Some Results of Reverse θ- Centralizers on prime Rings

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Abstract:

Let R be an associative ring with center Z (R). In this paper we introduce the definition of reverse θ- centralizers of R which is a generalization of reverse-centralizers of R then we proved some results concerning reverse θ- centralizers in prime and semiprime rings. Then we introduce the definition of double reverse θ-centralizers which is a generalization of a double reverse- centralizers

after that we shall generalized some results of double reverse-centralizers to a

double reverse θ-centralizers.

Keywords:

Prime ring, semiprime ring, θ-centralizers, reverse-centralizers, reverse θ-

centralizers, double reverse θ-centralizers.

Introduction:

Throughout this paper, R will represent an associative ring with center Z(R). This paper consists of three sections. In section one, we recall some basic definitions and other concepts which will be used in this paper. Also we shall give some necessary remarks and some examples that illustrate these concepts.

In section two, we give the definition of reverse θ-centralizer, and we proved

some results when R is prime or semiprime ring. In section three, we shall

introduce the definition of double reverse θ-centralizer, and we prove some

results when R is prime and semiprime ring.

§1 Basic concepts:

Definition 1.1: [1]

A ring R is called a prime ring if for any a, b ∈ R, a R b ={0}, implies that either a=0 or b=0.

Definition 1.2: [1]

A ring R is called a semiprime ring if for any a∈R, aRa ={0}, implies that a=0.

Remark 1.3: [1]

Every prime ring is a semiprime ring, but the converse in general is not true.
The following example justifies this remark.

Example 1.4: [6]

Z_6 is a semiprime ring but is not prime. Let a ∈R such that a R a ={0}, implies that a^2 =0, hence a=0, therefore R is a semiprime ring. But R is not prime, since 2≠0 and 3≠0 and implies that 2R3={0}.

Definition 1.5: [4]

Let R be an arbitrary ring. If there exists a positive integer n such that na=0, for all a ∈R, then the smallest positive integer with this property is called characteristic of the ring, by symbols we write char R=n. If no such positive integer exists (that is, n=0 is only integer for which na=0, for all a in R), then R is said to be of characteristic zero.

Definition 1.6: [4]

A ring R is said to be n-torsion free where n ≠ 0 is an integer if whenever na=0 with a ∈ R, then a=0.

Remark 1.7: [4]

A characteristic not equal n is equivalent to n-torsion free in a prime ring.

Definition 1.8: [2]

Let R be a ring. Define a Lie product [.,.] on R as follows:

[x,y] =xy-yx, for all x,y∈ R.

Properties 1.9: [2]

Let R be a ring, then for all x,y,z∈ R, we have:

1- [x,yz] =y[x,z] +[x,y]z
2- [xy,z] =x [y,z] + [x,z]y
3- [x+y,z] = [x,z] + [y,z]
4- [x,y+z] = [x,y] + [x,z]

Definition 1.10: [3]

Let R be a ring. Define aJordan product on R as follws: aob =ab+ba, for all a,b∈ R.

Definition 1.11: [2]

Let R be a ring, the center of R denoted by Z (R) and is defined by:
Z (R) = {x ∈ R /xr=rx, for all r ∈ R}

Definition 1.12: [2]

Let R be ring with center Z (R). A mapping f:R→R is said to be centralizing if [f(x), x] ∈ Z (R), For all x ∈ R, and f is said to be commuting if [f(x), x] =0 for all x ∈ R.

Definition 1.13: [6]

Let R be ring, an additive mapping f:R→R is called a homomorphism if f(xy) = f(x) f(y), for all x,y∈ R. And is called anti-homomorphism if f(xy) = f(y) f(x), for all x,y∈ R.

Definition 1.14: [6]

Let R be ring, an additive mapping f:R→R is said to be Jordan homomorphism if $f(x^2) = f(x) f(x)$ holds for all $x \in R$.

Remark 1.15: [6]

Every homomorphism is a Jordan homomorphism. But the converse in general is not true.

The Following example illustrate this remark

Example 1.16: [6]

Let F be field, and let M_2 (F) be a ring of all matrices of order 2 over F.

Define f:R→R as $F\left(\begin{bmatrix} a & b \\ c & d \end{bmatrix}\right) = \begin{bmatrix} a & c \\ b & d \end{bmatrix}$, for all $a,b,c,d \in F$.

Then f is a Jordan homomorphism but is not homomorphism.

Definition 1.17: [3]

A left (right) centralizer of a ring R is an additive mapping T:R→R which satisfies $T(xy) = T(x)\, y$ $(T(xy) = xT(y))$, for all $x,y \in R$. A centralizer of a ring R is both left and right centralizer.

Remark 1.18: [3]

Let R be a ring with an identity element, T:R→R is a left (right) centralizer if and only if T is of the form $T(x) = ax$ $(T(x) = x\,a)$, for some fixed element $a \in R$.

Example 1.19: [1]

Let F be field, and let D_2 (F) be a ring of all diagonal matrices of order 2 over F.

Let $T:D_2(F) \to D_2(F)$ be an additive mapping defined as

$T\left(\begin{bmatrix} a & 0 \\ 0 & b \end{bmatrix}\right) = \begin{bmatrix} 0 & 0 \\ 0 & b \end{bmatrix}$, for all $a,b \in F$.

Then T is a centralizer.

Definition 1.20: [5]

Let R be a ring and let T,S:R→R be additive mappings, then a pair (T,S) is called a double centralizer if T is a left centralizer, S is a right centralizer, and they satisfy a balanced condition x T(y) =S(x)y for all x,y∈ R.

Example 1.21: [5]

Define T,S: M_2 (F) →M_2 (F) by

$T(\begin{bmatrix} a & b \\ c & d \end{bmatrix}) = \begin{bmatrix} o & o \\ c & d \end{bmatrix}$, for all a,b,c,d∈ F.

$S(\begin{bmatrix} a & b \\ c & d \end{bmatrix}) = \begin{bmatrix} o & b \\ o & d \end{bmatrix}$, for all a,b,c,d∈ F.

Then (T,S) is a double centralizer.

Remark 1.22: [5]

Let R be a ring and let T:R→R be centralizer, then it is clear that (T,T) is a double centralizer.

Definition 1.23: [4]

An additive mapping T:R→R is called a left (right) θ- centralizer if for all x,y∈ R, T(xy) = T(x) θ(y) (T(xy) = θ(x) T(y)). A θ- centralizer of R is both left and right θ- centralizer, whereθ is a homomorphism on R.

Definition 1.24: [5]

Let R be a ring. An additive mapping T:R→R is said to be left (right) reverse- centralizer of R, if T(xy) = T(y)x (resp. T(xy) =yT(x)), for all x,y∈ R. A reverse- centralizer of R is both left and right reverse- centralizer.

Example 1.25: [5]

Let F be a Field, and R be ring of triangular matrices of the form.

x= $\begin{bmatrix} 0 & a & c & b \\ 0 & 0 & 0 & c \\ 0 & 0 & 0 & -a \\ 0 & 0 & 0 & 0 \end{bmatrix}$, for all a,b,c,d ∈ F, x ∈ R .

Define T:R→R by T(x) = $\begin{bmatrix} 0 & 0 & 0 & c \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$, for all c ∈F and x ∈ R.

Then T is a reverse-centralizer.

Definition 1.26: [5]

Let R be a ring, and let T,S :R →R be additive mappings then a pair (T,S) is called a double reverse-centralizer, if T is a left reverse- centralizer, S is a right reverse-centralizer and they satisfy the condition xT(y) = S(x)y, for all x,y∈ R.

Definition 1.27: [6]

A nonempty subset U of R is said to be a (two-sided) ideal of R if U is a subgroup of R under addition and for every u ∈ U andr ∈ R, both ur and ru are in U.

§2 Reverse θ-centralizers:

Definition 2.1:

Let R be a ring, and θ be an anti-homomorphism on R. An additive mapping

T:R→R is called a left (right) reverse θ-centralizer if for all x,y∈ R, T(xy) =

T(y) θ(x) (T(xy) = θ(y) T(x). A reverse θ-centralizer of R is both left and right

reverse θ-centralizer.

<u>Example 2.2:</u>

Let F be a field, and let M_2 (F) be a ring of all matrices of order 2 over F.

Define T: M_2 (F) → M_2 (F) as T ($\begin{bmatrix} a & b \\ c & d \end{bmatrix}$) = $\begin{bmatrix} o & o \\ b & d \end{bmatrix}$, for all a,b,c,d ∈ F.

andDefine θ: $M_2(F) \rightarrow M_2(F)$ asθ ($\begin{bmatrix} a & b \\ c & d \end{bmatrix}$) =$\begin{bmatrix} a & c \\ b & d \end{bmatrix}$, for all a,b,c,d $\in$ F.

Then T is a reverse θ-centralizer.

Theorem 2.3:

Let R be a prime ring, I be an ideal of R, and T is a left reverse θ-centralizer, if

T = θ on I, then T = θ on R, where θ be a non-zero surjectiveanti-

homomorphism.

Proof:

By the hypothesis, we have

$$T(x) = \theta(x) \qquad \text{for all } x \in I \qquad (1)$$

Replacing x by xr in (1), when $r \in R$, $x \in I$, we get

$$T(xr) = \theta(xr)$$

$$T(r)\,\theta(x) = \theta(r)\,\theta(x)$$

$$(T(r)-\theta(r))\,\theta(x) = 0 \text{ for all } r \in R,\ x \in I \qquad (2)$$

Again, replace x by xt in (2), when $t \in R$, $x \in I$, to get

$$(T(r)-\theta(r))\,\theta(xt) = 0 \text{ for all } t, r \in R,\ x \in I.$$

$$(T(r)-\theta(r))\,\theta(t)\theta(x) = 0$$

By the surjectivity of θ and the primeness of R it follows that $T = \theta$.

Theorem 2.4:

Let R be a semiprime ring and let T: R →R be a mapping satisfying T(y) θ(x) = θ(y) T(x), for all x,y∈ R, then T is reverseθ-centralizer where θ is a surjective anti-homomorphism on R.

proof:

we need to show that T is an additive and T(xy) = T(y) θ(x) = θ(y) T(x), for all x,y, ∈ R. So, let x,y,z, ∈ R. Then

(T(x+y)- T(x)- T(y)) θ(z) =T(x+y) θ(z)- T(x) θ(z)- T(y) θ(z)

= θ(x+y) T(z)- θ(x) T(z)- θ(y) T(z)

$= \theta(x)\, T(z) + \theta(y)\, T(z) - \theta(x)\, T(z) - \theta(y)\, T(z) = 0$

By the surjectivity of θ and the semiprimeness of R, we get

$T(x+y) = T(x) + T(y)$, for all $x, y, \in R$.

To prove the second property, consider

$(T(xy) - T(y)\, \theta(x))\, \theta(z) = T(xy)\, \theta(z) - T(y)\theta(x)\, \theta(z)$

$= \theta(xy)\, T(z) - \theta(y)\, T(x)\, \theta(z)$

$= \theta(y)\, \theta(x)\, T(z) - \theta(y)\, \theta(x)\, T(z) = 0$

Again, by the surjectivityof θ and the semiprimeness of R, we get

$$T(xy) = T(y)\, \theta(x) = \theta(y)\, T(x), \text{ for all } x,y, \in R.$$

Theorem 2.5:

Let R be a 2-torsion free semiprime ring and T be a left reverse θ-centralizer which satisfies T(xoy) =0, for all x,y, ∈ R, where θ is a surjective anti-homomorphism on R, thenT=0

Proof:

we have

T(xy+yx) =0, for all x,y, ∈ R. (1)

On the other hand, we obtain

T(xy) + T(yx) =0, for all x,y, ∈ R.

$T(y)\,\theta(x) + T(x)\,\theta(y) = 0$, for all x,y, ∈ R. (2)

Replacing x by xz+zx in (2), we find

$T(y)\,\theta(xz+zx) + T(xz+zx)\,\theta(y) = 0$ (3)

From (1) and (3), we obtain

$T(y)\,\theta(xz+zx) = 0$, for all x,y,z ∈ R. (4)

Again replacing z by xz+zx, to get

$T(y)\,\theta(x^2z+zx^2) + 2T(y)\,\theta(xzx) = 0$, for all x,y,z ∈ R. (5)

From (4) and R is a 2-torsion free, gives

T(y) θ (xzx) =0, for all x,y,z∈ R. (6)

Since θ is onto, replace θ(z) with θ(z) T(y), implies that

T(y) θ (x) θ(z)T(y) θ(x) =0, for all x,y,z∈ R.

By the surjectivity ofθ and the semiprimeness of R, we get

T(y) θ(x) =0, for all x,y, ∈ R.

A gain by the semiprimeness of R, we have T=0.

Theorem 2.6:

Let R be a prime ring, and let I be an ideal of R. If T(xr) =T(r) θ(x), for all x $\in$ R and x$\in$ I, then T is a left reverse θ-centralizer on R, where θ is a non-zero surjective anti-homomorphism on R.

Proof:

By the assumption of theorem, we have

T(xr) = T(r) θ(x), for all r $\in$ R and x $\in$ I.

This reduces to

T(xsr) = T(sr) θ(x)= T(r) θ(s) θ(x), for all r,s$\in$ R and x $\in$ I.

It the follows that:(T(sr)- T(r)θ(s))θ(x) =0, for all r,s, $\in$ R and x $\in$ I.

i.e. (T(sr)- T(r) θ(s))θ(t) θ(x) =0, for all r,s,t$\in$ R and x $\in$ I.

By the surjectivity of θ and the primeness of R, we obtain T(sr) = T(r) θ(s), for all r,s$\in$ R.

Lemma 2.7:

Let R be a noncommutative prim ring, and T: R→R be a left reverse θ –

centralizer. If T(x) ∈ Z(R) holds for all x ∈ R, then T=0, where θ is a surjective

anti- homomorphism on R.

Proof:

We have

$[T(x), y] = 0$, for all $x,y \in R$ (1)

Putting zx for x in (1), we get $[T(zx), y] = 0$

$[T(x)\, \theta(z), y] = 0$, for all $x,y,z \in R$ (2)

This gives: $T(x)\, [\theta(z), y] + [T(x), y]\, \theta(z) = 0$, for all $x,y,z \in R$. (3)

From (1), we have: $T(x)\, [\theta(z), y] = 0$, for all $x,y,z \in R$ (4)

Putting wx for x in (4), we get

$T(x)\, \theta(w)\, [\theta(z), y] = 0$, for all $x,y,z,w \in R$.

Since R is a noncommutative prime ring and by the surjectivty of θ, it follows

T=0.

Lemma 2.8:

Let R be a ring with an identity element, and T: R→R is a left (right) reverse θ –

centralizer if and only if T is of the form T(x) =aθ(x) (T(x) = θ(x) a) for some

fixed element a∈ R where θ is surjective anti- homomorphism on R.

Proof:

Let T be a leftreverse θ –centralizer, then T(yx) = T(x) θ(y), for all

x,y$\in$ R.Replace x by 1 we get T(y) =aθ(y), for all y $\in$ R.

Where a=T(1). If T(yx) = θ(x) T(y), we obtain the assertion of the lemma with

similar approach as above. To show the converse, assume

T(x) = aθ(x), for all x $\in$ R, then

T(yx) =a θ(yx) =a θ(x) θ(y) =T(x) θ(y), for allx,y$\in$ R, Hence T is a left reverse θ –centralizer.

Similarly, we can show that T is a right reverse θ –centralizer if $T(x) = \theta(x)\, a$,

for all $x \in R$.

Theorem 2.9:

Let R be a prime ring, and T is a left reverse θ –centralizer of R which satisfies

$T(x) = a\,\theta(x) + \theta(x)\, a$, for all $x \in R$ and fixed $a \in R$. Then $a \in Z(R)$ where θ is a

non-zero surjective anti- homomorphism on R.

Proof:

We have

$T(yx) = T(x)\,\theta(y)$, for all $x,y \in R$ (1)

i.e. $T(yx) = (a\,\theta(x) + \theta(x)\,a)\,\theta(y)$

On the other hand, we obtain

$T(yx) = a\,\theta(yx) + \theta(yx)\,a$, for all $x,y \in R$ (2)

On combining last two equations, we obtain

$\theta(x)\,[a, \theta(y)] = 0$, for all $x,y \in R$ (3)

Further taking $x=rx$ in (3), we get

$\theta(x)\,\theta(r)[\,a,\theta(y)] = 0$, for all x,y∈ R (4)

By the surjectivity of θ and the primeness of R, yieds $[a,\theta(y)] = 0$, for all y ∈ R.

§3 Double Reverse θ-centralizers:

Definition 3.1:

Let R be a ring, and let T,S: R→R be additive mappings then a pair (T,S) is called a double reverse θ –centralizer,if T is left reverse θ –centralizer, S is a right reverse θ –centralizer and they satisfy the condition $\theta(x)\, T(y) = S(x)\, \theta(y)$,

for all $x,y \in R$. where θ is an anti-homomorphism on R.

Example 3.2:

Let F be a field, and let M_2 (F) be a ring of all matrices of order 2 over F.

And θ on $M_2(F)$ defined by

$\theta\left(\begin{bmatrix} a & b \\ c & d \end{bmatrix}\right)=\begin{bmatrix} a & c \\ b & d \end{bmatrix}$,for all $a,b,c,d \in F$.

Let T,S: M_2 (F) $\rightarrow M_2(F)$ be additive mappings defined as.

$T\left(\begin{bmatrix} a & b \\ c & d \end{bmatrix}\right) = \begin{bmatrix} o & o \\ b & d \end{bmatrix}$, for all $a,b,c,d \in F$.

$S\left(\begin{bmatrix} a & b \\ c & d \end{bmatrix}\right) = \begin{bmatrix} 0 & c \\ 0 & d \end{bmatrix}$, for all a,b,c,d $\in$ F.

Then (T,S) is a double reverse θ –centralizer.

Theorem 3.3:

Let R be a semiprime ring and T,S: R→R be mappings satisfying

$\theta(x)\, T(y) = S(x)\, \theta(y)$, for all x,y$\in$ R …(1). Where θ is an anti-homomorphism

on R.Then (T,S) is a double reverse θ –centralizer.

Proof:

We need to show that T,S are additive mappings, and

$T(xy) = T(y)\, \theta(x)$, for all x,y$\in$ R.

$S(xy) = \theta(y)\, S(x)$, for all $x,y \in R$.

Now replacing y by y+z in (1), we get

$\theta(x)\, T(y+z) = S(x)\, \theta(y+z)$, for all $x,y,z \in R$.

$\theta(x)\, T(y+z) = S(x)\, \theta(y) + S(x)\, \theta(z)$

$\theta(x)\, T(y+z) = \theta(x)\, T(y) + \theta(x)\, T(z)$, for all $x,y,z \in R$. (2)

Hence $\theta(x)\, (T(y+z) - T(y) - T(z)) = 0$, for all $x,y,z \in R$. (3)

By the semiprimeness of R, we get, T(y+z) = T(y) + T(z), for all y,z$\in$ R.

Similarly, we can show that

S(x+y) = S(x) + S(y), for all x,y$\in$ R.

Now, replacing y with yz in (1), we obtain

θ(x) T(yz) = S(x) θ(yz), for all x,y,z$\in$ R.

θ(x) T(yz) = S(x) θ(z) θ(y) , for all x,y,z$\in$ R.

θ(x) T(yz) = θ(x) T(z) θ(y), for all x,y,z$\in$ R.

Implies that: θ(x) (T(yz)- T(z) θ(y)) =0, for all x,y,z$\in$ R. (4)

By the semiprimeness of R we get, $T(yz) = T(z)\ \theta(y)$, for all $y,z \in R$.

Similarly we can show that: $S(xy) = \theta(y)\ S(x)$, for all $x,y \in R$.

Then (T,S) i a double reverse θ –centralizer.

Theorem 3.4:

Let R be a prime ring, I be non-zero ideal of R. Let $T,S: R \rightarrow R$be additive mappings such that T is a left reverse θ –centralizer, S is aright reverse θ –

centralizer. Where θ is an anti- homomorphism on R, and they satisfying $\theta(x)$

$T(y) = S(x)\,\theta(y)$, for all $x,y \in I$. Then (T,S) is a double reverse θ –centralizer.

Proof:

We have: $\theta(x)\,T(y) = S(x)\,\theta(y)$, for all $x,y \in I$. (1)

Replace x with rx in (1), when $x \in I$ and $r \in R$, we get

$\theta(x)\,(\theta(r)\,T(y) - S(r)\,\theta(y)) = 0$, for all $r \in R$ and $x,y \in I$. (2)

i.e. $\theta(x)\,R(\theta(r)T(y) - S(r)\,\theta(y)) = 0$, for all $r \in R$ and $x,y \in I$.

By the primeness of R and since I be a non-zero ideal of R, we get

$\theta(r)\ T(y) = S(r)\ \theta(y)$, for all $r \in R$ and $y \in I$. (3)

Replace y with yt in (3), where $t \in R$ and $y \in I$, we get

$(\theta(r)\ T(t) - S(r)\ \theta(t))\ \theta(y) = 0$, for all $t,r \in R$ and $y \in I$.

Implies that: $(\theta(r)\ T(t) - S(r)\ \theta(t))\ RI = 0$, for all $t,r \in R$.

By the primeness of R, we get.

$\theta(r)\ T(t) = S(r)\ \theta(t)$, for all $t,r \in R$.

Then (T,S) is a double reverse θ –centralizer.

Theorem 3.5:

Let R be a prime ring, I be a non-zero ideal of R and (T,S) be a double reverse

θ –centralizer. Where θ is an anti- homomorphism on R.

If T=S on I, then T=S on R

Proof:

We have: T(x) =S(x), for all x ∈ I. (1)

Replacing x with xr in (1), when r ∈ R and x ∈ I, we get, T(xr) = S(xr)

T(r) θ(x) =θ(r) S(x) = θ(r) T(x), for all r ∈ R x, ∈ I. (2)

Since (T,S) is a double reverse θ –centralizer, then

$T(r)\,\theta(x) = S(r)\,\theta(x)$, for all $r \in R$, $x \in I$. (3)

i.e. $(T(r) - S(r))\,R\,I = 0$, for all $r \in R$.

Since R is a prime ring and I be a non-zero ideal of R, we get T=S.

Theorem 3.6:

Let R be a semiprime ring, and (T,S) be a double reverse θ –centralizer. Where θ is an anti- homomorphism on R. Then T (or S) is a reverse θ –centralizer if and only if T=S.

Proof:

We have: $T(yx) = T(x)\,\theta(y) = \theta(x)\,T(y)$, for all $x,y \in R$.

On the other hand, $\theta(x)\,T(y) = S(x)\,\theta(y)$, for all $x,y \in R$.

This gives: $(T(x)- S(x))\,\theta(y)\,(T(x)- S(x)) = 0$, for all $x,y \in R$.

By the semiprimeness of R, we get T=S.

Conversely, suppose $T(x) = S(x)$, for all $x \in R$.

i.e. $T(x)\,\theta(y) = \theta(x)\,S(y) = \theta(x)\,T(y)$, for all $x,y \in R$.

Implies that T(xy) = T(x) θ(y) = θ(x) T(y), for all x,y$\in$ R.

Theorem 3.7:

Let R be a prime ring, I be a non-zero ideal of R, and (T,S) be a double reverse θ –centralizer. Where θ is an anti- homomorphism on R.

If T(xr) = S(r) θ(x), for all r $\in$ R, x $\in$ I, then T=S.

Proof:

We have: T(xr) = T(r) θ(x) = S(r) θ(x), for allr $\in$ R, x $\in$ I. (1)

This reduces to: (T(r)- S(r))θ(x) = 0, for allr $\in$ R, x $\in$ I. (2)

Replacing x with xt in (2), when t ∈ R, x ∈ I. Leads to

(T(r)- S(r)) θ(xt) = 0, for allr,t∈ R, x ∈ I.

(T(r)- S(r)) θ(t) θ(x) = 0, for allr,t∈ R, x ∈ I.

i.e. (T(r)- S(r)) RI = 0, for allr ∈ R.

since R is a prime ring and I be a non-zero ideal, we have T=S

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بعض النتائج حول تمركزات -θ العكسية

على الحلقات الاولية

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المستخلص:

لتكن R حلقة تجميعية مركزها Z(R). في هذا البحث قدمنا تعريف تمركزات –θالعكسية على الحلقة R والذي هو تعميم التمركزات العكسية على الحلقة R. وبعد ذلك برهنا بعض النتائج المتعلقة بتمركزات -θالعكسية في الحلقات الاولية وشبه الاولية. بعد ذلك قدمنا تعريف تمركزات -θ العكسية المزدوجة والذي هو تعميم التمركزات العكسية المزدوجة. وبعد ذلك سنقوم بتعميم بعض النتائج المتعلقة بالتمركزات العكسية المزدوجة الى التمركزات -θ العكسية المزدوجة.