

Repsn

**A GAP4 Package
for constructing representations of finite groups**

Version 2.1

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Chapter 1

Introduction

This manual describes the Repsn package for computing matrix representations in characteristic zero of finite groups. Most of the functions in Repsn have been written according to the algorithm described in the author's Ph.D thesis [DA03] (see [DA05]).

For constructing representations of simple groups and their covers we use the algorithm described in [Dix93]. To use this algorithm for constructing a representation of a group G affording an irreducible character χ of G , we need to have a subgroup H of G such that the restriction of χ to H has a linear constituent with multiplicity one. In this case we say H is a *character subgroup* relative to χ (or a χ -subgroup). A χ -subgroup for each irreducible character χ of degree less than 32 of simple groups and their covers are listed in [DA03].

All Repsn functions are written entirely in the GAP language. It is proved in [DA05] that the algorithm is correct for any group with a character of degree less than 32. Indeed, if the group is solvable, there is no restriction on the character degree. In practice the program is quite fast when the degree is small, but can be very slow when it is necessary to call one of the subprograms which extend irreducible representations. In the latter case the number of element wise operations required to extend a representation of degree d is proportional to d^6 .

Repsn is implemented in the GAP language, and runs on any system supporting GAP4. The Repsn package is loaded into the current GAP session with the command

```
gap> LoadPackage( "repsn" );
```

(see section *Loading a GAP Package* in the GAP Reference Manual). One could install the Repsn package on GAP4.3. In this case it is loaded with the command

```
gap> RequirePackage( "repsn" );
```

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Chapter 2

Irreducible Representations

Let G be a finite group and chi be an ordinary irreducible character of G . In this chapter we introduce some functions to construct a complex representation R of G affording chi . We proceed recursively, reducing the problem to smaller subgroups of G or characters of smaller degree until we obtain a problem which we can deal with directly. Inputs of most of the functions are a given group G , and an irreducible character chi . The output is a mapping (representation) which assigns to each generator x of G a matrix $R(x)$. We can use these functions for all groups and all irreducible characters chi of degree less than 32 although in principle the same methods can be extended to characters of larger degree. The main methods in these functions which are used to construct representations of finite groups are induction, extension, tensor product and Dixon's method (for constructing representations of simple groups and their covers).

2.1 Constructing Representations

This section introduces the main function to compute a representation of a finite group G affording an irreducible character chi of G .

2.1.1 IrreducibleAffordingRepresentation

◇ IrreducibleAffordingRepresentation(chi) (function)

called with an irreducible character chi of a group G , this function returns a mapping (representation) which maps each generator of G to a $d * d$ matrix, where d is the degree of chi . The group generated by these matrices (the image of the map) is a matrix group which is isomorphic to G modulo the kernel of the map. If G is a solvable group then there is no restriction on the degree of chi . In the case that G is not solvable and the character chi has degree bigger than 31 the output maybe is not correct. In this case sometimes the output mapping does not afford the given character or it does not return any mapping.

2.1.2 IsAffordingRepresentation

◇ IsAffordingRepresentation(chi , rep) (function)

If `chi` and `rep` are a character and a representation of a group G , respectively, then `IsAffordingRepresentation` returns true if the trace of `rep(x)` equals `chi(x)` for all elements x in G .

Example

```
gap> G := GL(2,7);;
gap> chi := Irr(G)[ 29 ];;
gap> rep := IrreducibleAffordingRepresentation( chi );
CompositionMapping( [ (8,15,22,29,36,43) (9,16,23,30,37,44)
(10,17,24,31,38,45) (11,18,25,32,39,46) (12,19,26,33,40,47)
(13,20,27,34,41,48) (14,21,28,35,42,49), (2,29,12) (3,36,20)
(4,43,28) (5,8,30) (6,15,38) (7,22,46) (9,44,14) (10,16,17)
(11,37,27) (13,23,39) (18,24,25) (19,45,35) (21,31,47)
(26,32,33) (34,40,41) (42,48,49) ] ->
[ [ [ 0, 0, 0, -1, 0, 0, 0 ],
    [ 1, 0, -1, -1, 1, 0, -1 ],
    [ 2, -1, -2, -2, 1, 2, -1 ],
    [ 0, 0, -1, 0, 0, 0, 0 ],
    [ 1, 0, -2, 0, 0, 1, -1 ],
    [ 1, 0, -2, -1, 1, 1, -1 ],
    [ -2, 1, 1, 1, -1, -1, 0 ] ],
  [ [ 1, -1, -1, -1, 0, 2, -1 ],
    [ 0, 0, 1, 0, 0, 0, 0 ],
    [ 0, 0, 0, 0, 0, 1, 0 ],
    [ 0, 1, -1, 0, 0, 0, -1 ],
    [ 0, 1, 0, 1, 0, -1, 0 ],
    [ 0, 1, 0, 0, 0, 0, 0 ],
    [ 0, 0, 0, 0, -1, 0, 0 ] ] ], (action isomorphism) )
gap> IsAffordingRepresentation( chi, rep );
true
```

We can obtain the size of the image of this representation by `Size(Image(rep))` and compute the value for an arbitrary element x in G by `x^rep`.

2.2 Induction

2.2.1 InducedSubgroupRepresentation

◇ `InducedSubgroupRepresentation(G, rep)`

(function)

computes a representation of G induced from the representation `rep` of a subgroup H of G . If `rep` has degree d then the degree of the output representation is $d * |G : H|$.

Example

```
gap> G := SymmetricGroup( 6 );;
gap> H := AlternatingGroup( 6 );;
gap> chi := Irr( H )[ 2 ];;
gap> rep := IrreducibleAffordingRepresentation( chi );;
gap> InducedSubgroupRepresentation( G, rep );
[ (1,2,3,4,5,6), (1,2) ] ->
[ [ [ 0, 0, 0, 0, 0, 1, 1, -1, -1, -1 ],
    [ 0, 0, 0, 0, 0, 1, 0, -1, 0, -1 ],
```

```

[ 0, 0, 0, 0, 0, 1, 0, 0, -1, -1 ],
[ 0, 0, 0, 0, 0, 1, 0, 0, 0, 0 ],
[ 0, 0, 0, 0, 0, 0, 1, -1, 0, -1 ],
[ 1, 1, -1, -1, -1, 0, 0, 0, 0, 0 ],
[ 1, 0, 0, -1, -1, 0, 0, 0, 0, 0 ],
[ 1, 0, 0, 0, 0, 0, 0, 0, 0, 0 ],
[ 1, 0, -1, 0, -1, 0, 0, 0, 0, 0 ],
[ 0, 1, 0, -1, -1, 0, 0, 0, 0, 0 ] ],
[ [ 0, 0, 0, 0, 0, 1, 0, 0, 0, 0 ],
  [ 0, 0, 0, 0, 0, 0, 1, 0, 0, 0 ],
  [ 0, 0, 0, 0, 0, 0, 0, 1, 0, 0 ],
  [ 0, 0, 0, 0, 0, 0, 0, 1, 0, 0 ],
  [ 0, 0, 0, 0, 0, 1, 1, -1, -1, -1 ],
  [ 1, 0, 0, 0, 0, 0, 0, 0, 0, 0 ],
  [ 0, 1, 0, 0, 0, 0, 0, 0, 0, 0 ],
  [ 0, 0, 0, 1, 0, 0, 0, 0, 0, 0 ],
  [ 0, 0, 1, 0, 0, 0, 0, 0, 0, 0 ],
  [ 1, 1, -1, -1, -1, 0, 0, 0, 0, 0 ] ] ]

```

2.3 Extension

In this section we introduce some functions for extending a representation of a subgroup to the whole group.

2.3.1 ExtendedRepresentation

◇ `ExtendedRepresentation(chi, rep)` (function)

Suppose H is a subgroup of a group G and χ is an irreducible character of G such that the restriction of χ to H , ϕ say, is irreducible. If rep is an irreducible representation of H affording ϕ then `ExtendedRepresentation` extends the representation rep of H to a representation of G affording χ . This function call can be quite expensive when the representation rep has a large degree.

Example

```

gap> G := AlternatingGroup( 6 );;
gap> H := Group([ (1,2,3,4,6), (1,4)(5,6) ]);;
gap> chi := Irr( G )[ 2 ];;
gap> phi := RestrictedClassFunction( chi, H );;
gap> IsIrreducibleCharacter( phi );
true
gap> rep := IrreducibleAffordingRepresentation( phi );;
gap> ext := ExtendedRepresentation( chi, rep );
#I Need to extend a representation of degree 5. This may take a while.
[ (1,2,3,4,5), (4,5,6) ] -> [
[ [ 0, 1, 0, -1, -1 ],
  [ 0, 0, 0, 1, 0 ],
  [ -1, -1, -1, 0, 0 ],
  [ 0, 0, 0, 0, -1 ],
  [ 0, 0, 1, 1, 1 ] ],

```

```

[ [ 1, 0, 1, 0, 1 ],
  [ 0, 1, 0, 0, 0 ],
  [ -1, -1, 0, 1, 0 ],
  [ 1, 1, 1, 0, 0 ],
  [ 0, 0, -1, 0, 0 ] ] ]
gap> IsAffordingRepresentation( chi, ext );
true

```

2.3.2 ExtendedRepresentationNormal

◇ `ExtendedRepresentationNormal(chi, rep)`

(function)

Suppose H is a normal subgroup of a group G and χ is an irreducible character of G such that the restriction of χ to H , ϕ say, is irreducible. If rep is an irreducible representation of H affording ϕ then `ExtendedRepresentationNormal` extends the representation rep of H to a representation of G affording χ . This function is more efficient than `ExtendedRepresentation`.

Example

```

gap> G := GL(2,7);;
gap> chi := Irr( G )[ 29 ];;
gap> H := SL(2,7);;
gap> phi := RestrictedClassFunction( chi, H );;
gap> IsIrreducibleCharacter( phi );
true
gap> rep := IrreducibleAffordingRepresentation( phi );;
gap> ext := ExtendedRepresentationNormal( chi, rep );
#I Need to extend a representation of degree 7. This may take a while.
CompositionMapping( [(8,15,22,29,36,43)(9,16,23,30,37,44)
(10,17,24,31,38,45)(11,18,25,32,39,46)(12,19,26,33,40,47)
(13,20,27,34,41,48)(14,21,28,35,42,49),(2,29,12)(3,36,20)
(4,43,28)(5,8,30)(6,15,38)(7,22,46)(9,44,14)(10,16,17)
(11,37,27)(13,23,39)(18,24,25)(19,45,35)(21,31,47)
(26,32,33)(34,40,41)(42,48,49) ] ->
[ [ [ -1, 0, 0, 1, 0, -1, 0 ], [ -1, 0, 0, 0, 0, 0, 0 ],
  [ -1, 1, 0, 0, -1, 0, 0 ], [ 0, -1, 0, 0, 0, 0, 0 ],
  [ -1, -1, 1, 0, 1, -1, 0 ], [ 0, 0, 0, -1, 0, 0, 0 ],
  [ -1, 0, 1, -1, 1, 0, -1 ] ],
[ [ 1, -1, 0, 1, 0, -1, 1 ], [ 1, 0, -1, 1, -1, 0, 1 ],
  [ 1, -1, 0, 1, -1, 0, 1 ], [ 0, 0, -1, 0, 0, 0, 0 ],
  [ -1, 0, 0, 1, 0, -1, 0 ], [ -1, 0, 0, 0, 0, 0, 0 ],
  [ -1, 1, 0, 0, -1, 0, 0 ] ] ], (action isomorphism) )
gap> IsAffordingRepresentation( chi, ext );
true

```

2.4 Character Subgroups

If χ is an irreducible character of a group G and H is a subgroup of G such that the restriction of χ to H has a linear constituent with multiplicity one, then we call H a character subgroup relative to χ or a χ -subgroup.

2.4.1 CharacterSubgroupRepresentation

◇ CharacterSubgroupRepresentation(chi) (function)

◇ CharacterSubgroupRepresentation(chi, H) (function)

returns a representation affording *chi* by finding a *chi*-subgroup and using the method described in [Dix93]. If the second argument is a *chi*-subgroup then it returns a representation affording *chi* without searching for a *chi*-subgroup. In this case an error is signalled if no *chi*-subgroup exists.

2.4.2 IsCharacterSubgroup

◇ IsCharacterSubgroup(chi, H) (function)

is true if *H* is a *chi*-subgroup and false otherwise.

Example

```
gap> G := AlternatingGroup( 8 );;
gap> chi := Irr( G )[ 2 ];;
gap> H := AlternatingGroup( 3 );;
gap> IsCharacterSubgroup( chi, H );
true
gap> rep := CharacterSubgroupRepresentation( G, chi, H );
[ (1,2,3,4,5,6,7), (6,7,8) ] -> [ [ [
  1/3*E(3)+2/3*E(3)^2, 0, 0, -E(3), 0, -1/3*E(3)-2/3*E(3)^2, 1 ],
  [ 2/3*E(3)+4/3*E(3)^2, 0, 1, 0, 0, 1/3*E(3)-1/3*E(3)^2, 0 ],
  [ 2/3*E(3)+4/3*E(3)^2, 0, 0, 1, 0, 1/3*E(3)-1/3*E(3)^2, 0 ],
  [ E(3)^2, 0, 0, 0, 0, 0, 0 ],
  [ 2/3*E(3)+4/3*E(3)^2, 0, 0, 0, 1, 1/3*E(3)-1/3*E(3)^2, 0 ],
  [ -2/3*E(3)-1/3*E(3)^2, 0, 0, -1, 0, 2/3*E(3)+1/3*E(3)^2, E(3)^2 ],
  [ 0, 1, 0, 0, 0, 0, 0 ] ],
  [ [ 1, 0, 0, 0, 0, 0, 0 ], [ 0, 1, 0, 0, 0, 0, 0 ],
    [ 0, 0, 0, 1, 0, 0, 0 ], [ 0, 0, 0, 0, 1, 0, 0 ],
    [ 0, 0, 1, 0, 0, 0, 0 ], [ 0, 0, 0, 0, 0, 1, 0 ],
    [ 0, 0, 0, -E(3), E(3), 0, 1 ] ] ] ]
```

2.4.3 AllCharacterPSubgroups

◇ AllCharacterPSubgroups(G, chi) (function)

returns a list of all *p*-subgroups of *G* which are *chi*-subgroups. The subgroups are chosen up to conjugacy in *G*.

2.4.4 AllCharacterStandardSubgroups

◇ AllCharacterStandardSubgroups(G, chi) (function)

returns a list containing well described subgroups of *G* which are *chi*-subgroups. This list may contain Sylow subgroups and their derived subgroups, normalizers and centralizers in *G*.

2.4.5 AllCharacterSubgroups

◇ AllCharacterSubgroups(G, chi)

(function)

returns a list of all chi-subgroups of G among the lattice of subgroups. This function call can be quite expensive for larger groups. The call is expensive in particular if the lattice of subgroups of the given group is not yet known.

2.5 Equivalent Representation

2.5.1 EquivalentRepresentation

◇ EquivalentRepresentation(rep)

(function)

computes an equivalent representation to an irreducible representation rep by transforming rep to a new basis by spinning up one vector (i.e. getting the other basis vectors as images under the first one under words in the generators). If the input representation, rep, is reducible then EquivalentRepresentation does not return any mapping. In this case see section 3.

Example

```
gap> G := SymmetricGroup( 7 );;
gap> chi := Irr( G )[ 2 ];;
gap> rep := CharacterSubgroupRepresentation( G, chi );;
gap> equ := EquivalentRepresentation( rep );
[ (1,2,3,4,5,6,7), (1,2) ] ->
[ [ [ 0, 0, 0, E(5)+E(5)^2+E(5)^3+2*E(5)^4, -1, -E(5)-E(5)^2-E(5)^3-2*E(5)^4 ],
    [ E(5)^3-E(5)^4, E(5)^2+E(5)^3+E(5)^4, E(5)+E(5)^3-E(5)^4, -E(5)+E(5)^2
      -3*E(5)^3-E(5)^4, -E(5)-E(5)^3+E(5)^4, 2*E(5)-2*E(5)^2+2*E(5)^3 ]
  , [ 0, 0, 0, 1, 0, 0 ],
  [ 0, 4/5*E(5)+3/5*E(5)^2+2/5*E(5)^3+1/5*E(5)^4, E(5), 1, -E(5),
    6/5*E(5)+2/5*E(5)^2+3/5*E(5)^3+4/5*E(5)^4 ], [ 0, 1, 0, 0, 0, 0 ],
  [ 0, 0, E(5), 1, -E(5), 2*E(5)+E(5)^2+E(5)^3+E(5)^4 ] ],
[ [ -1, 0, E(5)+E(5)^2+E(5)^3+2*E(5)^4, -E(5)-E(5)^2-3*E(5)^4,
    -E(5)-E(5)^2-E(5)^3-2*E(5)^4, E(5)+E(5)^2+3*E(5)^4 ],
  [ 0, -1, 0, 0, 0, 0 ],
  [ 0, 0, 0, E(5)+E(5)^2+E(5)^3+2*E(5)^4, -1, -E(5)-E(5)^2-E(5)^3-2*E(5)^4
    ], [ 0, 0, -1, -E(5)^4, 1, E(5)+E(5)^2+E(5)^3+2*E(5)^4 ],
  [ 0, 0, -E(5)^4, -E(5)^3+E(5)^4, E(5)+E(5)^2+E(5)^3+2*E(5)^4,
    E(5)^3-E(5)^4 ], [ 0, 0, 0, 0, 0, -1 ] ] ]
gap> IsAffordingRepresentation( chi, equ );
true
```

Chapter 3

Reducible Representations

In this chapter we introduce some functions which deal with a complex reducible representation R of a finite group G .

3.1 Constituents of Representations

3.1.1 ConstituentsOfRepresentation

◇ `ConstituentsOfRepresentation(rep)` (function)

called with a representation rep of a group G . This function returns a list of irreducible representations of G which are constituents of rep , and their corresponding multiplicities. For example, if rep is a representation of G affording a character X such that $X = mY + nZ$, where Y and Z are irreducible characters of G , and m and n are the corresponding multiplicities, then `ConstituentsOfRepresentation` returns $[[m, S], [n, T]]$ where S and T are irreducible representations of G affording Y and Z , respectively. This function call can be quite expensive when G is a large group.

3.1.2 IsReducibleRepresentation

◇ `IsReducibleRepresentation(rep)` (function)

If rep is a representation of a group G then `IsReducibleRepresentation` returns true if rep is a reducible representation of G .

3.2 Block Representations

3.2.1 EquivalentBlockRepresentation

◇ `EquivalentBlockRepresentation(rep)` (function)

◇ `EquivalentBlockRepresentation(list)` (function)

If rep is a reducible representation of a group G , this function returns a block diagonal representation of G equivalent to rep . If $\text{list} = [[m1, R1], [m2, R2], \dots, [mt, Rt]]$ is a list of irreducible representations $R1, R2, \dots, Rt$ of G with multiplicities $m1, m2, \dots, mt$, then

`EquivalentBlockRepresentation` returns a block diagonal representation of G containing the blocks $R1, R2, \dots, Rt$.

Example

```
gap> G := AlternatingGroup( 5 );;
gap> H := SylowSubgroup( G, 2 );;
gap> chi := TrivialCharacter( H );;
gap> Hrep := IrreducibleAffordingRepresentation( chi );;
gap> rep := InducedSubgroupRepresentation( G, Hrep );;
gap> IsReducibleRepresentation( rep );
true
gap> con := ConstituentsOfRepresentation( rep );
[ [ 1, [ (1,2,3,4,5), (3,4,5) ] -> [ [ [ 1 ] ], [ [ 1 ] ] ] ],
  [ 1, [ (1,2,3,4,5), (3,4,5) ] ->
    [ [ [ E(3), -1/3*E(3)-2/3*E(3)^2, 0, 1/3*E(3)-1/3*E(3)^2 ],
        [ 1, -4/3*E(3)+1/3*E(3)^2, E(3), -2/3*E(3)-1/3*E(3)^2 ],
        [ 1, -E(3), E(3), 0 ],
        [ 1, -1/3*E(3)+1/3*E(3)^2, 1, 1/3*E(3)+2/3*E(3)^2 ] ],
      [ [ 1, -2/3*E(3)-1/3*E(3)^2, 0, 2/3*E(3)+1/3*E(3)^2 ],
        [ 0, -E(3), E(3), 1 ],
        [ 0, -4/3*E(3)-2/3*E(3)^2, E(3), -2/3*E(3)-1/3*E(3)^2 ],
        [ 0, 0, 1, 0 ] ] ] ],
  [ 2, [ (1,2,3,4,5), (3,4,5) ] ->
    [ [ [ -1, 1, 1, 1, -1 ],
        [ 0, 0, 0, 0, 1 ],
        [ -1, 0, 0, 1, -1 ],
        [ 0, 0, 1, 0, 0 ],
        [ 0, -1, 0, -1, 1 ] ],
      [ [ 0, 0, 0, 0, 1 ],
        [ 0, -1, -1, -1, 0 ],
        [ 0, 1, 0, 0, 0 ],
        [ 0, 0, 0, 1, 0 ],
        [ -1, 0, 0, 1, -1 ] ] ] ] ]
gap> EquivalentBlockRepresentation( con );
[ (1,2,3,4,5), (3,4,5) ] ->
[ [ [ 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0 ],
    [ 0, E(3), -1/3*E(3)-2/3*E(3)^2, 0, 1/3*E(3)-1/3*E(3)^2, 0,
      0, 0, 0, 0, 0, 0, 0, 0, 0 ],
    [ 0, 1, -4/3*E(3)+1/3*E(3)^2, E(3), -2/3*E(3)-1/3*E(3)^2, 0,
      0, 0, 0, 0, 0, 0, 0, 0, 0 ],
    [ 0, 1, -E(3), E(3), 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0 ],
    [ 0, 1, -1/3*E(3)+1/3*E(3)^2, 1, 1/3*E(3)+2/3*E(3)^2, 0, 0,
      0, 0, 0, 0, 0, 0, 0, 0 ],
    [ 0, 0, 0, 0, 0, -1, 1, 1, 1, -1, 0, 0, 0, 0, 0 ],
    [ 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0 ],
    [ 0, 0, 0, 0, 0, -1, 0, 0, 1, -1, 0, 0, 0, 0, 0 ],
    [ 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0 ],
    [ 0, 0, 0, 0, 0, 0, -1, 0, -1, 1, 0, 0, 0, 0, 0 ],
    [ 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 1, 1, 1, -1 ],
    [ 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1 ],
    [ 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 1, -1 ],
    [ 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0 ],
    [ 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, -1, 1 ] ],
  [ [ 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0 ],
```

```

[ 0, 1, -2/3*E(3)-1/3*E(3)^2, 0, 2/3*E(3)+1/3*E(3)^2, 0, 0,
  0, 0, 0, 0, 0, 0, 0, 0 ],
[ 0, 0, -E(3), E(3), 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0 ],
[ 0, 0, -4/3*E(3)-2/3*E(3)^2, E(3), -2/3*E(3)-1/3*E(3)^2, 0,
  0, 0, 0, 0, 0, 0, 0, 0 ],
[ 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0 ],
[ 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0 ],
[ 0, 0, 0, 0, 0, 0, -1, -1, -1, 0, 0, 0, 0, 0, 0 ],
[ 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0 ],
[ 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0 ],
[ 0, 0, 0, 0, 0, -1, 0, 0, 1, -1, 0, 0, 0, 0, 0 ],
[ 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1 ],
[ 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, -1, -1, 0 ],
[ 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0 ],
[ 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0 ],
[ 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 1, -1 ] ] ]

```

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