal{I})$, $cl(A)$ and $int_\delta(A)$ denote closure and δ-interior of A respectively.

2 Preliminaries

Definition 2.1. *[1] A subset A of an ideal topological space $(X, \tau, \mathcal{I})$ is said to be $\delta_{\mathcal{I}}$-semi-open if $A \subseteq cl^*(int_\delta(A))$.*

A subset A of an ideal topological space $(X, \tau, \mathcal{I})$ is said to be $\delta_{\mathcal{I}}$-semi-closed if its complement is $\delta_{\mathcal{I}}$-semi-open.

Definition 2.2. *[2] A function $f : (X, \tau, \mathcal{I}) \to (Y, \sigma)$ is said to be $\delta_{\mathcal{I}}$-semi-continuous if $f^{-1}(V)$ is $\delta_{\mathcal{I}}$-semi-open in X for each open set V of Y.*

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Definition 2.3. *[2] A function $f : (X, \tau, \mathcal{I}) \to (Y, \sigma)$ is said to be $\delta_{\mathcal{I}}$-semi-irresolute if inverse image of every $\delta_{\mathcal{I}}$-semi-open set in Y is $\delta_{\mathcal{I}}$-semi-open set in X.*

Definition 2.4. *A function $f : (X, \tau) \to (Y, \sigma)$ is said to be*

1. *contra continuous [5] if $f^{-1}(V)$ is a closed in X for every open set V of Y,*
2. *contra semi-continuous [6] if $f^{-1}(V)$ is a semi-closed in X for every open set V of Y,*
3. *contra pre-continuous [7] if $f^{-1}(V)$ is a pre-closed in X for every open set V of Y,*
4. *contra α-continuous [8] if $f^{-1}(V)$ is a α-closed in X for every open set V of Y,*
5. *contra β-continuous [4] if $f^{-1}(V)$ is a β-closed in X for every open set V of Y,*
6. *contra b-continuous [10] if $f^{-1}(V)$ is a b-closed in X for every open set V of Y.*

Definition 2.5. *A function $f : (X, \tau, \mathcal{I}) \to (Y, \sigma)$ is said to be*

1. *contra $\mathcal{I}$-continuous [9] if $f^{-1}(V)$ is a $\mathcal{I}$-closed in X for every open set V of Y,*
2. *contra semi-$\mathcal{I}$-continuous [9] if $f^{-1}(V)$ is a semi-$\mathcal{I}$-closed in X for every open set V of Y,*
3. *contra pre-$\mathcal{I}$-continuous [11] if $f^{-1}(V)$ is a pre-$\mathcal{I}$-closed in X for every open set V of Y,*
4. *contra α-$\mathcal{I}$-continuous [12] if $f^{-1}(V)$ is a α-$\mathcal{I}$-closed in X for every open set V of Y,*
5. *contra b-$\mathcal{I}$-continuous [13] if $f^{-1}(V)$ is a b-$\mathcal{I}$-closed in X for every open set V of Y,*
6. *contra β-$\mathcal{I}$-continuous [3] if $f^{-1}(V)$ is a β-$\mathcal{I}$-closed in X for every open set V of Y,*
7. *contra δ-$\mathcal{I}$-continuous [11] if $f^{-1}(V)$ is a δ-$\mathcal{I}$-closed in X for every open set V of Y.*

3 Contra $\delta_{\mathcal{I}}$-semi-continuous functions

Definition 3.1. *A function $f : (X, \tau, \mathcal{I}) \to (Y, \sigma)$ is said to be contra $\delta_{\mathcal{I}}$-semi-continuous if $f^{-1}(V)$ is $\delta_{\mathcal{I}}$-semi-closed in $(X, \tau, \mathcal{I})$ for each open set V of (Y, σ).*

Example 3.2. *Let $X = \{a, b, c\}$ with topology $\tau = \{\emptyset, \{a\}, \{b\}, \{a, b\}, \{b, c\}, X\}$, and an ideal $\mathcal{I} = \{\emptyset, \{a\}, \{b\}, \{a, b\}\}$ and let $Y = \{p, q, r\}$ with topology $\sigma = \{\emptyset, \{r\}, \{p, q\}, Y\}$. Let $f : (X, \tau, \mathcal{I}) \to (Y, \sigma)$ be a function defined by $f(a) = r$, $f(b) = p$, and $f(c) = q$. Then f is Contra $\delta_{\mathcal{I}}$-semi-continuous.*

Proposition 3.3. *For a function $f : (X, \tau, \mathcal{I}) \to (Y, \sigma)$ the following hold.*

1. *Every contra $\delta_{\mathcal{I}}$-semi-continuous funtion is contra semi-continuous, contra β-continuous and contra b-continuous.*
2. *Every contra $\delta_{\mathcal{I}}$-semi-continuous funtion is contra δ-$\mathcal{I}$-continuous, contra semi-$\mathcal{I}$-continuous and contra b-$\mathcal{I}$-continuous.*

Proof. Obvious from the Theorem 3.3 [1].

Remark 3.4. *The converses of the above proposition need not be true as seen from the following example.*

Example 3.5. *Let* $X=\{a,b,c\}$ *with topology* $\tau=\{\emptyset,\{a\},\{b\},\{a,b\},\{b,c\},X\}$ *and an ideal* $\mathcal{I}=\{\emptyset,\{a\},\{b\},\{a,b\}\}$ *and let* $Y=\{p,q,r\}$ *with topology* $\sigma=\{\emptyset,\{q\},\{r\},\{q,r\},Y\}$. *Let* $f:(X,\tau,\mathcal{I})\to(Y,\sigma)$ *be a function defined by* $f(a)=q$, $f(b)=p$ *and* $f(c)=r$. *Then f is contra semi-continuous, contra* β*-continuous, contra b-continuous, contra semi-* $\mathcal{I}$*-continuous, contra b-*$\mathcal{I}$*-continuous, contra* β*-*$\mathcal{I}$*-continuous, contra* δ*-*$\mathcal{I}$*-continuous but not contra* $\delta_{\mathcal{I}}$*-semi-continuous.*

Theorem 3.6. *For a function* $f:(X,\tau,\mathcal{I})\to(Y,\sigma)$*,the following are equivalent:*

1. f *is contra* $\delta_{\mathcal{I}}$*-semi-continuous.*
2. *For every closed subset* F *of* Y, $f^{-1}(F)$ *is* $\delta_{\mathcal{I}}$*-semi-open in* X.
3. *For each* $x\in X$ *and each closed subset* F *of* Y *with* $f(x)\in F$, *there exists a* $\delta_{\mathcal{I}}$*-semi-open subset* U *of* X *with* $x\in U$ *such that* $f(U)\subseteq F$.

Proof. $1\Rightarrow2$. Obvious.
$2\Rightarrow3$. Let $x\in X$ and F be any closed set in Y with $f(x)\in F$. By (2), $f^{-1}(F)$ is $\delta_{\mathcal{I}}$-semi-open in X. Put $U=f^{-1}(F)$. Then there is a $\delta_{\mathcal{I}}$-semi-open set U in X containing x such that $f(U)\subseteq F$.
$3\Rightarrow2$. Let F be any closed subset of Y. If $x\in f^{-1}(F)$ then $f(x)\in F$, and there exists a $\delta_{\mathcal{I}}$-semi-open subset U_x of X with $x\in U_x$ such that $f(U_x)\subseteq F$. Therefore, we obtain $f^{-1}(F)=\bigcup\{U_x|x\in f^{-1}(F)\}$. By Theorem 3.13 [1] we have that $f^{-1}(F)$ is $\delta_{\mathcal{I}}$-semi-open in X.

Remark 3.7. *From the following examples,*

1. *The notions of contra* $\mathcal{I}$*-continuity and contra* $\delta_{\mathcal{I}}$*-semi-continuity are independent.*
2. *The notions of semi-*$\mathcal{I}$*-continuity and contra* $\delta_{\mathcal{I}}$*-semi-continuity are independent.*
3. *The notions of* $\delta_{\mathcal{I}}$*-semi-continuity and contra* $\delta_{\mathcal{I}}$*-semi-continuity are independent.*
4. *The notions of contra* $\delta_{\mathcal{I}}$*-semi-continuity and contra pre-continuity(resp. contra pre-*$\mathcal{I}$*-continuity)are independent.*
5. *The notions of contra* $\delta_{\mathcal{I}}$*-semi-continuity and contra* α*-continuity(resp. contra* α*-*$\mathcal{I}$*-continuity)are independent.*

Example 3.8. *The function in Example 3.2 is contra* $\delta_{\mathcal{I}}$*-semi-continuous but not contra* $\mathcal{I}$*-continuous.*

Example 3.9. *Let* $X=\{a,b,c\}$ *with topology* $\tau=\{\emptyset,\{c\},\{a,b\},X\}$ *and an ideal* $\mathcal{I}=\{\emptyset,\{a\}\}$ *and let* $Y=\{p,q,r\}$ *with topology* $\sigma=\{\emptyset,\{q\},\{r\},\{q,r\},Y\}$. *Let* $f:(X,\tau,\mathcal{I})\to(Y,\sigma)$ *be a function defined as* $f(a)=q$, $f(b)=p$ *and* $f(c)=r$. *Then f is contra* $\mathcal{I}$*-continuous but not contra* $\delta_{\mathcal{I}}$*-semi-continuous.*

Example 3.10. *Let* $f:(X,\tau,\mathcal{I})$ *and* (Y,σ) *be the same spaces as in Example 3.2. Let* $f:(X,\tau,\mathcal{I})\to(Y,\sigma)$ *be a function defined as* $f(a)=q$, $f(b)=p$ *and* $f(c)=r$. *Then* f *is semi-*$\mathcal{I}$*-continuous but not contra* $\delta_{\mathcal{I}}$*-semi-continuous.*

Example 3.11. *Let* $X=\{a,b,c,d\}$ *with topology* $\tau=\{\emptyset,\{d\},\{a,c\},\{a,c,d\},X\}$, *and an ideal* $\mathcal{I}=\{\emptyset,\{a\},\{d\},\{a,$ *and let* $Y=\{p,q,r,s\}$ *with topology* $\sigma=\{\emptyset,\{p\},\{r\},\{p,r\},Y\}$. *Let* $f:(X,\tau,\mathcal{I})\to(Y,\sigma)$ *be a function defined as* $f(a)=q, f(b)=p$, $f(c)=s$ *and* $f(d)=r$. *Then* f *is contra* $\delta_{\mathcal{I}}$*-semi-continuous but not semi-*$\mathcal{I}$*-continuous.*

Example 3.12. *Let* $X = \{a, b, c, d\}$ *with topology* $\tau = \{\emptyset, \{a\}, \{c\}, \{a, c\}, X\}$*, and an ideal* $\mathcal{I} = \{\emptyset, \{a\}\}$ *and let* $Y = \{p, q, r, s\}$ *with topology* $\sigma = \{\emptyset, \{q\}, \{s\}, \{q, s\}, Y\}$*. Let* $f : (X, \tau, \mathcal{I}) \to (Y, \sigma)$ *be a function defined by* $f(a) = q, f(b) = p$, $f(c) = s$ *and* $f(d) = r$*. Then* f *is* $\delta_{\mathcal{I}}$*-semi-continuous but not contra* $\delta_{\mathcal{I}}$*-semi-continuous.*

Example 3.13. *The function in Example* 3.11 *is contra* $\delta_{\mathcal{I}}$*-semi-continuous but not* $\delta_{\mathcal{I}}$*-semi-continuous.*

Example 3.14. *The function in Example* 3.5 *is contra pre-continuous, contra* α*-continuous, contra pre-*$\mathcal{I}$*-continuous and contra* α*-*$\mathcal{I}$*-continuous but not contra* $\delta_{\mathcal{I}}$*-semi-continuous.*

Example 3.15. *Let* $X = \{a, b, c\}$ *with topology* $\tau = \{\emptyset, \{b\}, \{c\}, \{b, c\}, X\}$ *and an ideal* $\mathcal{I} = \{\emptyset, \{a\}\}$ *and let* $Y = \{p, q, r\}$ *with topology* $\sigma = \{\emptyset, \{p\}, \{q\}, \{p, q\}, \{q, r\}, Y\}$*. Let* $f : (X, \tau, \mathcal{I}) \to (Y, \sigma)$ *be a function defined by* $f(a) = q$, $f(b) = p$ *and* $f(c) = r$*. Then f is contra* $\delta_{\mathcal{I}}$*-semi-continuous but not contra pre-continuous, contra* α*-continuous, contra pre-*$\mathcal{I}$*-continuous and contra* α*-*$\mathcal{I}$*-continuous.*

Proposition 3.16. *If a function* $f : (X, \tau, \mathcal{I}) \to (Y, \sigma)$ *is contra* $\delta_{\mathcal{I}}$*-semi-continuous and* Y *is regular, then* f *is* $\delta_{\mathcal{I}}$*-semi-continuous.*

Proof. Let $x \in X$ and let V be an open subset of Y with $f(x) \in V$. Since Y is regular, there exists an open set W in Y such that $f(x) \in W \subseteq cl(W) \subseteq V$. Since f is contra $\delta_{\mathcal{I}}$-semi-continuous, by Theorem 3.6. there exists a $\delta_{\mathcal{I}}$-semi-open set U in X with $x \in U$ such that $f(U) \subseteq cl(W)$. Then $f(U) \subseteq cl(W) \subseteq V$. Hence by Theorem 3.10 of [2], f is $\delta_{\mathcal{I}}$-semi-continuous.

Theorem 3.17. *For a function* $f : (X, \tau, \mathcal{I}) \to (Y, \sigma)$*,the following are equivalent:*

1. f *is contra* $\delta_{\mathcal{I}}$*-semi-continuous.*
2. $f^{-1}(A) \subseteq cl^*(int_\delta(f^{-1}(cl(A))))$ *for every suset* A *in* Y*.*
3. $B \subseteq cl^*(int_\delta(f^{-1}(cl(f(B)))))$ *for every suset* B *in* X*.*

Proof. $1 \Rightarrow 2$. Let $A \subseteq Y$. We have $cl(A)$ is closed in Y, by assumption $f^{-1}(cl(A))$ is $\delta_{\mathcal{I}}$-semi-open in X. Therefore $f^{-1}(cl(A)) \subseteq cl^*(int_\delta(f^{-1}(cl(A))))$ and so $f^{-1}(A) \subseteq cl^*(int_\delta(f^{-1}(cl(A))))$.
$2 \Rightarrow 3$. Let $B \subseteq X$. Then $f(B) \subseteq Y$, by assumption $f^{-1}(f(B)) \subseteq cl^*(int_\delta(f^{-1}(cl(f(B)))))$. This implies $B \subseteq cl^*(int_\delta(f^{-1}(cl(f(B)))))$.
$3 \Rightarrow 1$. Let A be a closed set in Y. Then $f^{-1}(A) \subseteq X$, by assumption $f^{-1}(A) \subseteq cl^*(int_\delta(f^{-1}(cl(f(f^{-1}(A)))))) \subseteq cl^*(int_\delta(f^{-1}(cl(A)))) = cl^*(int_\delta(f^{-1}(A)))$. This implies $f^{-1}(A)$ is $\delta_{\mathcal{I}}$-semi-open in X and hence f is contra $\delta_{\mathcal{I}}$-semi-continuous.

Proposition 3.18. *Let* $f : (X, \tau, \mathcal{I}) \to (Y, \sigma)$ *and* $g : (Y, \sigma, \mathcal{J}) \to (Z, \mu)$*. Then the following properties are hold:*

1. *If* f *is contra* $\delta_{\mathcal{I}}$*-semi-continuous and* g *is continuous, then* $g \circ f$ *is contra* $\delta_{\mathcal{I}}$*-semi-continuous.*
2. *If* f *is contra* $\delta_{\mathcal{I}}$*-semi-continuous and* g *is contra continuous, then* $g \circ f$ *is* $\delta_{\mathcal{I}}$*-semi-continuous.*
3. *If* f *is* $\delta_{\mathcal{I}}$*-semi-continuous and* g *is contra continuous, then* $g \circ f$ *is contra* $\delta_{\mathcal{I}}$*-semi-continuous.*

Proof.1 Let V be any closed set in Z. Since g is continuous, $g^{-1}(V)$ is closed in Y. Since f is contra $\delta_{\mathcal{I}}$-semi-continuous, $f^{-1}(g^{-1}(V)) = (g \circ f)^{-1}(V)$ is $\delta_{\mathcal{I}}$-semi-open in X. Therefore $g \circ f$ is contra $\delta_{\mathcal{I}}$-semi-continuous.
2. Let V be any closed set in Z. Since g is contra continuous, $g^{-1}(V)$ is open in Y. Since f is contra $\delta_{\mathcal{I}}$-semi-continuous, $f^{-1}(g^{-1}(V)) = (g \circ f)^{-1}(V)$ is $\delta_{\mathcal{I}}$-semi-closed in X. Therefore g ∘ f is $\delta_{\mathcal{I}}$-semi-continuous.
3. Let V be any closed set in Z. Since g is contra continuous, $g^{-1}(V)$ is open in Y. Since f is $\delta_{\mathcal{I}}$-semi-continuous, $f^{-1}(g^{-1}(V)) = (g \circ f)^{-1}(V)$ is $\delta_{\mathcal{I}}$-semi-open in X. Therefore g ∘ f is contra $\delta_{\mathcal{I}}$-semi-continuous.

Definition 3.19. *A function $f : (X, \tau, \mathcal{I}) \to (Y, \sigma, \mathcal{J})$ is said to be contra $\delta_{\mathcal{I}}$-semi-irresolute if $f^{-1}(V)$ is $\delta_{\mathcal{I}}$-semi-closed in $(X, \tau, \mathcal{I})$ for every $\delta_{\mathcal{I}}$-semi-open set V of $(Y, \sigma, \mathcal{J})$.*

Remark 3.20. *The concept of contra $\delta_{\mathcal{I}}$-semi-irresolute and $\delta_{\mathcal{I}}$-semi-irresolute functions are independent of each other.*

Example 3.21. *Let $X=\{a, b, c, d\}$ with topology $\tau=\{\emptyset, \{d\}, \{a, c\}, \{a, c, d\}, X\}$ and an ideal $\mathcal{I}=\{\emptyset, \{a\}, \{d\}, \{a,$ and let $Y=\{p, q, r, s\}$ with topology $\sigma=\{\emptyset, \{p\}, \{q, s\}, \{p, q, s\}, Y\}$ and an ideal $\mathcal{J}=\{\emptyset, \{a\}\}$. Let $f : (X, \tau, \mathcal{I}) \to (Y, \sigma, \mathcal{J})$ be a function defined as $f(a) = q, f(b) = r, f(c) = s$ and $f(d) = p$. Then f is $\delta_{\mathcal{I}}$-semi-irresolute but not contra $\delta_{\mathcal{I}}$-semi-irresolute.*

Example 3.22. *Let $X = Y = \{a, b, c, d\}$ with topologies $\tau=\{\emptyset, \{a\}, \{c\}, \{a, c\},$ $X\}$ and $\sigma=\{\emptyset, \{p\}, \{q, s\}, \{p, q, s\}, Y\}$ and ideals $\mathcal{I} = \{\emptyset, \{a\}\}$ and $\mathcal{J} = \{\emptyset, \{a\}\}$ respectively. Let $f : (X, \tau, \mathcal{I}) \to (Y, \sigma, \mathcal{J})$ be an identity function. Then f is contra $\delta_{\mathcal{I}}$-semi-irresolute but not $\delta_{\mathcal{I}}$-semi-irresolute.*

Proposition 3.23. *Let $f : (X, \tau, \mathcal{I}) \to (Y, \sigma)$ and $g : (Y, \sigma, \mathcal{J}) \to (Z, \mu)$. Then the following properties are hold:*

1. *$g \circ f$ is contra $\delta_{\mathcal{I}}$-semi-irresolute if g is $\delta_{\mathcal{I}}$-semi-irresolute and f is contra $\delta_{\mathcal{I}}$-semi-irresolute.*

2. *$g \circ f$ is contra $\delta_{\mathcal{I}}$-semi-irresolute if g is contra $\delta_{\mathcal{I}}$-semi-irresolute f is $\delta_{\mathcal{I}}$-semi-irresolute.*

Proof.1 Let V be a $\delta_{\mathcal{I}}$-semi-open subset of Z. Then V^c is $\delta_{\mathcal{I}}$-semi-closed subset of Z. Since g is $\delta_{\mathcal{I}}$-semi-irresolute, we have $g^{-1}(V^c)$ is $\delta_{\mathcal{I}}$-semi-closed set in Y. Also $g^{-1}(V^c) = [g^{-1}(V)]^c$ is $\delta_{\mathcal{I}}$-semi-closed set in Y which implies $g^{-1}(V)$ is $\delta_{\mathcal{I}}$-semi-open in Y. Since f is contra $\delta_{\mathcal{I}}$-semi-irresolute, we have $f^{-1}(g^{-1}(V)) = (g \circ f)^{-1}(V)$ is $\delta_{\mathcal{I}}$-semi-closed in X. Hence $g \circ f$ is contra $\delta_{\mathcal{I}}$-semi-irresolute.
2. Similar to 1.

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BIOGRAPHY

Dr. V. Inthumathi received Doctoral degree in the field of Ideal topological spaces from Bharathiar University in 2012. She is working as an Associate Professor in Department of Mathematics in Nallamuthu Gounder Mahalingam college, Pollachi, India. She has 24 years of teaching experience. she has published about 45 research articles in reputed journals. She guided 23 M.Phil scholars and guiding 4 Ph.D. scholars. Currently she is doing research in the area of soft topological spaces and Nano ideal topological spaces.

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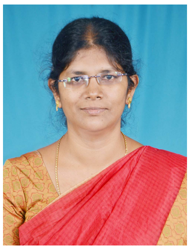

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