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Isomorphisms of Direct Products of Finite Cyclic Groups

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Summary. In this article, we formalize that every finite cyclic group is isomorphic to a direct product of finite cyclic groups which orders are relative prime. This theorem is closely related to the Chinese Remainder theorem ([18]) and is a useful lemma to prove the basis theorem for finite abelian groups and the fundamental theorem of finite abelian groups. Moreover, we formalize some facts about the product of a finite sequence of abelian groups.

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The notation and terminology used in this paper are introduced in the following articles: [5], [1], [2], [4], [11], [6], [7], [20], [17], [18], [19], [3], [8], [13], [15], [16], [12], [23], [21], [10], [22], [14], and [9].

Let G be an Abelian add-associative right zeroed right complementable non empty additive loop structure. Note that $\langle G \rangle$ is non empty and Abelian group yielding as a finite sequence.

Let G, F be Abelian add-associative right zeroed right complementable non empty additive loop structures. Note that $\langle G, F \rangle$ is non empty and Abelian group yielding as a finite sequence.

We now state the proposition

(1) Let X be an Abelian group. Then there exists a homomorphism I from X to $\prod \langle X \rangle$ such that I is bijective and for every element x of X holds $I(x) = \langle x \rangle$.

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Let G, F be non empty Abelian group yielding finite sequences. Note that $G \frown F$ is Abelian group yielding.

One can prove the following propositions:

(2) Let X, Y be Abelian groups. Then there exists a homomorphism I from $X \times Y$ to $\prod\langle X, Y\rangle$ such that I is bijective and for every element x of X and for every element y of Y holds $I(x, y) = \langle x, y\rangle$.

(3) Let X, Y be sequences of groups. Then there exists a homomorphism I from $\prod X \times \prod Y$ to $\prod(X \frown Y)$ such that

(i) I is bijective, and

(ii) for every element x of $\prod X$ and for every element y of $\prod Y$ there exist finite sequences x_1, y_1 such that $x = x_1$ and $y = y_1$ and $I(x, y) = x_1 \frown y_1$.

(4) Let G, F be Abelian groups. Then

(i) for every set x holds x is an element of $\prod\langle G, F\rangle$ iff there exists an element x_1 of G and there exists an element x_2 of F such that $x = \langle x_1, x_2\rangle$,

(ii) for all elements x, y of $\prod\langle G, F\rangle$ and for all elements x_1, y_1 of G and for all elements x_2, y_2 of F such that $x = \langle x_1, x_2\rangle$ and $y = \langle y_1, y_2\rangle$ holds $x + y = \langle x_1 + y_1, x_2 + y_2\rangle$,

(iii) $0_{\prod\langle G,F\rangle} = \langle 0_G, 0_F\rangle$, and

(iv) for every element x of $\prod\langle G, F\rangle$ and for every element x_1 of G and for every element x_2 of F such that $x = \langle x_1, x_2\rangle$ holds $-x = \langle -x_1, -x_2\rangle$.

(5) Let G, F be Abelian groups. Then

(i) for every set x holds x is an element of $G \times F$ iff there exists an element x_1 of G and there exists an element x_2 of F such that $x = \langle x_1, x_2\rangle$,

(ii) for all elements x, y of $G \times F$ and for all elements x_1, y_1 of G and for all elements x_2, y_2 of F such that $x = \langle x_1, x_2\rangle$ and $y = \langle y_1, y_2\rangle$ holds $x + y = \langle x_1 + y_1, x_2 + y_2\rangle$,

(iii) $0_{G \times F} = \langle 0_G, 0_F\rangle$, and

(iv) for every element x of $G \times F$ and for every element x_1 of G and for every element x_2 of F such that $x = \langle x_1, x_2\rangle$ holds $-x = \langle -x_1, -x_2\rangle$.

(6) Let G, H, I be groups, h be a homomorphism from G to H, and h_1 be a homomorphism from H to I. Then $h_1 \cdot h$ is a homomorphism from G to I.

Let G, H, I be groups, let h be a homomorphism from G to H, and let h_1 be a homomorphism from H to I. Then $h_1 \cdot h$ is a homomorphism from G to I.

One can prove the following propositions:

(7) Let G, H be groups and h be a homomorphism from G to H. If h is bijective, then h^{-1} is a homomorphism from H to G.

(8) Let X, Y be sequences of groups. Then there exists a homomorphism I from $\prod\langle\prod X, \prod Y\rangle$ to $\prod(X \frown Y)$ such that

(i) I is bijective, and

(ii) for every element x of $\prod X$ and for every element y of $\prod Y$ there exist finite sequences x_1, y_1 such that $x = x_1$ and $y = y_1$ and $I(\langle x, y \rangle) = x_1 \frown y_1$.

(9) Let X, Y be Abelian groups. Then there exists a homomorphism I from $X \times Y$ to $X \times \prod \langle Y \rangle$ such that I is bijective and for every element x of X and for every element y of Y holds $I(x, y) = \langle x, \langle y \rangle \rangle$.

(10) Let X be a sequence of groups and Y be an Abelian group. Then there exists a homomorphism I from $\prod X \times Y$ to $\prod (X \frown \langle Y \rangle)$ such that

(i) I is bijective, and

(ii) for every element x of $\prod X$ and for every element y of Y there exist finite sequences x_1, y_1 such that $x = x_1$ and $\langle y \rangle = y_1$ and $I(x, y) = x_1 \frown y_1$.

(11) Let n be a non zero natural number. Then the additive loop structure of $(\mathbb{Z}_n^{\mathrm{R}})$ is non empty, Abelian, right complementable, add-associative, and right zeroed.

Let n be a natural number. The functor $\mathbb{Z}/n\mathbb{Z}$ yields an additive loop structure and is defined by:

(Def. 1) $\mathbb{Z}/n\mathbb{Z} =$ the additive loop structure of $(\mathbb{Z}_n^{\mathrm{R}})$.

Let n be a non zero natural number. Observe that $\mathbb{Z}/n\mathbb{Z}$ is non empty and strict.

Let n be a non zero natural number. Note that $\mathbb{Z}/n\mathbb{Z}$ is Abelian, right complementable, add-associative, and right zeroed.

Next we state a number of propositions:

(12) Let X be a sequence of groups, x, y, z be elements of $\prod X$, and x_1, y_1, z_1 be finite sequences. Suppose $x = x_1$ and $y = y_1$ and $z = z_1$. Then $z = x + y$ if and only if for every element j of $\operatorname{dom} \overline{X}$ holds $z_1(j) =$ (the addition of $X(j))(x_1(j), y_1(j))$.

(13) For every CR-sequence m and for every natural number j and for every integer x such that $j \in \operatorname{dom} m$ holds $x \bmod \prod m \bmod m(j) = x \bmod m(j)$.

(14) Let m be a CR-sequence and X be a sequence of groups. Suppose $\operatorname{len} m = \operatorname{len} X$ and for every element i of $\mathbb{N}$ such that $i \in \operatorname{dom} X$ there exists a non zero natural number m_1 such that $m_1 = m(i)$ and $X(i) = \mathbb{Z}/m_1\mathbb{Z}$. Then there exists a homomorphism I from $\mathbb{Z}/(\prod m)\mathbb{Z}$ to $\prod X$ such that for every integer x if $x \in$ the carrier of $\mathbb{Z}/(\prod m)\mathbb{Z}$, then $I(x) = \operatorname{mod}(x, m)$.

(15) Let X, Y be non empty sets. Then there exists a function I from $X \times Y$ into $X \times \prod \langle Y \rangle$ such that I is one-to-one and onto and for all sets x, y such that $x \in X$ and $y \in Y$ holds $I(x, y) = \langle x, \langle y \rangle \rangle$.

(16) For every non empty set X holds $\overline{\overline{\prod \langle X \rangle}} = \overline{\overline{X}}$.

(17) Let X be a non-empty non empty finite sequence and Y be a non empty set. Then there exists a function I from $\prod X \times Y$ into $\prod (X \frown \langle Y \rangle)$ such that

(i) I is one-to-one and onto, and

(ii) for all sets x, y such that $x \in \prod X$ and $y \in Y$ there exist finite sequences x_1, y_1 such that $x = x_1$ and $\langle y \rangle = y_1$ and $I(x, y) = x_1 \frown y_1$.

(18) Let m be a finite sequence of elements of $\mathbb{N}$ and X be a non-empty non empty finite sequence. Suppose $\operatorname{len} m = \operatorname{len} X$ and for every element i of $\mathbb{N}$ such that $i \in \operatorname{dom} X$ holds $\overline{\overline{X(i)}} = m(i)$. Then $\overline{\overline{\prod X}} = \prod m$.

(19) Let m be a CR-sequence and X be a sequence of groups. Suppose $\operatorname{len} m = \operatorname{len} X$ and for every element i of $\mathbb{N}$ such that $i \in \operatorname{dom} X$ there exists a non zero natural number m_1 such that $m_1 = m(i)$ and $X(i) = \mathbb{Z}/m_1\mathbb{Z}$. Then $\overline{\overline{\text{the carrier of } \prod X}} = \prod m$.

(20) Let m be a CR-sequence, X be a sequence of groups, and I be a function from $\mathbb{Z}/(\prod m)\mathbb{Z}$ into $\prod X$. Suppose that

(i) $\operatorname{len} m = \operatorname{len} X$,

(ii) for every element i of $\mathbb{N}$ such that $i \in \operatorname{dom} X$ there exists a non zero natural number m_1 such that $m_1 = m(i)$ and $X(i) = \mathbb{Z}/m_1\mathbb{Z}$, and

(iii) for every integer x such that $x \in$ the carrier of $\mathbb{Z}/(\prod m)\mathbb{Z}$ holds $I(x) = \operatorname{mod}(x, m)$.

Then I is one-to-one.

(21) Let m be a CR-sequence and X be a sequence of groups. Suppose $\operatorname{len} m = \operatorname{len} X$ and for every element i of $\mathbb{N}$ such that $i \in \operatorname{dom} X$ there exists a non zero natural number m_1 such that $m_1 = m(i)$ and $X(i) = \mathbb{Z}/m_1\mathbb{Z}$. Then there exists a homomorphism I from $\mathbb{Z}/(\prod m)\mathbb{Z}$ to $\prod X$ such that I is bijective and for every integer x such that $x \in$ the carrier of $\mathbb{Z}/(\prod m)\mathbb{Z}$ holds $I(x) = \operatorname{mod}(x, m)$.

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