

## WINGED-EDGE DATA STRUCTURE

Hanan Samet

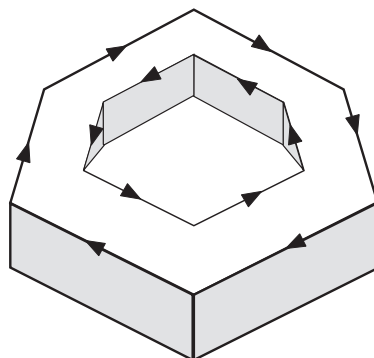
Computer Science Department and  
Center for Automation Research and  
Institute for Advanced Computer Studies  
University of Maryland  
College Park, Maryland 20742  
e-mail: [hjs@umiacs.umd.edu](mailto:hjs@umiacs.umd.edu)

Copyright © 1997 Hanan Samet

These notes may not be reproduced by any means (mechanical or electronic or any other) without the express written permission of Hanan Samet

## EXAMPLE GEOMETRIC DATABASE

- Boundary model (BRep)
- Assume a solid object bounded by compact orientable two-manifold surfaces (i.e., only two faces meet at an edge)
- Primitive topological entities
  1. vertices
  2. edges
  3. faces
- Nonprimitive topological entities for multiply-connected objects (e.g., holes, internal cavities)
  1. shell—a maximally connected set of faces
    - Ex: cube within a cube has two shells (internal and external)
  2. loop on a face—closed chain of edges bounding the face
    - Ex: nut with 2 loops for each of top and bottom faces



## DESCRIPTION OF THE BOUNDARY OF AN OBJECT

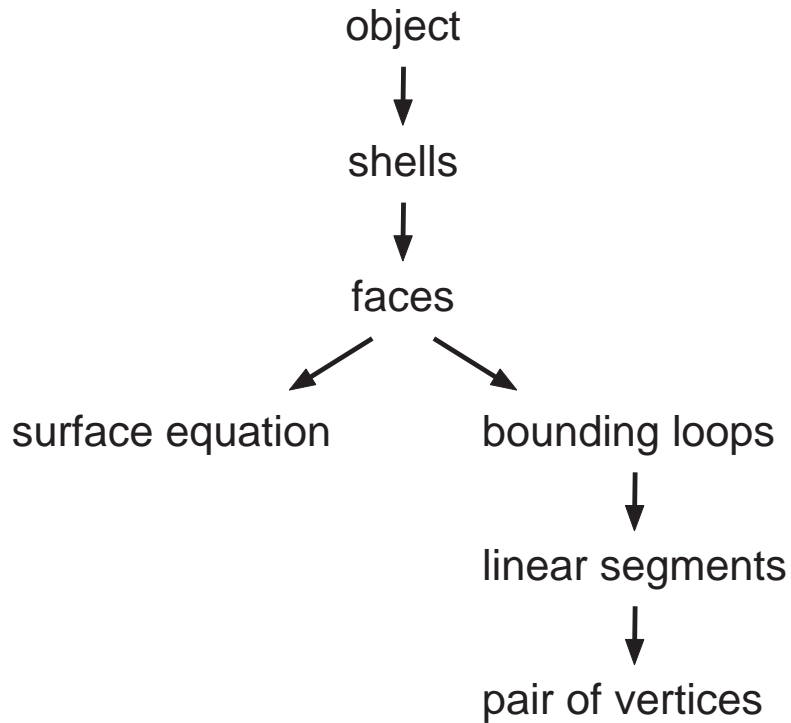
### 1. Topological description

- adjacency relationships between pairs of individual topological entities (e.g., edge-face, loop-face,...)
- maximum of 25 adjacency relationships (ordered pairs)

### 2. Geometric description

- shape and location in space of each of the primitive topological entities
  - a. face: surface equation
  - b. edge: endpoints, spline curve, etc.
  - c. vertex: Cartesian coordinates
  - d. shell and loop: none since a collection of primitive topological entities

## HIERARCHICAL REPRESENTATION



1. Decompose object into shells
2. Each shell is a collection of faces
3. Each face
  - surface equation, AND
  - collection of its bounding loops
4. Each loop is a chain of edges
5. Each edge is a collection of linear segments
6. Each linear segment is a pair of vertices

## SPECIFYING A BOUNDARY MODEL

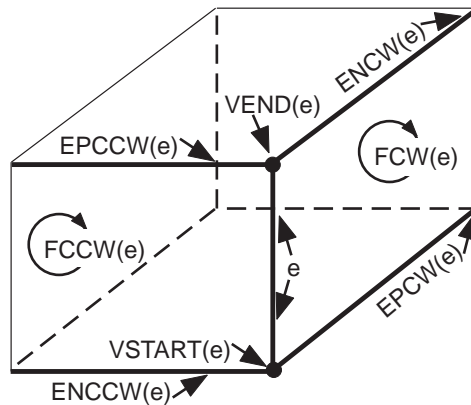
1. Set of topological entities defining the object's boundary
2. Subset of 25 different adjacency relationships between pairs of individual entities
  - relations are ordered
  - edge-face is different from face-edge
    - a. edge-face associates with each edge the two adjacent faces
    - b. face-edge associates with each face the edges that bound it

## EXAMPLE BOUNDARY REPRESENTATIONS

1. Symmetric structure uses face-edge, vertex-edge, edge-face, and edge-vertex relationships
2. Face adjacency graph uses face-edge, vertex-face, edge-face, and face-vertex relationships
3. If multiple shells and multiply-connected faces
  - edge-face = edge-loop and loop-face relationships
  - face-edge = face-loop and loop-edge relationships
4. Edge-based
  - drawback of face-edge and vertex-face is that they violate the first normal form (1NF) since a variable amount of information is associated with the second attribute (i.e., edge and face, respectively)
  - no such problem with edge-face and edge-vertex relationships since assume 2-manifold surface (e.g., only two faces may meet at a vertex)
  - basis of winged-edge representation

## WINGED-EDGE REPRESENTATION

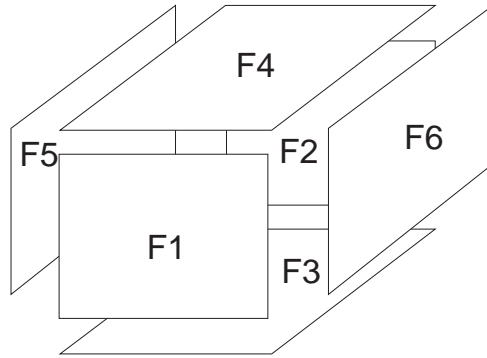
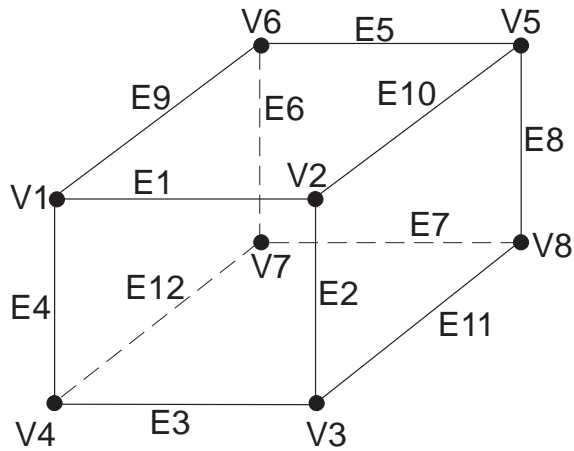
- Physical interpretation of attributes of relations



- Vertex relation:
  - vertex (primary key)
  - 4.  $x, y, z$  coordinate values (key)
  5. identity of an edge which starts at the vertex (ESTART)
    - enables extracting set of edges incident at a vertex in time proportional to the number of edges
- Face relation:
  - face (primary key)
  - identity of an edge which is part of the face (ESTART)
    - enables extracting set of edges comprising a face in time proportional to the number of edges

- Edge relation:
  1. edge (primary key)
  - 2–3. start (VSTART) and end (VEND) vertices (key)
  - 4–5. two adjacent faces (FCW and FCCW) (key)
  - 6–7. preceding and next edges in one face (EPCW and ENCW) (key)
  - 8–9. preceding and next edges in other face (EPCCW and ENCCW) (key)
- Question: are the relations in 2NF, 3NF, or BCNF?

# EXAMPLE OBJECT AND ITS REPRESENTATION



Vertex Table

VERTEX	X	Y	Z	ESTART
V <sub>1</sub>	X <sub>1</sub>	Y <sub>1</sub>	Z <sub>1</sub>	E <sub>1</sub>
V <sub>2</sub>	X <sub>2</sub>	Y <sub>2</sub>	Z <sub>2</sub>	E <sub>2</sub>
V <sub>3</sub>	X <sub>3</sub>	Y <sub>3</sub>	Z <sub>3</sub>	E <sub>3</sub>
V <sub>4</sub>	X <sub>4</sub>	Y <sub>4</sub>	Z <sub>4</sub>	E <sub>4</sub>
V <sub>5</sub>	X <sub>5</sub>	Y <sub>5</sub>	Z <sub>5</sub>	E <sub>5</sub>
V <sub>6</sub>	X <sub>6</sub>	Y <sub>6</sub>	Z <sub>6</sub>	E <sub>6</sub>
V <sub>7</sub>	X <sub>7</sub>	Y <sub>7</sub>	Z <sub>7</sub>	E <sub>7</sub>
V <sub>8</sub>	X <sub>8</sub>	Y <sub>8</sub>	Z <sub>8</sub>	E <sub>8</sub>

Face Table

FACE	ESTART
F <sub>1</sub>	E <sub>1</sub>
F <sub>2</sub>	E <sub>5</sub>
F <sub>3</sub>	E <sub>11</sub>
F <sub>4</sub>	E <sub>9</sub>
F <sub>5</sub>	E <sub>4</sub>
F <sub>6</sub>	E <sub>8</sub>

Edge Table

EDGE	VSTART	VEND	EPCW	ENCW	EPCCW	ENCCW	FCW	FCCW
E <sub>1</sub>	V <sub>1</sub>	V <sub>2</sub>	E <sub>4</sub>	E <sub>2</sub>	E <sub>10</sub>	E <sub>9</sub>	F <sub>1</sub>	F <sub>4</sub>
E <sub>2</sub>	V <sub>2</sub>	V <sub>3</sub>	E <sub>1</sub>	E <sub>3</sub>	E <sub>11</sub>	E <sub>10</sub>	F <sub>1</sub>	F <sub>6</sub>
E <sub>3</sub>	V <sub>3</sub>	V <sub>4</sub>	E <sub>2</sub>	E <sub>4</sub>	E <sub>12</sub>	E <sub>11</sub>	F <sub>1</sub>	F <sub>3</sub>
E <sub>4</sub>	V <sub>4</sub>	V <sub>1</sub>	E <sub>3</sub>	E <sub>1</sub>	E <sub>9</sub>	E <sub>12</sub>	F <sub>1</sub>	F <sub>5</sub>
E <sub>5</sub>	V <sub>5</sub>	V <sub>6</sub>	E <sub>8</sub>	E <sub>6</sub>	E <sub>9</sub>	E <sub>10</sub>	F <sub>2</sub>	F <sub>4</sub>
E <sub>6</sub>	V <sub>6</sub>	V <sub>7</sub>	E <sub>5</sub>	E <sub>7</sub>	E <sub>12</sub>	E <sub>9</sub>	F <sub>2</sub>	F <sub>5</sub>
E <sub>7</sub>	V <sub>7</sub>	V <sub>8</sub>	E <sub>6</sub>	E <sub>8</sub>	E <sub>11</sub>	E <sub>12</sub>	F <sub>2</sub>	F <sub>3</sub>
E <sub>8</sub>	V <sub>8</sub>	V <sub>5</sub>	E <sub>7</sub>	E <sub>5</sub>	E <sub>10</sub>	E <sub>11</sub>	F <sub>2</sub>	F <sub>6</sub>
E <sub>9</sub>	V <sub>1</sub>	V <sub>6</sub>	E <sub>1</sub>	E <sub>5</sub>	E <sub>6</sub>	E <sub>4</sub>	F <sub>4</sub>	F <sub>5</sub>
E <sub>10</sub>	V <sub>5</sub>	V <sub>2</sub>	E <sub>5</sub>	E <sub>1</sub>	E <sub>2</sub>	E <sub>8</sub>	F <sub>4</sub>	F <sub>6</sub>
E <sub>11</sub>	V <sub>3</sub>	V <sub>8</sub>	E <sub>3</sub>	E <sub>7</sub>	E <sub>8</sub>	E <sub>2</sub>	F <sub>3</sub>	F <sub>6</sub>
E <sub>12</sub>	V <sub>7</sub>	V <sub>4</sub>	E <sub>7</sub>	E <sub>3</sub>	E <sub>4</sub>	E <sub>6</sub>	F <sub>3</sub>	F <sub>5</sub>

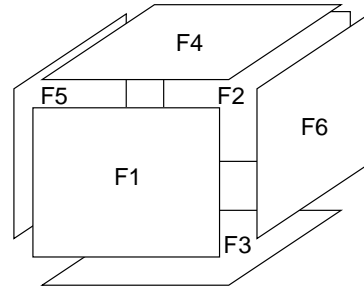
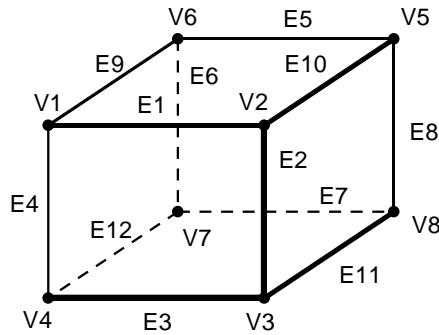
## REMOVING REDUNDANT INFORMATION IN THE RELATIONS

- Minimum information in the relations:
  1. vertex relation: vertex, x, y, z
  2. face relation: face, ESTART
  3. edge relation: edge, VSTART, VEND, FCW, FCCW
- Without FCW and FCCW we cannot get to the faces from the edges and hence we cannot determine the edges that are adjacent to a face
- EPCW and ENCW or EPCCW and ENCCW are inadequate by themselves to identify the edges that are adjacent to a face
- Face relation is not absolutely necessary
- Face relation (ESTART) is only useful to avoid having to perform an  $O(\text{number of edges})$  search on the FCW or FCCW fields to determine an edge given a face
- The ESTART field should also be included in the vertex relation

### CW EDGES IN A FACE

1. look up face F in face table and find an edge E
2. find E in edge table; repeat until read E again
  - if  $F=FCW(E)$  then next edge is  $ENCW(E)$
  - else  $F=FCCW(E)$  and next edge is  $ENCCW(E)$
- Ex: get edges in face  $F_3$  in clockwise order

FACE	ESTART
F <sub>1</sub>	E <sub>1</sub>
F <sub>2</sub>	E <sub>5</sub>
F <sub>3</sub>	E <sub>7</sub>
F <sub>4</sub>	E <sub>9</sub>
F <sub>5</sub>	E <sub>4</sub>
F <sub>6</sub>	E <sub>8</sub>



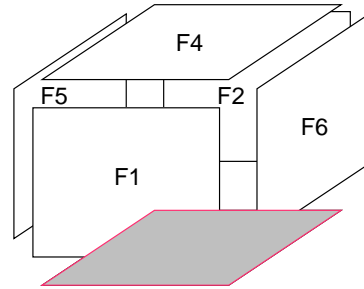
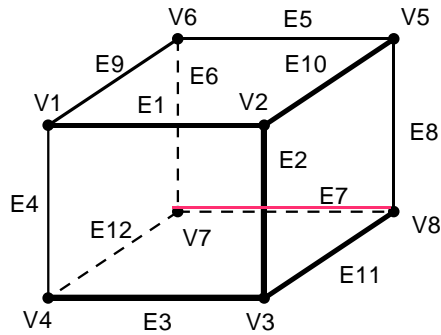
EDGE	VSTART	VEND	EPCW	ENCW	EPCCW	ENCCW	FCW	FCCW
E <sub>1</sub>	V <sub>1</sub>	V <sub>2</sub>	E <sub>4</sub>	E <sub>2</sub>	E <sub>10</sub>	E <sub>9</sub>	F <sub>1</sub>	F <sub>4</sub>
E <sub>2</sub>	V <sub>2</sub>	V <sub>3</sub>	E <sub>1</sub>	E <sub>3</sub>	E <sub>11</sub>	E <sub>10</sub>	F <sub>1</sub>	F <sub>6</sub>
E <sub>3</sub>	V <sub>3</sub>	V <sub>4</sub>	E <sub>2</sub>	E <sub>4</sub>	E <sub>12</sub>	E <sub>11</sub>	F <sub>1</sub>	F <sub>3</sub>
E <sub>4</sub>	V <sub>4</sub>	V <sub>1</sub>	E <sub>3</sub>	E <sub>1</sub>	E <sub>9</sub>	E <sub>12</sub>	F <sub>1</sub>	F <sub>5</sub>
E <sub>5</sub>	V <sub>5</sub>	V <sub>6</sub>	E <sub>8</sub>	E <sub>6</sub>	E <sub>9</sub>	E <sub>10</sub>	F <sub>2</sub>	F <sub>4</sub>
E <sub>6</sub>	V <sub>6</sub>	V <sub>7</sub>	E <sub>5</sub>	E <sub>7</sub>	E <sub>12</sub>	E <sub>9</sub>	F <sub>2</sub>	F <sub>5</sub>
E <sub>7</sub>	V <sub>7</sub>	V <sub>8</sub>	E <sub>6</sub>	E <sub>8</sub>	E <sub>11</sub>	E <sub>12</sub>	F <sub>2</sub>	F <sub>3</sub>
E <sub>8</sub>	V <sub>8</sub>	V <sub>5</sub>	E <sub>7</sub>	E <sub>5</sub>	E <sub>10</sub>	E <sub>11</sub>	F <sub>2</sub>	F <sub>6</sub>
E <sub>9</sub>	V <sub>1</sub>	V <sub>6</sub>	E <sub>1</sub>	E <sub>5</sub>	E <sub>6</sub>	E <sub>4</sub>	F <sub>4</sub>	F <sub>5</sub>
E <sub>10</sub>	V <sub>5</sub>	V <sub>2</sub>	E <sub>5</sub>	E <sub>1</sub>	E <sub>2</sub>	E <sub>8</sub>	F <sub>4</sub>	F <sub>6</sub>
E <sub>11</sub>	V <sub>3</sub>	V <sub>8</sub>	E <sub>3</sub>	E <sub>7</sub>	E <sub>8</sub>	E <sub>2</sub>	F <sub>3</sub>	F <sub>6</sub>
E <sub>12</sub>	V <sub>7</sub>	V <sub>4</sub>	E <sub>7</sub>	E <sub>3</sub>	E <sub>4</sub>	E <sub>6</sub>	F <sub>3</sub>	F <sub>5</sub>



## CW EDGES IN A FACE

- look up face  $F$  in face table and find an edge  $E$
  - find  $E$  in edge table; repeat until read  $E$  again
    - if  $F=FCW(E)$  then next edge is  $ENCW(E)$
    - else  $F=FCCW(E)$  and next edge is  $ENCCW(E)$
- Ex: get edges in face  $F_3$  in clockwise order

FACE	ESTART
$F_1$	$E_1$
$F_2$	$E_5$
$F_3$	$E_7$
$F_4$	$E_9$
$F_5$	$E_4$
$F_6$	$E_8$



EDGE	VSTART	VEND	EPCW	ENCW	EPCCW	ENCCW	FCW	FCCW
$E_1$	$V_1$	$V_2$	$E_4$	$E_2$	$E_{10}$	$E_9$	$F_1$	$F_4$
$E_2$	$V_2$	$V_3$	$E_1$	$E_3$	$E_{11}$	$E_{10}$	$F_1$	$F_6$
$E_3$	$V_3$	$V_4$	$E_2$	$E_4$	$E_{12}$	$E_{11}$	$F_1$	$F_3$
$E_4$	$V_4$	$V_1$	$E_3$	$E_1$	$E_9$	$E_{12}$	$F_1$	$F_5$
$E_5$	$V_5$	$V_6$	$E_8$	$E_6$	$E_9$	$E_{10}$	$F_2$	$F_4$
$E_6$	$V_6$	$V_7$	$E_5$	$E_7$	$E_{12}$	$E_9$	$F_2$	$F_5$
$E_7$	$V_7$	$V_8$	$E_6$	$E_8$	$E_{11}$	$E_{12}$	$F_2$	$F_3$
$E_8$	$V_8$	$V_5$	$E_7$	$E_5$	$E_{10}$	$E_{11}$	$F_2$	$F_6$
$E_9$	$V_1$	$V_6$	$E_1$	$E_5$	$E_6$	$E_4$	$F_4$	$F_5$
$E_{10}$	$V_5$	$V_2$	$E_5$	$E_1$	$E_2$	$E_8$	$F_4$	$F_6$
$E_{11}$	$V_3$	$V_8$	$E_3$	$E_7$	$E_8$	$E_2$	$F_3$	$F_6$
$E_{12}$	$V_7$	$V_4$	$E_7$	$E_3$	$E_4$	$E_6$	$F_3$	$F_5$

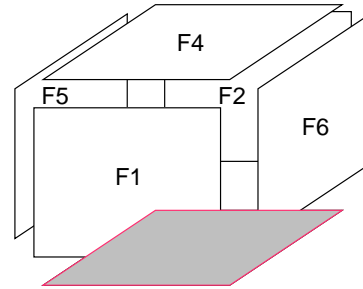
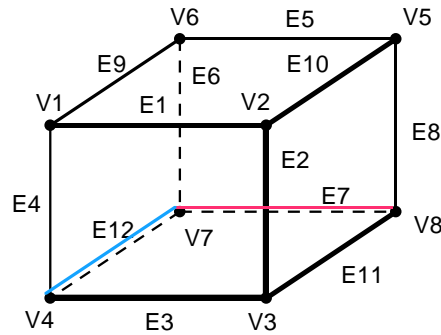
- look up face  $F_3$  in face table and find edge  $E_7$



## CW EDGES IN A FACE

- look up face  $F$  in face table and find an edge  $E$
  - find  $E$  in edge table; repeat until read  $E$  again
    - if  $F=FCW(E)$  then next edge is  $ENCW(E)$
    - else  $F=FCCW(E)$  and next edge is  $ENCCW(E)$
- Ex: get edges in face  $F_3$  in clockwise order

FACE	ESTART
$F_1$	$E_1$
$F_2$	$E_5$
$F_3$	$E_7$
$F_4$	$E_9$
$F_5$	$E_4$
$F_6$	$E_8$



EDGE	VSTART	VEND	EPCW	ENCW	EPCCW	ENCCW	FCW	FCCW
$E_1$	$V_1$	$V_2$	$E_4$	$E_2$	$E_{10}$	$E_9$	$F_1$	$F_4$
$E_2$	$V_2$	$V_3$	$E_1$	$E_3$	$E_{11}$	$E_{10}$	$F_1$	$F_6$
$E_3$	$V_3$	$V_4$	$E_2$	$E_4$	$E_{12}$	$E_{11}$	$F_1$	$F_3$
$E_4$	$V_4$	$V_1$	$E_3$	$E_1$	$E_9$	$E_{12}$	$F_1$	$F_5$
$E_5$	$V_5$	$V_6$	$E_8$	$E_6$	$E_9$	$E_{10}$	$F_2$	$F_4$
$E_6$	$V_6$	$V_7$	$E_5$	$E_7$	$E_{12}$	$E_9$	$F_2$	$F_5$
$E_7$	$V_7$	$V_8$	$E_6$	$E_8$	$E_{11}$	$E_{12}$	$F_2$	$F_3$
$E_8$	$V_8$	$V_5$	$E_7$	$E_5$	$E_{10}$	$E_{11}$	$F_2$	$F_6$
$E_9$	$V_1$	$V_6$	$E_1$	$E_5$	$E_6$	$E_4$	$F_4$	$F_5$
$E_{10}$	$V_5$	$V_2$	$E_5$	$E_1$	$E_2$	$E_8$	$F_4$	$F_6$
$E_{11}$	$V_3$	$V_8$	$E_3$	$E_7$	$E_8$	$E_2$	$F_3$	$F_6$
$E_{12}$	$V_7$	$V_4$	$E_7$	$E_3$	$E_4$	$E_6$	$F_3$	$F_5$

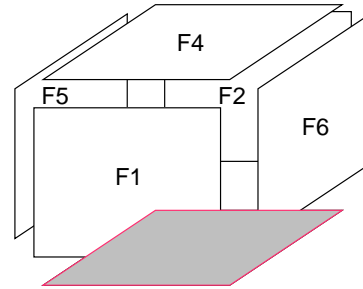
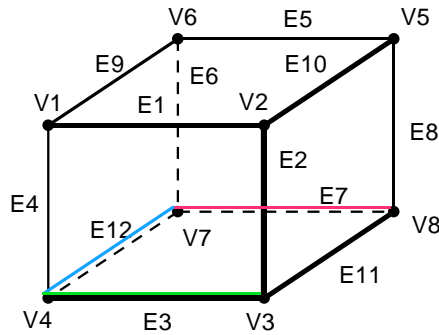
- look up face  $F_3$  in face table and find edge  $E_7$
- look up edge  $E_7$  in edge table and since  $F_3=FCCW(E_7)$ , next edge is  $ENCCW(E_7)=E_{12}$



## CW EDGES IN A FACE

1. look up face  $F$  in face table and find an edge  $E$
2. find  $E$  in edge table; repeat until read  $E$  again
  - if  $F=FCW(E)$  then next edge is  $ENCW(E)$
  - else  $F=FCCW(E)$  and next edge is  $ENCCW(E)$
- Ex: get edges in face  $F_3$  in clockwise order

FACE	ESTART
$F_1$	$E_1$
$F_2$	$E_5$
$F_3$	$E_7$
$F_4$	$E_9$
$F_5$	$E_4$
$F_6$	$E_8$



EDGE	VSTART	VEND	EPCW	ENCW	EPCCW	ENCCW	FCW	FCCW
$E_1$	$V_1$	$V_2$	$E_4$	$E_2$	$E_{10}$	$E_9$	$F_1$	$F_4$
$E_2$	$V_2$	$V_3$	$E_1$	$E_3$	$E_{11}$	$E_{10}$	$F_1$	$F_6$
$E_3$	$V_3$	$V_4$	$E_2$	$E_4$	$E_{12}$	$E_{11}$	$F_1$	$F_3$
$E_4$	$V_4$	$V_1$	$E_3$	$E_1$	$E_9$	$E_{12}$	$F_1$	$F_5$
$E_5$	$V_5$	$V_6$	$E_8$	$E_6$	$E_9$	$E_{10}$	$F_2$	$F_4$
$E_6$	$V_6$	$V_7$	$E_5$	$E_7$	$E_{12}$	$E_9$	$F_2$	$F_5$
$E_7$	$V_7$	$V_8$	$E_6$	$E_8$	$E_{11}$	$E_{12}$	$F_2$	$F_3$
$E_8$	$V_8$	$V_5$	$E_7$	$E_5$	$E_{10}$	$E_{11}$	$F_2$	$F_6$
$E_9$	$V_1$	$V_6$	$E_1$	$E_5$	$E_6$	$E_4$	$F_4$	$F_5$
$E_{10}$	$V_5$	$V_2$	$E_5$	$E_1$	$E_2$	$E_8$	$F_4$	$F_6$
$E_{11}$	$V_3$	$V_8$	$E_3$	$E_7$	$E_8$	$E_2$	$F_3$	$F_6$
$E_{12}$	$V_7$	$V_4$	$E_7$	$E_3$	$E_4$	$E_6$	$F_3$	$F_5$

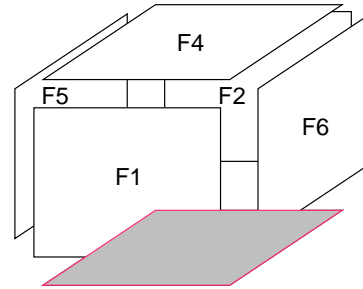
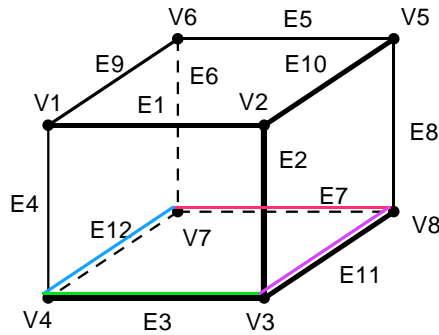
1. look up face  $F_3$  in face table and find edge  $E_7$
2. look up edge  $E_7$  in edge table and since  $F_3=FCCW(E_7)$ , next edge is  $ENCCW(E_7)=E_{12}$
3. look up edge  $E_{12}$  in edge table and since  $F_3=FCW(E_{12})$ , next edge is  $ENCW(E_{12})=E_3$



## CW EDGES IN A FACE

- look up face  $F$  in face table and find an edge  $E$
- find  $E$  in edge table; repeat until read  $E$  again
  - if  $F=FCW(E)$  then next edge is  $ENCW(E)$
  - else  $F=FCCW(E)$  and next edge is  $ENCCW(E)$
- Ex: get edges in face  $F_3$  in clockwise order

FACE	ESTART
$F_1$	$E_1$
$F_2$	$E_5$
$F_3$	$E_7$
$F_4$	$E_9$
$F_5$	$E_4$
$F_6$	$E_8$



EDGE	VSTART	VEND	EPCW	ENCW	EPCCW	ENCCW	FCW	FCCW
$E_1$	$V_1$	$V_2$	$E_4$	$E_2$	$E_{10}$	$E_9$	$F_1$	$F_4$
$E_2$	$V_2$	$V_3$	$E_1$	$E_3$	$E_{11}$	$E_{10}$	$F_1$	$F_6$
$E_3$	$V_3$	$V_4$	$E_2$	$E_4$	$E_{12}$	$E_{11}$	$F_1$	$F_3$
$E_4$	$V_4$	$V_1$	$E_3$	$E_1$	$E_9$	$E_{12}$	$F_1$	$F_5$
$E_5$	$V_5$	$V_6$	$E_8$	$E_6$	$E_9$	$E_{10}$	$F_2$	$F_4$
$E_6$	$V_6$	$V_7$	$E_5$	$E_7$	$E_{12}$	$E_9$	$F_2$	$F_5$
$E_7$	$V_7$	$V_8$	$E_6$	$E_8$	$E_{11}$	$E_{12}$	$F_2$	$F_3$
$E_8$	$V_8$	$V_5$	$E_7$	$E_5$	$E_{10}$	$E_{11}$	$F_2$	$F_6$
$E_9$	$V_1$	$V_6$	$E_1$	$E_5$	$E_6$	$E_4$	$F_4$	$F_5$
$E_{10}$	$V_5$	$V_2$	$E_5$	$E_1$	$E_2$	$E_8$	$F_4$	$F_6$
$E_{11}$	$V_3$	$V_8$	$E_3$	$E_7$	$E_8$	$E_2$	$F_3$	$F_6$
$E_{12}$	$V_7$	$V_4$	$E_7$	$E_3$	$E_4$	$E_6$	$F_3$	$F_5$

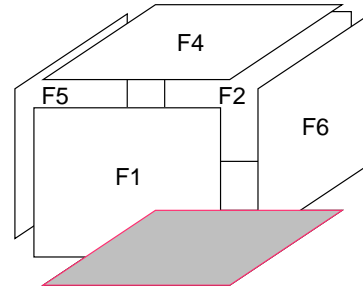
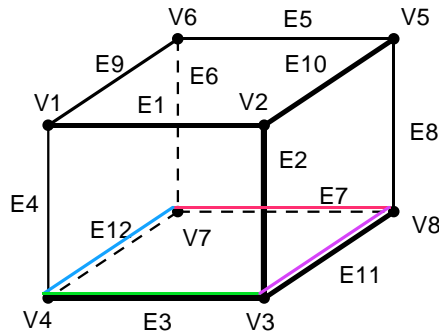
- look up face  $F_3$  in face table and find edge  $E_7$
- look up edge  $E_7$  in edge table and since  $F_3=FCCW(E_7)$ , next edge is  $ENCCW(E_7)=E_{12}$
- look up edge  $E_{12}$  in edge table and since  $F_3=FCW(E_{12})$ , next edge is  $ENCW(E_{12})=E_3$
- look up edge  $E_3$  in edge table and since  $F_3=FCCW(E_3)$ , next edge is  $ENCCW(E_3)=E_{11}$



## CW EDGES IN A FACE

- look up face  $F$  in face table and find an edge  $E$
- find  $E$  in edge table; repeat until read  $E$  again
  - if  $F=FCW(E)$  then next edge is  $ENCW(E)$
  - else  $F=FCCW(E)$  and next edge is  $ENCCW(E)$
- Ex: get edges in face  $F_3$  in clockwise order

FACE	ESTART
$F_1$	$E_1$
$F_2$	$E_5$
$F_3$	$E_7$
$F_4$	$E_9$
$F_5$	$E_4$
$F_6$	$E_8$



EDGE	VSTART	VEND	EPCW	ENCW	EPCCW	ENCCW	FCW	FCCW
$E_1$	$V_1$	$V_2$	$E_4$	$E_2$	$E_{10}$	$E_9$	$F_1$	$F_4$
$E_2$	$V_2$	$V_3$	$E_1$	$E_3$	$E_{11}$	$E_{10}$	$F_1$	$F_6$
$E_3$	$V_3$	$V_4$	$E_2$	$E_4$	$E_{12}$	$E_{11}$	$F_1$	$F_3$
$E_4$	$V_4$	$V_1$	$E_3$	$E_1$	$E_9$	$E_{12}$	$F_1$	$F_5$
$E_5$	$V_5$	$V_6$	$E_8$	$E_6$	$E_9$	$E_{10}$	$F_2$	$F_4$
$E_6$	$V_6$	$V_7$	$E_5$	$E_7$	$E_{12}$	$E_9$	$F_2$	$F_5$
$E_7$	$V_7$	$V_8$	$E_6$	$E_8$	$E_{11}$	$E_{12}$	$F_2$	$F_3$
$E_8$	$V_8$	$V_5$	$E_7$	$E_5$	$E_{10}$	$E_{11}$	$F_2$	$F_6$
$E_9$	$V_1$	$V_6$	$E_1$	$E_5$	$E_6$	$E_4$	$F_4$	$F_5$
$E_{10}$	$V_5$	$V_2$	$E_5$	$E_1$	$E_2$	$E_8$	$F_4$	$F_6$
$E_{11}$	$V_3$	$V_8$	$E_3$	$E_7$	$E_8$	$E_2$	$F_3$	$F_6$
$E_{12}$	$V_7$	$V_4$	$E_7$	$E_3$	$E_4$	$E_6$	$F_3$	$F_5$

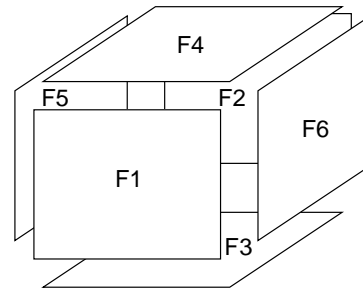
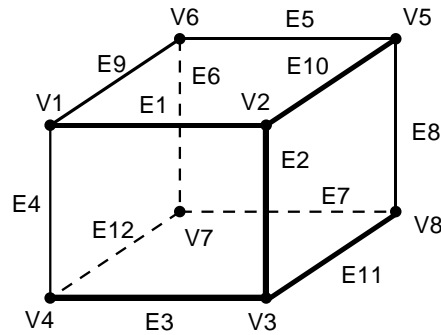
- look up face  $F_3$  in face table and find edge  $E_7$
- look up edge  $E_7$  in edge table and since  $F_3=FCCW(E_7)$ , next edge is  $ENCCW(E_7)=E_{12}$
- look up edge  $E_{12}$  in edge table and since  $F_3=FCW(E_{12})$ , next edge is  $ENCW(E_{12})=E_3$
- look up edge  $E_3$  in edge table and since  $F_3=FCCW(E_3)$ , next edge is  $ENCCW(E_3)=E_{11}$
- look up edge  $E_{11}$  in edge table and since  $F_3=FCW(E_{11})$ , next edge is  $ENCW(E_{11})=E_7$ ; now, we are done!



## CCW EDGES IN A FACE

1. look up face  $F$  in face table and find an edge  $E$
2. find  $E$  in edge table; repeat until read  $E$  again
  - if  $F=FCW(E)$  then next edge is  $EPCW(E)$
  - else  $F=FCCW(E)$  and next edge is  $EPCCW(E)$
- Ex: get edges in face  $F_3$  in counterclockwise order

FACE	ESTART
$F_1$	$E_1$
$F_2$	$E_5$
$F_3$	$E_7$
$F_4$	$E_9$
$F_5$	$E_4$
$F_6$	$E_8$



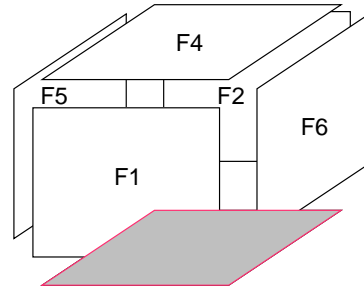
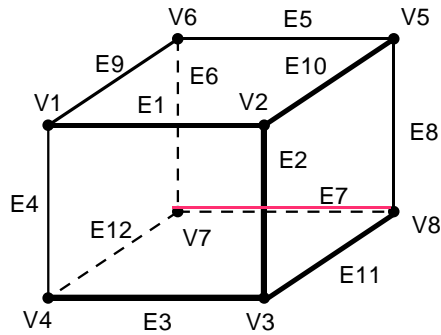
EDGE	VSTART	VEND	EPCW	ENCW	EPCCW	ENCCW	FCW	FCCW
$E_1$	$V_1$	$V_2$	$E_4$	$E_2$	$E_{10}$	$E_9$	$F_1$	$F_4$
$E_2$	$V_2$	$V_3$	$E_1$	$E_3$	$E_{11}$	$E_{10}$	$F_1$	$F_6$
$E_3$	$V_3$	$V_4$	$E_2$	$E_4$	$E_{12}$	$E_{11}$	$F_1$	$F_3$
$E_4$	$V_4$	$V_1$	$E_3$	$E_1$	$E_9$	$E_{12}$	$F_1$	$F_5$
$E_5$	$V_5$	$V_6$	$E_8$	$E_6$	$E_9$	$E_{10}$	$F_2$	$F_4$
$E_6$	$V_6$	$V_7$	$E_5$	$E_7$	$E_{12}$	$E_9$	$F_2$	$F_5$
$E_7$	$V_7$	$V_8$	$E_6$	$E_8$	$E_{11}$	$E_{12}$	$F_2$	$F_3$
$E_8$	$V_8$	$V_5$	$E_7$	$E_5$	$E_{10}$	$E_{11}$	$F_2$	$F_6$
$E_9$	$V_1$	$V_6$	$E_1$	$E_5$	$E_6$	$E_4$	$F_4$	$F_5$
$E_{10}$	$V_5$	$V_2$	$E_5$	$E_1$	$E_2$	$E_8$	$F_4$	$F_6$
$E_{11}$	$V_3$	$V_8$	$E_3$	$E_7$	$E_8$	$E_2$	$F_3$	$F_6$
$E_{12}$	$V_7$	$V_4$	$E_7$	$E_3$	$E_4$	$E_6$	$F_3$	$F_5$



## CCW EDGES IN A FACE

- look up face  $F$  in face table and find an edge  $E$
  - find  $E$  in edge table; repeat until read  $E$  again
    - if  $F=FCW(E)$  then next edge is  $EPCW(E)$
    - else  $F=FCCW(E)$  and next edge is  $EPCCW(E)$
- Ex: get edges in face  $F_3$  in counterclockwise order

FACE	ESTART
$F_1$	$E_1$
$F_2$	$E_5$
$F_3$	$E_7$
$F_4$	$E_9$
$F_5$	$E_4$
$F_6$	$E_8$



EDGE	VSTART	VEND	EPCW	ENCW	EPCCW	ENCCW	FCW	FCCW
$E_1$	$V_1$	$V_2$	$E_4$	$E_2$	$E_{10}$	$E_9$	$F_1$	$F_4$
$E_2$	$V_2$	$V_3$	$E_1$	$E_3$	$E_{11}$	$E_{10}$	$F_1$	$F_6$
$E_3$	$V_3$	$V_4$	$E_2$	$E_4$	$E_{12}$	$E_{11}$	$F_1$	$F_3$
$E_4$	$V_4$	$V_1$	$E_3$	$E_1$	$E_9$	$E_{12}$	$F_1$	$F_5$
$E_5$	$V_5$	$V_6$	$E_8$	$E_6$	$E_9$	$E_{10}$	$F_2$	$F_4$
$E_6$	$V_6$	$V_7$	$E_5$	$E_7$	$E_{12}$	$E_9$	$F_2$	$F_5$
$E_7$	$V_7$	$V_8$	$E_6$	$E_8$	$E_{11}$	$E_{12}$	$F_2$	$F_3$
$E_8$	$V_8$	$V_5$	$E_7$	$E_5$	$E_{10}$	$E_{11}$	$F_2$	$F_6$
$E_9$	$V_1$	$V_6$	$E_1$	$E_5$	$E_6$	$E_4$	$F_4$	$F_5$
$E_{10}$	$V_5$	$V_2$	$E_5$	$E_1$	$E_2$	$E_8$	$F_4$	$F_6$
$E_{11}$	$V_3$	$V_8$	$E_3$	$E_7$	$E_8$	$E_2$	$F_3$	$F_6$
$E_{12}$	$V_7$	$V_4$	$E_7$	$E_3$	$E_4$	$E_6$	$F_3$	$F_5$

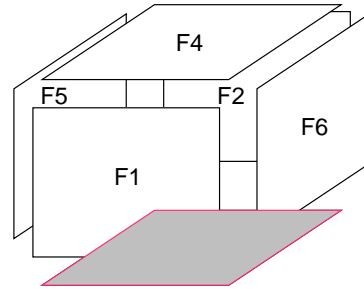
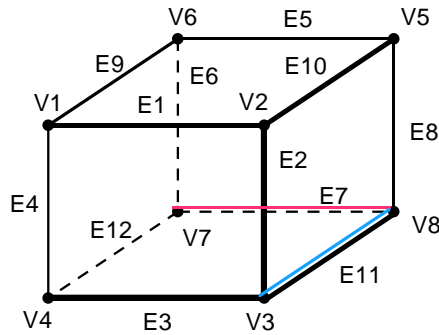
- look up face  $F_3$  in face table and find edge  $E_7$



## CCW EDGES IN A FACE

1. look up face  $F$  in face table and find an edge  $E$
2. find  $E$  in edge table; repeat until read  $E$  again
  - if  $F=FCW(E)$  then next edge is  $EPCW(E)$
  - else  $F=FCCW(E)$  and next edge is  $EPCCW(E)$
- Ex: get edges in face  $F_3$  in counterclockwise order

FACE	ESTART
$F_1$	$E_1$
$F_2$	$E_5$
$F_3$	$E_7$
$F_4$	$E_9$
$F_5$	$E_4$
$F_6$	$E_8$



EDGE	VSTART	VEND	EPCW	ENCW	EPCCW	ENCCW	FCW	FCCW
$E_1$	$V_1$	$V_2$	$E_4$	$E_2$	$E_{10}$	$E_9$	$F_1$	$F_4$
$E_2$	$V_2$	$V_3$	$E_1$	$E_3$	$E_{11}$	$E_{10}$	$F_1$	$F_6$
$E_3$	$V_3$	$V_4$	$E_2$	$E_4$	$E_{12}$	$E_{11}$	$F_1$	$F_3$
$E_4$	$V_4$	$V_1$	$E_3$	$E_1$	$E_9$	$E_{12}$	$F_1$	$F_5$
$E_5$	$V_5$	$V_6$	$E_8$	$E_6$	$E_9$	$E_{10}$	$F_2$	$F_4$
$E_6$	$V_6$	$V_7$	$E_5$	$E_7$	$E_{12}$	$E_9$	$F_2$	$F_5$
$E_7$	$V_7$	$V_8$	$E_6$	$E_8$	$E_{11}$	$E_{12}$	$F_2$	$F_3$
$E_8$	$V_8$	$V_5$	$E_7$	$E_5$	$E_{10}$	$E_{11}$	$F_2$	$F_6$
$E_9$	$V_1$	$V_6$	$E_1$	$E_5$	$E_6$	$E_4$	$F_4$	$F_5$
$E_{10}$	$V_5$	$V_2$	$E_5$	$E_1$	$E_2$	$E_8$	$F_4$	$F_6$
$E_{11}$	$V_3$	$V_8$	$E_3$	$E_7$	$E_8$	$E_2$	$F_3$	$F_6$
$E_{12}$	$V_7$	$V_4$	$E_7$	$E_3$	$E_4$	$E_6$	$F_3$	$F_5$

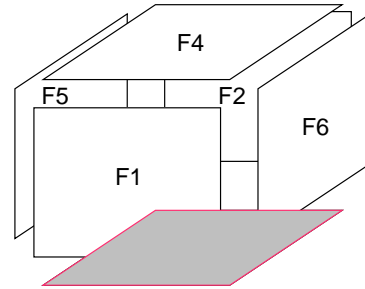
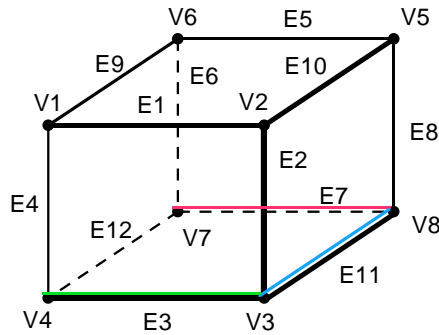
1. look up face  $F_3$  in face table and find edge  $E_7$
2. look up edge  $E_7$  in edge table and since  $F_3=FCCW(E_7)$ , next edge is  $EPCCW(E_7)=E_{11}$



## CCW EDGES IN A FACE

- look up face  $F$  in face table and find an edge  $E$
- find  $E$  in edge table; repeat until read  $E$  again
  - if  $F=FCW(E)$  then next edge is  $EPCW(E)$
  - else  $F=FCCW(E)$  and next edge is  $EPCCW(E)$
- Ex: get edges in face  $F_3$  in counterclockwise order

FACE	ESTART
$F_1$	$E_1$
$F_2$	$E_5$
$F_3$	$E_7$
$F_4$	$E_9$
$F_5$	$E_4$
$F_6$	$E_8$



EDGE	VSTART	VEND	EPCW	ENCW	EPCCW	ENCCW	FCW	FCCW
$E_1$	$V_1$	$V_2$	$E_4$	$E_2$	$E_{10}$	$E_9$	$F_1$	$F_4$
$E_2$	$V_2$	$V_3$	$E_1$	$E_3$	$E_{11}$	$E_{10}$	$F_1$	$F_6$
$E_3$	$V_3$	$V_4$	$E_2$	$E_4$	$E_{12}$	$E_{11}$	$F_1$	$F_3$
$E_4$	$V_4$	$V_1$	$E_3$	$E_1$	$E_9$	$E_{12}$	$F_1$	$F_5$
$E_5$	$V_5$	$V_6$	$E_8$	$E_6$	$E_9$	$E_{10}$	$F_2$	$F_4$
$E_6$	$V_6$	$V_7$	$E_5$	$E_7$	$E_{12}$	$E_9$	$F_2$	$F_5$
$E_7$	$V_7$	$V_8$	$E_6$	$E_8$	$E_{11}$	$E_{12}$	$F_2$	$F_3$
$E_8$	$V_8$	$V_5$	$E_7$	$E_5$	$E_{10}$	$E_{11}$	$F_2$	$F_6$
$E_9$	$V_1$	$V_6$	$E_1$	$E_5$	$E_6$	$E_4$	$F_4$	$F_5$
$E_{10}$	$V_5$	$V_2$	$E_5$	$E_1$	$E_2$	$E_8$	$F_4$	$F_6$
$E_{11}$	$V_3$	$V_8$	$E_3$	$E_7$	$E_8$	$E_2$	$F_3$	$F_6$
$E_{12}$	$V_7$	$V_4$	$E_7$	$E_3$	$E_4$	$E_6$	$F_3$	$F_5$

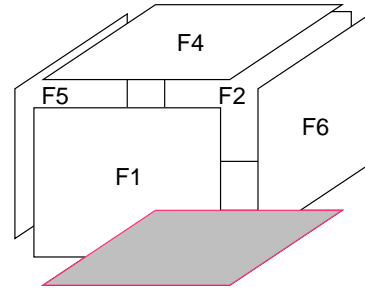
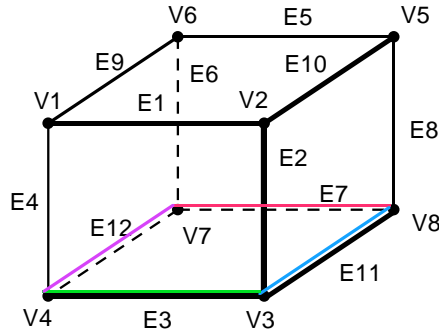
- look up face  $F_3$  in face table and find edge  $E_7$
- look up edge  $E_7$  in edge table and since  $F_3=FCCW(E_7)$ , next edge is  $EPCCW(E_7)=E_{11}$
- look up edge  $E_{11}$  in edge table and since  $F_3=FCW(E_{11})$ , next edge is  $EPCW(E_{11})=E_3$



## CCW EDGES IN A FACE

- look up face  $F$  in face table and find an edge  $E$
- find  $E$  in edge table; repeat until read  $E$  again
  - if  $F=FCW(E)$  then next edge is  $EPCW(E)$
  - else  $F=FCCW(E)$  and next edge is  $EPCCW(E)$
- Ex: get edges in face  $F_3$  in counterclockwise order

FACE	ESTART
$F_1$	$E_1$
$F_2$	$E_5$
$F_3$	$E_7$
$F_4$	$E_9$
$F_5$	$E_4$
$F_6$	$E_8$



EDGE	VSTART	VEND	EPCW	ENCW	EPCCW	ENCCW	FCW	FCCW
$E_1$	$V_1$	$V_2$	$E_4$	$E_2$	$E_{10}$	$E_9$	$F_1$	$F_4$
$E_2$	$V_2$	$V_3$	$E_1$	$E_3$	$E_{11}$	$E_{10}$	$F_1$	$F_6$
$E_3$	$V_3$	$V_4$	$E_2$	$E_4$	$E_{12}$	$E_{11}$	$F_1$	$F_3$
$E_4$	$V_4$	$V_1$	$E_3$	$E_1$	$E_9$	$E_{12}$	$F_1$	$F_5$
$E_5$	$V_5$	$V_6$	$E_8$	$E_6$	$E_9$	$E_{10}$	$F_2$	$F_4$
$E_6$	$V_6$	$V_7$	$E_5$	$E_7$	$E_{12}$	$E_9$	$F_2$	$F_5$
$E_7$	$V_7$	$V_8$	$E_6$	$E_8$	$E_{11}$	$E_{12}$	$F_2$	$F_3$
$E_8$	$V_8$	$V_5$	$E_7$	$E_5$	$E_{10}$	$E_{11}$	$F_2$	$F_6$
$E_9$	$V_1$	$V_6$	$E_1$	$E_5$	$E_6$	$E_4$	$F_4$	$F_5$
$E_{10}$	$V_5$	$V_2$	$E_5$	$E_1$	$E_2$	$E_8$	$F_4$	$F_6$
$E_{11}$	$V_3$	$V_8$	$E_3$	$E_7$	$E_8$	$E_2$	$F_3$	$F_6$
$E_{12}$	$V_7$	$V_4$	$E_7$	$E_3$	$E_4$	$E_6$	$F_3$	$F_5$

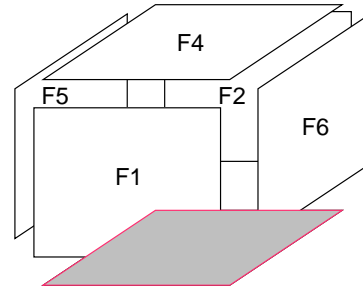
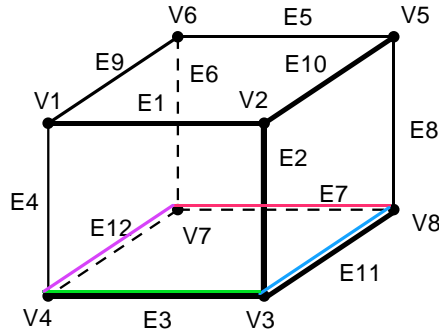
- look up face  $F_3$  in face table and find edge  $E_7$
- look up edge  $E_7$  in edge table and since  $F_3=FCCW(E_7)$ , next edge is  $EPCCW(E_7)=E_{11}$
- look up edge  $E_{11}$  in edge table and since  $F_3=FCW(E_{11})$ , next edge is  $EPCW(E_{11})=E_3$
- look up edge  $E_3$  in edge table and since  $F_3=FCCW(E_3)$ , next edge is  $EPCCW(E_3)=E_{12}$



## CCW EDGES IN A FACE

- look up face  $F$  in face table and find an edge  $E$
- find  $E$  in edge table; repeat until read  $E$  again
  - if  $F=FCW(E)$  then next edge is  $EPCW(E)$
  - else  $F=FCCW(E)$  and next edge is  $EPCCW(E)$
- Ex: get edges in face  $F_3$  in counterclockwise order

FACE	ESTART
$F_1$	$E_1$
$F_2$	$E_5$
$F_3$	$E_7$
$F_4$	$E_9$
$F_5$	$E_4$
$F_6$	$E_8$



EDGE	VSTART	VEND	EPCW	ENCW	EPCCW	ENCCW	FCW	FCCW
$E_1$	$V_1$	$V_2$	$E_4$	$E_2$	$E_{10}$	$E_9$	$F_1$	$F_4$
$E_2$	$V_2$	$V_3$	$E_1$	$E_3$	$E_{11}$	$E_{10}$	$F_1$	$F_6$
$E_3$	$V_3$	$V_4$	$E_2$	$E_4$	$E_{12}$	$E_{11}$	$F_1$	$F_3$
$E_4$	$V_4$	$V_1$	$E_3$	$E_1$	$E_9$	$E_{12}$	$F_1$	$F_5$
$E_5$	$V_5$	$V_6$	$E_8$	$E_6$	$E_9$	$E_{10}$	$F_2$	$F_4$
$E_6$	$V_6$	$V_7$	$E_5$	$E_7$	$E_{12}$	$E_9$	$F_2$	$F_5$
$E_7$	$V_7$	$V_8$	$E_6$	$E_8$	$E_{11}$	$E_{12}$	$F_2$	$F_3$
$E_8$	$V_8$	$V_5$	$E_7$	$E_5$	$E_{10}$	$E_{11}$	$F_2$	$F_6$
$E_9$	$V_1$	$V_6$	$E_1$	$E_5$	$E_6$	$E_4$	$F_4$	$F_5$
$E_{10}$	$V_5$	$V_2$	$E_5$	$E_1$	$E_2$	$E_8$	$F_4$	$F_6$
$E_{11}$	$V_3$	$V_8$	$E_3$	$E_7$	$E_8$	$E_2$	$F_3$	$F_6$
$E_{12}$	$V_7$	$V_4$	$E_7$	$E_3$	$E_4$	$E_6$	$F_3$	$F_5$

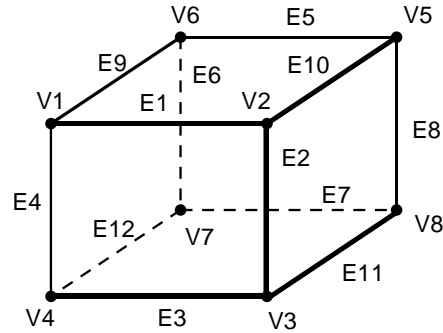
- look up face  $F_3$  in face table and find edge  $E_7$
- look up edge  $E_7$  in edge table and since  $F_3=FCCW(E_7)$ , next edge is  $EPCCW(E_7)=E_{11}$
- look up edge  $E_{11}$  in edge table and since  $F_3=FCW(E_{11})$ , next edge is  $EPCW(E_{11})=E_3$
- look up edge  $E_3$  in edge table and since  $F_3=FCCW(E_3)$ , next edge is  $EPCCW(E_3)=E_{12}$
- look up edge  $E_{12}$  in edge table and since  $F_3=FCW(E_{12})$ , next edge is  $EPCW(E_{12})=E_7$ ; now, we are done!



# CW EDGES MEETING AT A VERTEX

1. look up vertex  $v$  in face table and find an edge  $E$
2. find  $E$  in edge table; repeat until read  $E$  again
  - if  $v=VSTART(E)$  then next edge is  $EPCW(E)$
  - else  $v=VEND(E)$  and next edge is  $EPCCW(E)$
- Ex: get edges meeting at vertex  $v_5$  in clockwise order

VERTEX	X	Y	Z	ESTART
V <sub>1</sub>	X <sub>1</sub>	Y <sub>1</sub>	Z <sub>1</sub>	E <sub>1</sub>
V <sub>2</sub>	X <sub>2</sub>	Y <sub>2</sub>	Z <sub>2</sub>	E <sub>2</sub>
V <sub>3</sub>	X <sub>3</sub>	Y <sub>3</sub>	Z <sub>3</sub>	E <sub>3</sub>
V <sub>4</sub>	X <sub>4</sub>	Y <sub>4</sub>	Z <sub>4</sub>	E <sub>4</sub>
V <sub>5</sub>	X <sub>5</sub>	Y <sub>5</sub>	Z <sub>5</sub>	E <sub>5</sub>
V <sub>6</sub>	X <sub>6</sub>	Y <sub>6</sub>	Z <sub>6</sub>	E <sub>6</sub>
V <sub>7</sub>	X <sub>7</sub>	Y <sub>7</sub>	Z <sub>7</sub>	E <sub>7</sub>
V <sub>8</sub>	X <sub>8</sub>	Y <sub>8</sub>	Z <sub>8</sub>	E <sub>8</sub>



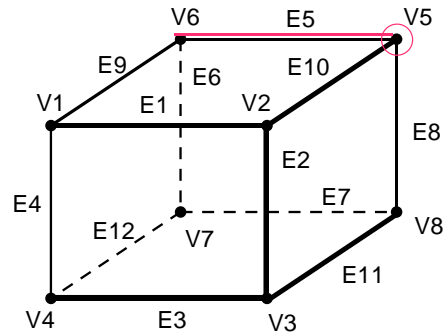
EDGE	VSTART	VEND	EPCW	ENCW	EPCCW	ENCCW	FCW	FCCW
E <sub>1</sub>	V <sub>1</sub>	V <sub>2</sub>	E <sub>4</sub>	E <sub>2</sub>	E <sub>10</sub>	E <sub>9</sub>	F <sub>1</sub>	F <sub>4</sub>
E <sub>2</sub>	V <sub>2</sub>	V <sub>3</sub>	E <sub>1</sub>	E <sub>3</sub>	E <sub>11</sub>	E <sub>10</sub>	F <sub>1</sub>	F <sub>6</sub>
E <sub>3</sub>	V <sub>3</sub>	V <sub>4</sub>	E <sub>2</sub>	E <sub>4</sub>	E <sub>12</sub>	E <sub>11</sub>	F <sub>1</sub>	F <sub>3</sub>
E <sub>4</sub>	V <sub>4</sub>	V <sub>1</sub>	E <sub>3</sub>	E <sub>1</sub>	E <sub>9</sub>	E <sub>12</sub>	F <sub>1</sub>	F <sub>5</sub>
E <sub>5</sub>	V <sub>5</sub>	V <sub>6</sub>	E <sub>8</sub>	E <sub>6</sub>	E <sub>9</sub>	E <sub>10</sub>	F <sub>2</sub>	F <sub>4</sub>
E <sub>6</sub>	V <sub>6</sub>	V <sub>7</sub>	E <sub>5</sub>	E <sub>7</sub>	E <sub>12</sub>	E <sub>9</sub>	F <sub>2</sub>	F <sub>5</sub>
E <sub>7</sub>	V <sub>7</sub>	V <sub>8</sub>	E <sub>6</sub>	E <sub>8</sub>	E <sub>11</sub>	E <sub>12</sub>	F <sub>2</sub>	F <sub>3</sub>
E <sub>8</sub>	V <sub>8</sub>	V <sub>5</sub>	E <sub>7</sub>	E <sub>5</sub>	E <sub>10</sub>	E <sub>11</sub>	F <sub>2</sub>	F <sub>6</sub>
E <sub>9</sub>	V <sub>1</sub>	V <sub>6</sub>	E <sub>1</sub>	E <sub>5</sub>	E <sub>6</sub>	E <sub>4</sub>	F <sub>4</sub>	F <sub>5</sub>
E <sub>10</sub>	V <sub>5</sub>	V <sub>2</sub>	E <sub>5</sub>	E <sub>1</sub>	E <sub>2</sub>	E <sub>8</sub>	F <sub>4</sub>	F <sub>6</sub>
E <sub>11</sub>	V <sub>3</sub>	V <sub>8</sub>	E <sub>3</sub>	E <sub>7</sub>	E <sub>8</sub>	E <sub>2</sub>	F <sub>3</sub>	F <sub>6</sub>
E <sub>12</sub>	V <sub>7</sub>	V <sub>4</sub>	E <sub>7</sub>	E <sub>3</sub>	E <sub>4</sub>	E <sub>6</sub>	F <sub>3</sub>	F <sub>5</sub>



## CW EDGES MEETING AT A VERTEX

- look up vertex  $v$  in face table and find an edge  $E$
  - find  $E$  in edge table; repeat until read  $E$  again
    - if  $v=VSTART(E)$  then next edge is  $EPCW(E)$
    - else  $v=VEND(E)$  and next edge is  $EPCCW(E)$
- Ex: get edges meeting at vertex  $v_5$  in clockwise order

VERTEX	X	Y	Z	ESTART
V <sub>1</sub>	X <sub>1</sub>	Y <sub>1</sub>	Z <sub>1</sub>	E <sub>1</sub>
V <sub>2</sub>	X <sub>2</sub>	Y <sub>2</sub>	Z <sub>2</sub>	E <sub>2</sub>
V <sub>3</sub>	X <sub>3</sub>	Y <sub>3</sub>	Z <sub>3</sub>	E <sub>3</sub>
V <sub>4</sub>	X <sub>4</sub>	Y <sub>4</sub>	Z <sub>4</sub>	E <sub>4</sub>
V <sub>5</sub>	X <sub>5</sub>	Y <sub>5</sub>	Z <sub>5</sub>	E <sub>5</sub>
V <sub>6</sub>	X <sub>6</sub>	Y <sub>6</sub>	Z <sub>6</sub>	E <sub>6</sub>
V <sub>7</sub>	X <sub>7</sub>	Y <sub>7</sub>	Z <sub>7</sub>	E <sub>7</sub>
V <sub>8</sub>	X <sub>8</sub>	Y <sub>8</sub>	Z <sub>8</sub>	E <sub>8</sub>



EDGE	VSTART	VEND	EPCW	ENCW	EPCCW	ENCCW	FCW	FCCW
E <sub>1</sub>	V <sub>1</sub>	V <sub>2</sub>	E <sub>4</sub>	E <sub>2</sub>	E <sub>10</sub>	E <sub>9</sub>	F <sub>1</sub>	F <sub>4</sub>
E <sub>2</sub>	V <sub>2</sub>	V <sub>3</sub>	E <sub>1</sub>	E <sub>3</sub>	E <sub>11</sub>	E <sub>10</sub>	F <sub>1</sub>	F <sub>6</sub>
E <sub>3</sub>	V <sub>3</sub>	V <sub>4</sub>	E <sub>2</sub>	E <sub>4</sub>	E <sub>12</sub>	E <sub>11</sub>	F <sub>1</sub>	F <sub>3</sub>
E <sub>4</sub>	V <sub>4</sub>	V <sub>1</sub>	E <sub>3</sub>	E <sub>1</sub>	E <sub>9</sub>	E <sub>12</sub>	F <sub>1</sub>	F <sub>5</sub>
E <sub>5</sub>	V <sub>5</sub>	V <sub>6</sub>	E <sub>8</sub>	E <sub>6</sub>	E <sub>9</sub>	E <sub>10</sub>	F <sub>2</sub>	F <sub>4</sub>
E <sub>6</sub>	V <sub>6</sub>	V <sub>7</sub>	E <sub>5</sub>	E <sub>7</sub>	E <sub>12</sub>	E <sub>9</sub>	F <sub>2</sub>	F <sub>5</sub>
E <sub>7</sub>	V <sub>7</sub>	V <sub>8</sub>	E <sub>6</sub>	E <sub>8</sub>	E <sub>11</sub>	E <sub>12</sub>	F <sub>2</sub>	F <sub>3</sub>
E <sub>8</sub>	V <sub>8</sub>	V <sub>5</sub>	E <sub>7</sub>	E <sub>5</sub>	E <sub>10</sub>	E <sub>11</sub>	F <sub>2</sub>	F <sub>6</sub>
E <sub>9</sub>	V <sub>1</sub>	V <sub>6</sub>	E <sub>1</sub>	E <sub>5</sub>	E <sub>6</sub>	E <sub>4</sub>	F <sub>4</sub>	F <sub>5</sub>
E <sub>10</sub>	V <sub>5</sub>	V <sub>2</sub>	E <sub>5</sub>	E <sub>1</sub>	E <sub>2</sub>	E <sub>8</sub>	F <sub>4</sub>	F <sub>6</sub>
E <sub>11</sub>	V <sub>3</sub>	V <sub>8</sub>	E <sub>3</sub>	E <sub>7</sub>	E <sub>8</sub>	E <sub>2</sub>	F <sub>3</sub>	F <sub>6</sub>
E <sub>12</sub>	V <sub>7</sub>	V <sub>4</sub>	E <sub>7</sub>	E <sub>3</sub>	E <sub>4</sub>	E <sub>6</sub>	F <sub>3</sub>	F <sub>5</sub>

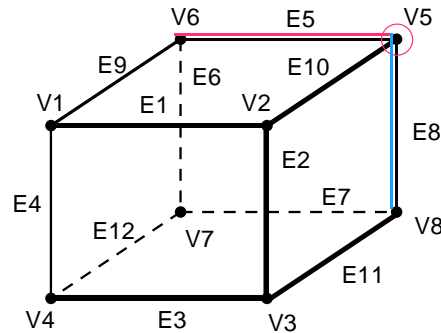
- look up vertex  $v_5$  in vertex table and find edge  $E_5$



## CW EDGES MEETING AT A VERTEX

- look up vertex  $v$  in face table and find an edge  $E$
  - find  $E$  in edge table; repeat until read  $E$  again
    - if  $v=VSTART(E)$  then next edge is  $EPCW(E)$
    - else  $v=VEND(E)$  and next edge is  $EPCCW(E)$
- Ex: get edges meeting at vertex  $v_5$  in clockwise order

VERTEX	X	Y	Z	ESTART
V <sub>1</sub>	X <sub>1</sub>	Y <sub>1</sub>	Z <sub>1</sub>	E <sub>1</sub>
V <sub>2</sub>	X <sub>2</sub>	Y <sub>2</sub>	Z <sub>2</sub>	E <sub>2</sub>
V <sub>3</sub>	X <sub>3</sub>	Y <sub>3</sub>	Z <sub>3</sub>	E <sub>3</sub>
V <sub>4</sub>	X <sub>4</sub>	Y <sub>4</sub>	Z <sub>4</sub>	E <sub>4</sub>
V <sub>5</sub>	X <sub>5</sub>	Y <sub>5</sub>	Z <sub>5</sub>	E <sub>5</sub>
V <sub>6</sub>	X <sub>6</sub>	Y <sub>6</sub>	Z <sub>6</sub>	E <sub>6</sub>
V <sub>7</sub>	X <sub>7</sub>	Y <sub>7</sub>	Z <sub>7</sub>	E <sub>7</sub>
V <sub>8</sub>	X <sub>8</sub>	Y <sub>8</sub>	Z <sub>8</sub>	E <sub>8</sub>



EDGE	VSTART	VEND	EPCW	ENCW	EPCCW	ENCCW	FCW	FCCW
E <sub>1</sub>	V <sub>1</sub>	V <sub>2</sub>	E <sub>4</sub>	E <sub>2</sub>	E <sub>10</sub>	E <sub>9</sub>	F <sub>1</sub>	F <sub>4</sub>
E <sub>2</sub>	V <sub>2</sub>	V <sub>3</sub>	E <sub>1</sub>	E <sub>3</sub>	E <sub>11</sub>	E <sub>10</sub>	F <sub>1</sub>	F <sub>6</sub>
E <sub>3</sub>	V <sub>3</sub>	V <sub>4</sub>	E <sub>2</sub>	E <sub>4</sub>	E <sub>12</sub>	E <sub>11</sub>	F <sub>1</sub>	F <sub>3</sub>
E <sub>4</sub>	V <sub>4</sub>	V <sub>1</sub>	E <sub>3</sub>	E <sub>1</sub>	E <sub>9</sub>	E <sub>12</sub>	F <sub>1</sub>	F <sub>5</sub>
E <sub>5</sub>	V <sub>5</sub>	V <sub>6</sub>	E <sub>8</sub>	E <sub>6</sub>	E <sub>9</sub>	E <sub>10</sub>	F <sub>2</sub>	F <sub>4</sub>
E <sub>6</sub>	V <sub>6</sub>	V <sub>7</sub>	E <sub>5</sub>	E <sub>7</sub>	E <sub>12</sub>	E <sub>9</sub>	F <sub>2</sub>	F <sub>5</sub>
E <sub>7</sub>	V <sub>7</sub>	V <sub>8</sub>	E <sub>6</sub>	E <sub>8</sub>	E <sub>11</sub>	E <sub>12</sub>	F <sub>2</sub>	F <sub>3</sub>
E <sub>8</sub>	V <sub>8</sub>	V <sub>5</sub>	E <sub>7</sub>	E <sub>5</sub>	E <sub>10</sub>	E <sub>11</sub>	F <sub>2</sub>	F <sub>6</sub>
E <sub>9</sub>	V <sub>1</sub>	V <sub>6</sub>	E <sub>1</sub>	E <sub>5</sub>	E <sub>6</sub>	E <sub>4</sub>	F <sub>4</sub>	F <sub>5</sub>
E <sub>10</sub>	V <sub>5</sub>	V <sub>2</sub>	E <sub>5</sub>	E <sub>1</sub>	E <sub>2</sub>	E <sub>8</sub>	F <sub>4</sub>	F <sub>6</sub>
E <sub>11</sub>	V <sub>3</sub>	V <sub>8</sub>	E <sub>3</sub>	E <sub>7</sub>	E <sub>8</sub>	E <sub>2</sub>	F <sub>3</sub>	F <sub>6</sub>
E <sub>12</sub>	V <sub>7</sub>	V <sub>4</sub>	E <sub>7</sub>	E <sub>3</sub>	E <sub>4</sub>	E <sub>6</sub>	F <sub>3</sub>	F <sub>5</sub>

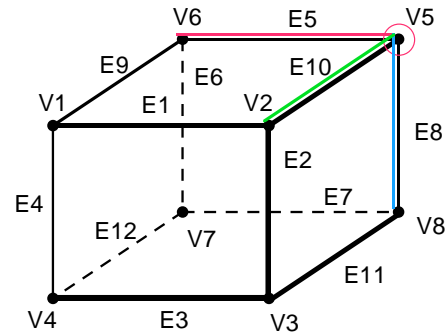
- look up vertex  $v_5$  in vertex table and find edge  $E_5$
- look up edge  $E_5$  in edge table and since  $v_5=VSTART(E_5)$ , next edge is  $EPCW(E_5)=E_8$



## CW EDGES MEETING AT A VERTEX

- look up vertex  $v$  in face table and find an edge  $E$
  - find  $E$  in edge table; repeat until read  $E$  again
    - if  $v=VSTART(E)$  then next edge is  $EPCW(E)$
    - else  $v=VEND(E)$  and next edge is  $EPCCW(E)$
- Ex: get edges meeting at vertex  $v_5$  in clockwise order

VERTEX	X	Y	Z	ESTART
V <sub>1</sub>	X <sub>1</sub>	Y <sub>1</sub>	Z <sub>1</sub>	E <sub>1</sub>
V <sub>2</sub>	X <sub>2</sub>	Y <sub>2</sub>	Z <sub>2</sub>	E <sub>2</sub>
V <sub>3</sub>	X <sub>3</sub>	Y <sub>3</sub>	Z <sub>3</sub>	E <sub>3</sub>
V <sub>4</sub>	X <sub>4</sub>	Y <sub>4</sub>	Z <sub>4</sub>	E <sub>4</sub>
V <sub>5</sub>	X <sub>5</sub>	Y <sub>5</sub>	Z <sub>5</sub>	E <sub>5</sub>
V <sub>6</sub>	X <sub>6</sub>	Y <sub>6</sub>	Z <sub>6</sub>	E <sub>6</sub>
V <sub>7</sub>	X <sub>7</sub>	Y <sub>7</sub>	Z <sub>7</sub>	E <sub>7</sub>
V <sub>8</sub>	X <sub>8</sub>	Y <sub>8</sub>	Z <sub>8</sub>	E <sub>8</sub>



EDGE	VSTART	VEND	EPCW	ENCW	EPCCW	ENCCW	FCW	FCCW
E <sub>1</sub>	V <sub>1</sub>	V <sub>2</sub>	E <sub>4</sub>	E <sub>2</sub>	E <sub>10</sub>	E <sub>9</sub>	F <sub>1</sub>	F <sub>4</sub>
E <sub>2</sub>	V <sub>2</sub>	V <sub>3</sub>	E <sub>1</sub>	E <sub>3</sub>	E <sub>11</sub>	E <sub>10</sub>	F <sub>1</sub>	F <sub>6</sub>
E <sub>3</sub>	V <sub>3</sub>	V <sub>4</sub>	E <sub>2</sub>	E <sub>4</sub>	E <sub>12</sub>	E <sub>11</sub>	F <sub>1</sub>	F <sub>3</sub>
E <sub>4</sub>	V <sub>4</sub>	V <sub>1</sub>	E <sub>3</sub>	E <sub>1</sub>	E <sub>9</sub>	E <sub>12</sub>	F <sub>1</sub>	F <sub>5</sub>
E <sub>5</sub>	V <sub>5</sub>	V <sub>6</sub>	E <sub>8</sub>	E <sub>6</sub>	E <sub>9</sub>	E <sub>10</sub>	F <sub>2</sub>	F <sub>4</sub>
E <sub>6</sub>	V <sub>6</sub>	V <sub>7</sub>	E <sub>5</sub>	E <sub>7</sub>	E <sub>12</sub>	E <sub>9</sub>	F <sub>2</sub>	F <sub>5</sub>
E <sub>7</sub>	V <sub>7</sub>	V <sub>8</sub>	E <sub>6</sub>	E <sub>8</sub>	E <sub>11</sub>	E <sub>12</sub>	F <sub>2</sub>	F <sub>3</sub>
E <sub>8</sub>	V <sub>8</sub>	V <sub>5</sub>	E <sub>7</sub>	E <sub>5</sub>	E <sub>10</sub>	E <sub>11</sub>	F <sub>2</sub>	F <sub>6</sub>
E <sub>9</sub>	V <sub>1</sub>	V <sub>6</sub>	E <sub>1</sub>	E <sub>5</sub>	E <sub>6</sub>	E <sub>4</sub>	F <sub>4</sub>	F <sub>5</sub>
E <sub>10</sub>	V <sub>5</sub>	V <sub>2</sub>	E <sub>5</sub>	E <sub>1</sub>	E <sub>2</sub>	E <sub>8</sub>	F <sub>4</sub>	F <sub>6</sub>
E <sub>11</sub>	V <sub>3</sub>	V <sub>8</sub>	E <sub>3</sub>	E <sub>7</sub>	E <sub>8</sub>	E <sub>2</sub>	F <sub>3</sub>	F <sub>6</sub>
E <sub>12</sub>	V <sub>7</sub>	V <sub>4</sub>	E <sub>7</sub>	E <sub>3</sub>	E <sub>4</sub>	E <sub>6</sub>	F <sub>3</sub>	F <sub>5</sub>

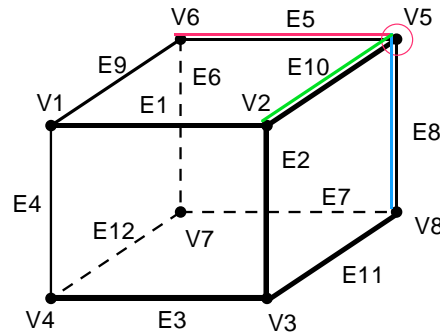
- look up vertex  $v_5$  in vertex table and find edge  $E_5$
- look up edge  $E_5$  in edge table and since  $v_5=VSTART(E_5)$ , next edge is  $EPCW(E_5)=E_8$
- look up edge  $E_8$  in edge table and since  $v_5=VEND(E_8)$ , next edge is  $EPCCW(E_8)=E_{10}$



## CW EDGES MEETING AT A VERTEX

- look up vertex  $v$  in face table and find an edge  $E$
- find  $E$  in edge table; repeat until read  $E$  again
  - if  $v=VSTART(E)$  then next edge is  $EPCW(E)$
  - else  $v=VEND(E)$  and next edge is  $EPCCW(E)$
- Ex: get edges meeting at vertex  $v_5$  in clockwise order

VERTEX	X	Y	Z	ESTART
V <sub>1</sub>	X <sub>1</sub>	Y <sub>1</sub>	Z <sub>1</sub>	E <sub>1</sub>
V <sub>2</sub>	X <sub>2</sub>	Y <sub>2</sub>	Z <sub>2</sub>	E <sub>2</sub>
V <sub>3</sub>	X <sub>3</sub>	Y <sub>3</sub>	Z <sub>3</sub>	E <sub>3</sub>
V <sub>4</sub>	X <sub>4</sub>	Y <sub>4</sub>	Z <sub>4</sub>	E <sub>4</sub>
V <sub>5</sub>	X <sub>5</sub>	Y <sub>5</sub>	Z <sub>5</sub>	E <sub>5</sub>
V <sub>6</sub>	X <sub>6</sub>	Y <sub>6</sub>	Z <sub>6</sub>	E <sub>6</sub>
V <sub>7</sub>	X <sub>7</sub>	Y <sub>7</sub>	Z <sub>7</sub>	E <sub>7</sub>
V <sub>8</sub>	X <sub>8</sub>	Y <sub>8</sub>	Z <sub>8</sub>	E <sub>8</sub>



EDGE	VSTART	VEND	EPCW	ENCW	EPCCW	ENCCW	FCW	FCCW
E <sub>1</sub>	V <sub>1</sub>	V <sub>2</sub>	E <sub>4</sub>	E <sub>2</sub>	E <sub>10</sub>	E <sub>9</sub>	F <sub>1</sub>	F <sub>4</sub>
E <sub>2</sub>	V <sub>2</sub>	V <sub>3</sub>	E <sub>1</sub>	E <sub>3</sub>	E <sub>11</sub>	E <sub>10</sub>	F <sub>1</sub>	F <sub>6</sub>
E <sub>3</sub>	V <sub>3</sub>	V <sub>4</sub>	E <sub>2</sub>	E <sub>4</sub>	E <sub>12</sub>	E <sub>11</sub>	F <sub>1</sub>	F <sub>3</sub>
E <sub>4</sub>	V <sub>4</sub>	V <sub>1</sub>	E <sub>3</sub>	E <sub>1</sub>	E <sub>9</sub>	E <sub>12</sub>	F <sub>1</sub>	F <sub>5</sub>
E <sub>5</sub>	V <sub>5</sub>	V <sub>6</sub>	E <sub>8</sub>	E <sub>6</sub>	E <sub>9</sub>	E <sub>10</sub>	F <sub>2</sub>	F <sub>4</sub>
E <sub>6</sub>	V <sub>6</sub>	V <sub>7</sub>	E <sub>5</sub>	E <sub>7</sub>	E <sub>12</sub>	E <sub>9</sub>	F <sub>2</sub>	F <sub>5</sub>
E <sub>7</sub>	V <sub>7</sub>	V <sub>8</sub>	E <sub>6</sub>	E <sub>8</sub>	E <sub>11</sub>	E <sub>12</sub>	F <sub>2</sub>	F <sub>3</sub>
E <sub>8</sub>	V <sub>8</sub>	V <sub>5</sub>	E <sub>7</sub>	E <sub>5</sub>	E <sub>10</sub>	E <sub>11</sub>	F <sub>2</sub>	F <sub>6</sub>
E <sub>9</sub>	V <sub>1</sub>	V <sub>6</sub>	E <sub>1</sub>	E <sub>5</sub>	E <sub>6</sub>	E <sub>4</sub>	F <sub>4</sub>	F <sub>5</sub>
E <sub>10</sub>	V <sub>5</sub>	V <sub>2</sub>	E <sub>5</sub>	E <sub>1</sub>	E <sub>2</sub>	E <sub>8</sub>	F <sub>4</sub>	F <sub>6</sub>
E <sub>11</sub>	V <sub>3</sub>	V <sub>8</sub>	E <sub>3</sub>	E <sub>7</sub>	E <sub>8</sub>	E <sub>2</sub>	F <sub>3</sub>	F <sub>6</sub>
E <sub>12</sub>	V <sub>7</sub>	V <sub>4</sub>	E <sub>7</sub>	E <sub>3</sub>	E <sub>4</sub>	E <sub>6</sub>	F <sub>3</sub>	F <sub>5</sub>

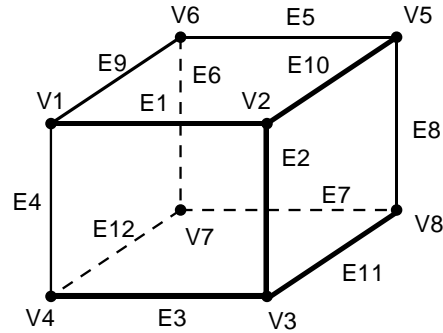
- look up vertex  $v_5$  in vertex table and find edge  $E_5$
- look up edge  $E_5$  in edge table and since  $v_5=VSTART(E_5)$ , next edge is  $EPCW(E_5)=E_8$
- look up edge  $E_8$  in edge table and since  $v_5=VEND(E_8)$ , next edge is  $EPCCW(E_8)=E_{10}$
- look up edge  $E_{10}$  in edge table and since  $v_5=VSTART(E_{10})$ , next edge is  $EPCW(E_{10})=E_5$ ; now, we are done!



# CCW EDGES MEETING AT A VERTEX

1. look up vertex  $v$  in face table and find an edge  $E$
2. find  $E$  in edge table; repeat until read  $E$  again
  - if  $v=VSTART(E)$  then next edge is  $ENCCW(E)$
  - else  $v=VEND(E)$  and next edge is  $ENCW(E)$
- Ex: get edges meeting at  $v_5$  in counterclockwise order

VERTEX	X	Y	Z	ESTART
V <sub>1</sub>	X <sub>1</sub>	Y <sub>1</sub>	Z <sub>1</sub>	E <sub>1</sub>
V <sub>2</sub>	X <sub>2</sub>	Y <sub>2</sub>	Z <sub>2</sub>	E <sub>2</sub>
V <sub>3</sub>	X <sub>3</sub>	Y <sub>3</sub>	Z <sub>3</sub>	E <sub>3</sub>
V <sub>4</sub>	X <sub>4</sub>	Y <sub>4</sub>	Z <sub>4</sub>	E <sub>4</sub>
V <sub>5</sub>	X <sub>5</sub>	Y <sub>5</sub>	Z <sub>5</sub>	E <sub>5</sub>
V <sub>6</sub>	X <sub>6</sub>	Y <sub>6</sub>	Z <sub>6</sub>	E <sub>6</sub>
V <sub>7</sub>	X <sub>7</sub>	Y <sub>7</sub>	Z <sub>7</sub>	E <sub>7</sub>
V <sub>8</sub>	X <sub>8</sub>	Y <sub>8</sub>	Z <sub>8</sub>	E <sub>8</sub>



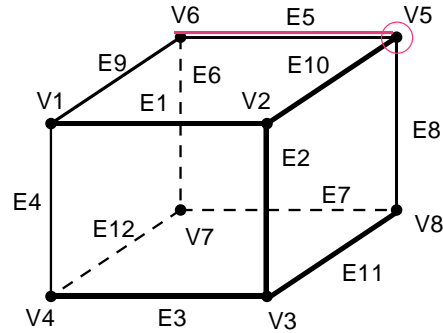
EDGE	VSTART	VEND	EPCW	ENCW	EPCCW	ENCCW	FCW	FCCW
E <sub>1</sub>	V <sub>1</sub>	V <sub>2</sub>	E <sub>4</sub>	E <sub>2</sub>	E <sub>10</sub>	E <sub>9</sub>	F <sub>1</sub>	F <sub>4</sub>
E <sub>2</sub>	V <sub>2</sub>	V <sub>3</sub>	E <sub>1</sub>	E <sub>3</sub>	E <sub>11</sub>	E <sub>10</sub>	F <sub>1</sub>	F <sub>6</sub>
E <sub>3</sub>	V <sub>3</sub>	V <sub>4</sub>	E <sub>2</sub>	E <sub>4</sub>	E <sub>12</sub>	E <sub>11</sub>	F <sub>1</sub>	F <sub>3</sub>
E <sub>4</sub>	V <sub>4</sub>	V <sub>1</sub>	E <sub>3</sub>	E <sub>1</sub>	E <sub>9</sub>	E <sub>12</sub>	F <sub>1</sub>	F <sub>5</sub>
E <sub>5</sub>	V <sub>5</sub>	V <sub>6</sub>	E <sub>8</sub>	E <sub>6</sub>	E <sub>9</sub>	E <sub>10</sub>	F <sub>2</sub>	F <sub>4</sub>
E <sub>6</sub>	V <sub>6</sub>	V <sub>7</sub>	E <sub>5</sub>	E <sub>7</sub>	E <sub>12</sub>	E <sub>9</sub>	F <sub>2</sub>	F <sub>5</sub>
E <sub>7</sub>	V <sub>7</sub>	V <sub>8</sub>	E <sub>6</sub>	E <sub>8</sub>	E <sub>11</sub>	E <sub>12</sub>	F <sub>2</sub>	F <sub>3</sub>
E <sub>8</sub>	V <sub>8</sub>	V <sub>5</sub>	E <sub>7</sub>	E <sub>5</sub>	E <sub>10</sub>	E <sub>11</sub>	F <sub>2</sub>	F <sub>6</sub>
E <sub>9</sub>	V <sub>1</sub>	V <sub>6</sub>	E <sub>1</sub>	E <sub>5</sub>	E <sub>6</sub>	E <sub>4</sub>	F <sub>4</sub>	F <sub>5</sub>
E <sub>10</sub>	V <sub>5</sub>	V <sub>2</sub>	E <sub>5</sub>	E <sub>1</sub>	E <sub>2</sub>	E <sub>8</sub>	F <sub>4</sub>	F <sub>6</sub>
E <sub>11</sub>	V <sub>3</sub>	V <sub>8</sub>	E <sub>3</sub>	E <sub>7</sub>	E <sub>8</sub>	E <sub>2</sub>	F <sub>3</sub>	F <sub>6</sub>
E <sub>12</sub>	V <sub>7</sub>	V <sub>4</sub>	E <sub>7</sub>	E <sub>3</sub>	E <sub>4</sub>	E <sub>6</sub>	F <sub>3</sub>	F <sub>5</sub>



# CCW EDGES MEETING AT A VERTEX

1. look up vertex  $v$  in face table and find an edge  $E$
2. find  $E$  in edge table; repeat until read  $E$  again
  - if  $v=VSTART(E)$  then next edge is  $ENCCW(E)$
  - else  $v=VEND(E)$  and next edge is  $ENCW(E)$
- Ex: get edges meeting at  $v_5$  in counterclockwise order

VERTEX	X	Y	Z	ESTART
V <sub>1</sub>	X <sub>1</sub>	Y <sub>1</sub>	Z <sub>1</sub>	E <sub>1</sub>
V <sub>2</sub>	X <sub>2</sub>	Y <sub>2</sub>	Z <sub>2</sub>	E <sub>2</sub>
V <sub>3</sub>	X <sub>3</sub>	Y <sub>3</sub>	Z <sub>3</sub>	E <sub>3</sub>
V <sub>4</sub>	X <sub>4</sub>	Y <sub>4</sub>	Z <sub>4</sub>	E <sub>4</sub>
V <sub>5</sub>	X <sub>5</sub>	Y <sub>5</sub>	Z <sub>5</sub>	E <sub>5</sub>
V <sub>6</sub>	X <sub>6</sub>	Y <sub>6</sub>	Z <sub>6</sub>	E <sub>6</sub>
V <sub>7</sub>	X <sub>7</sub>	Y <sub>7</sub>	Z <sub>7</sub>	E <sub>7</sub>
V <sub>8</sub>	X <sub>8</sub>	Y <sub>8</sub>	Z <sub>8</sub>	E <sub>8</sub>



EDGE	VSTART	VEND	EPCW	ENCW	EPCCW	ENCCW	FCW	FCCW
E <sub>1</sub>	V <sub>1</sub>	V <sub>2</sub>	E <sub>4</sub>	E <sub>2</sub>	E <sub>10</sub>	E <sub>9</sub>	F <sub>1</sub>	F <sub>4</sub>
E <sub>2</sub>	V <sub>2</sub>	V <sub>3</sub>	E <sub>1</sub>	E <sub>3</sub>	E <sub>11</sub>	E <sub>10</sub>	F <sub>1</sub>	F <sub>6</sub>
E <sub>3</sub>	V <sub>3</sub>	V <sub>4</sub>	E <sub>2</sub>	E <sub>4</sub>	E <sub>12</sub>	E <sub>11</sub>	F <sub>1</sub>	F <sub>3</sub>
E <sub>4</sub>	V <sub>4</sub>	V <sub>1</sub>	E <sub>3</sub>	E <sub>1</sub>	E <sub>9</sub>	E <sub>12</sub>	F <sub>1</sub>	F <sub>5</sub>
E <sub>5</sub>	V <sub>5</sub>	V <sub>6</sub>	E <sub>8</sub>	E <sub>6</sub>	E <sub>9</sub>	E <sub>10</sub>	F <sub>2</sub>	F <sub>4</sub>
E <sub>6</sub>	V <sub>6</sub>	V <sub>7</sub>	E <sub>5</sub>	E <sub>7</sub>	E <sub>12</sub>	E <sub>9</sub>	F <sub>2</sub>	F <sub>5</sub>
E <sub>7</sub>	V <sub>7</sub>	V <sub>8</sub>	E <sub>6</sub>	E <sub>8</sub>	E <sub>11</sub>	E <sub>12</sub>	F <sub>2</sub>	F <sub>3</sub>
E <sub>8</sub>	V <sub>8</sub>	V <sub>5</sub>	E <sub>7</sub>	E <sub>5</sub>	E <sub>10</sub>	E <sub>11</sub>	F <sub>2</sub>	F <sub>6</sub>
E <sub>9</sub>	V <sub>1</sub>	V <sub>6</sub>	E <sub>1</sub>	E <sub>5</sub>	E <sub>6</sub>	E <sub>4</sub>	F <sub>4</sub>	F <sub>5</sub>
E <sub>10</sub>	V <sub>5</sub>	V <sub>2</sub>	E <sub>5</sub>	E <sub>1</sub>	E <sub>2</sub>	E <sub>8</sub>	F <sub>4</sub>	F <sub>6</sub>
E <sub>11</sub>	V <sub>3</sub>	V <sub>8</sub>	E <sub>3</sub>	E <sub>7</sub>	E <sub>8</sub>	E <sub>2</sub>	F <sub>3</sub>	F <sub>6</sub>
E <sub>12</sub>	V <sub>7</sub>	V <sub>4</sub>	E <sub>7</sub>	E <sub>3</sub>	E <sub>4</sub>	E <sub>6</sub>	F <sub>3</sub>	F <sub>5</sub>

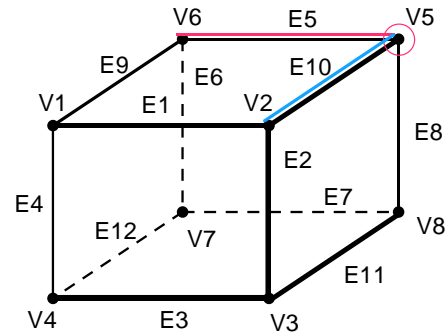
1. look up vertex  $v_5$  in vertex table and find edge  $E_5$



## CCW EDGES MEETING AT A VERTEX

- look up vertex  $v$  in face table and find an edge  $E$
  - find  $E$  in edge table; repeat until read  $E$  again
    - if  $v=VSTART(E)$  then next edge is  $ENCCW(E)$
    - else  $v=VEND(E)$  and next edge is  $ENCW(E)$
- Ex: get edges meeting at  $v_5$  in counterclockwise order

VERTEX	X	Y	Z	ESTART
V <sub>1</sub>	X <sub>1</sub>	Y <sub>1</sub>	Z <sub>1</sub>	E <sub>1</sub>
V <sub>2</sub>	X <sub>2</sub>	Y <sub>2</sub>	Z <sub>2</sub>	E <sub>2</sub>
V <sub>3</sub>	X <sub>3</sub>	Y <sub>3</sub>	Z <sub>3</sub>	E <sub>3</sub>
V <sub>4</sub>	X <sub>4</sub>	Y <sub>4</sub>	Z <sub>4</sub>	E <sub>4</sub>
V <sub>5</sub>	X <sub>5</sub>	Y <sub>5</sub>	Z <sub>5</sub>	E <sub>5</sub>
V <sub>6</sub>	X <sub>6</sub>	Y <sub>6</sub>	Z <sub>6</sub>	E <sub>6</sub>
V <sub>7</sub>	X <sub>7</sub>	Y <sub>7</sub>	Z <sub>7</sub>	E <sub>7</sub>
V <sub>8</sub>	X <sub>8</sub>	Y <sub>8</sub>	Z <sub>8</sub>	E <sub>8</sub>



EDGE	VSTART	VEND	EPCW	ENCW	EPCCW	ENCCW	FCW	FCCW
E <sub>1</sub>	V <sub>1</sub>	V <sub>2</sub>	E <sub>4</sub>	E <sub>2</sub>	E <sub>10</sub>	E <sub>9</sub>	F <sub>1</sub>	F <sub>4</sub>
E <sub>2</sub>	V <sub>2</sub>	V <sub>3</sub>	E <sub>1</sub>	E <sub>3</sub>	E <sub>11</sub>	E <sub>10</sub>	F <sub>1</sub>	F <sub>6</sub>
E <sub>3</sub>	V <sub>3</sub>	V <sub>4</sub>	E <sub>2</sub>	E <sub>4</sub>	E <sub>12</sub>	E <sub>11</sub>	F <sub>1</sub>	F <sub>3</sub>
E <sub>4</sub>	V <sub>4</sub>	V <sub>1</sub>	E <sub>3</sub>	E <sub>1</sub>	E <sub>9</sub>	E <sub>12</sub>	F <sub>1</sub>	F <sub>5</sub>
E <sub>5</sub>	V <sub>5</sub>	V <sub>6</sub>	E <sub>8</sub>	E <sub>6</sub>	E <sub>9</sub>	E <sub>10</sub>	F <sub>2</sub>	F <sub>4</sub>
E <sub>6</sub>	V <sub>6</sub>	V <sub>7</sub>	E <sub>5</sub>	E <sub>7</sub>	E <sub>12</sub>	E <sub>9</sub>	F <sub>2</sub>	F <sub>5</sub>
E <sub>7</sub>	V <sub>7</sub>	V <sub>8</sub>	E <sub>6</sub>	E <sub>8</sub>	E <sub>11</sub>	E <sub>12</sub>	F <sub>2</sub>	F <sub>3</sub>
E <sub>8</sub>	V <sub>8</sub>	V <sub>5</sub>	E <sub>7</sub>	E <sub>5</sub>	E <sub>10</sub>	E <sub>11</sub>	F <sub>2</sub>	F <sub>6</sub>
E <sub>9</sub>	V <sub>1</sub>	V <sub>6</sub>	E <sub>1</sub>	E <sub>5</sub>	E <sub>6</sub>	E <sub>4</sub>	F <sub>4</sub>	F <sub>5</sub>
E <sub>10</sub>	V <sub>5</sub>	V <sub>2</sub>	E <sub>5</sub>	E <sub>1</sub>	E <sub>2</sub>	E <sub>8</sub>	F <sub>4</sub>	F <sub>6</sub>
E <sub>11</sub>	V <sub>3</sub>	V <sub>8</sub>	E <sub>3</sub>	E <sub>7</sub>	E <sub>8</sub>	E <sub>2</sub>	F <sub>3</sub>	F <sub>6</sub>
E <sub>12</sub>	V <sub>7</sub>	V <sub>4</sub>	E <sub>7</sub>	E <sub>3</sub>	E <sub>4</sub>	E <sub>6</sub>	F <sub>3</sub>	F <sub>5</sub>

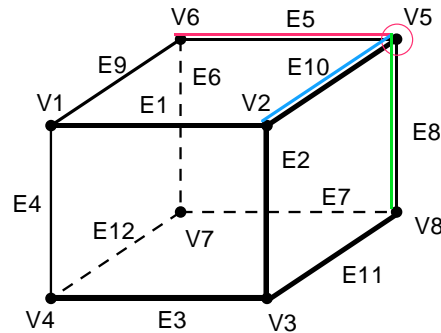
- look up vertex  $v_5$  in vertex table and find edge  $E_5$
- look up edge  $E_5$  in edge table and since  $v_5=VSTART(E_5)$ , next edge is  $ENCCW(E_5)=E_{10}$



## CCW EDGES MEETING AT A VERTEX

- look up vertex  $v$  in face table and find an edge  $E$
  - find  $E$  in edge table; repeat until read  $E$  again
    - if  $v=VSTART(E)$  then next edge is  $ENCCW(E)$
    - else  $v=VEND(E)$  and next edge is  $ENCW(E)$
- Ex: get edges meeting at  $v_5$  in counterclockwise order

VERTEX	X	Y	Z	ESTART
V <sub>1</sub>	X <sub>1</sub>	Y <sub>1</sub>	Z <sub>1</sub>	E <sub>1</sub>
V <sub>2</sub>	X <sub>2</sub>	Y <sub>2</sub>	Z <sub>2</sub>	E <sub>2</sub>
V <sub>3</sub>	X <sub>3</sub>	Y <sub>3</sub>	Z <sub>3</sub>	E <sub>3</sub>
V <sub>4</sub>	X <sub>4</sub>	Y <sub>4</sub>	Z <sub>4</sub>	E <sub>4</sub>
V <sub>5</sub>	X <sub>5</sub>	Y <sub>5</sub>	Z <sub>5</sub>	E <sub>5</sub>
V <sub>6</sub>	X <sub>6</sub>	Y <sub>6</sub>	Z <sub>6</sub>	E <sub>6</sub>
V <sub>7</sub>	X <sub>7</sub>	Y <sub>7</sub>	Z <sub>7</sub>	E <sub>7</sub>
V <sub>8</sub>	X <sub>8</sub>	Y <sub>8</sub>	Z <sub>8</sub>	E <sub>8</sub>



EDGE	VSTART	VEND	EPCW	ENCW	EPCCW	ENCCW	FCW	FCCW
E <sub>1</sub>	V <sub>1</sub>	V <sub>2</sub>	E <sub>4</sub>	E <sub>2</sub>	E <sub>10</sub>	E <sub>9</sub>	F <sub>1</sub>	F <sub>4</sub>
E <sub>2</sub>	V <sub>2</sub>	V <sub>3</sub>	E <sub>1</sub>	E <sub>3</sub>	E <sub>11</sub>	E <sub>10</sub>	F <sub>1</sub>	F <sub>6</sub>
E <sub>3</sub>	V <sub>3</sub>	V <sub>4</sub>	E <sub>2</sub>	E <sub>4</sub>	E <sub>12</sub>	E <sub>11</sub>	F <sub>1</sub>	F <sub>3</sub>
E <sub>4</sub>	V <sub>4</sub>	V <sub>1</sub>	E <sub>3</sub>	E <sub>1</sub>	E <sub>9</sub>	E <sub>12</sub>	F <sub>1</sub>	F <sub>5</sub>
E <sub>5</sub>	V <sub>5</sub>	V <sub>6</sub>	E <sub>8</sub>	E <sub>6</sub>	E <sub>9</sub>	E <sub>10</sub>	F <sub>2</sub>	F <sub>4</sub>
E <sub>6</sub>	V <sub>6</sub>	V <sub>7</sub>	E <sub>5</sub>	E <sub>7</sub>	E <sub>12</sub>	E <sub>9</sub>	F <sub>2</sub>	F <sub>5</sub>
E <sub>7</sub>	V <sub>7</sub>	V <sub>8</sub>	E <sub>6</sub>	E <sub>8</sub>	E <sub>11</sub>	E <sub>12</sub>	F <sub>2</sub>	F <sub>3</sub>
E <sub>8</sub>	V <sub>8</sub>	V <sub>5</sub>	E <sub>7</sub>	E <sub>5</sub>	E <sub>10</sub>	E <sub>11</sub>	F <sub>2</sub>	F <sub>6</sub>
E <sub>9</sub>	V <sub>1</sub>	V <sub>6</sub>	E <sub>1</sub>	E <sub>5</sub>	E <sub>6</sub>	E <sub>4</sub>	F <sub>4</sub>	F <sub>5</sub>
E <sub>10</sub>	V <sub>5</sub>	V <sub>2</sub>	E <sub>5</sub>	E <sub>1</sub>	E <sub>2</sub>	E <sub>8</sub>	F <sub>4</sub>	F <sub>6</sub>
E <sub>11</sub>	V <sub>3</sub>	V <sub>8</sub>	E <sub>3</sub>	E <sub>7</sub>	E <sub>8</sub>	E <sub>2</sub>	F <sub>3</sub>	F <sub>6</sub>
E <sub>12</sub>	V <sub>7</sub>	V <sub>4</sub>	E <sub>7</sub>	E <sub>3</sub>	E <sub>4</sub>	E <sub>6</sub>	F <sub>3</sub>	F <sub>5</sub>

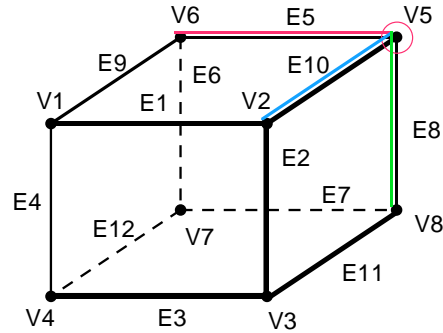
- look up vertex  $v_5$  in vertex table and find edge  $E_5$
- look up edge  $E_5$  in edge table and since  $v_5=VSTART(E_5)$ , next edge is  $ENCCW(E_5)=E_{10}$
- look up edge  $E_{10}$  in edge table and since  $v_5=VSTART(E_{10})$ , next edge is  $ENCCW(E_{10})=E_8$



## CCW EDGES MEETING AT A VERTEX

- look up vertex  $v$  in face table and find an edge  $E$
  - find  $E$  in edge table; repeat until read  $E$  again
    - if  $v=VSTART(E)$  then next edge is  $ENCCW(E)$
    - else  $v=VEND(E)$  and next edge is  $ENCW(E)$
- Ex: get edges meeting at  $v_5$  in counterclockwise order

VERTEX	X	Y	Z	ESTART
V <sub>1</sub>	X <sub>1</sub>	Y <sub>1</sub>	Z <sub>1</sub>	E <sub>1</sub>
V <sub>2</sub>	X <sub>2</sub>	Y <sub>2</sub>	Z <sub>2</sub>	E <sub>2</sub>
V <sub>3</sub>	X <sub>3</sub>	Y <sub>3</sub>	Z <sub>3</sub>	E <sub>3</sub>
V <sub>4</sub>	X <sub>4</sub>	Y <sub>4</sub>	Z <sub>4</sub>	E <sub>4</sub>
V <sub>5</sub>	X <sub>5</sub>	Y <sub>5</sub>	Z <sub>5</sub>	E <sub>5</sub>
V <sub>6</sub>	X <sub>6</sub>	Y <sub>6</sub>	Z <sub>6</sub>	E <sub>6</sub>
V <sub>7</sub>	X <sub>7</sub>	Y <sub>7</sub>	Z <sub>7</sub>	E <sub>7</sub>
V <sub>8</sub>	X <sub>8</sub>	Y <sub>8</sub>	Z <sub>8</sub>	E <sub>8</sub>



EDGE	VSTART	VEND	EPCW	ENCW	EPCCW	ENCCW	FCW	FCCW
E <sub>1</sub>	V <sub>1</sub>	V <sub>2</sub>	E <sub>4</sub>	E <sub>2</sub>	E <sub>10</sub>	E <sub>9</sub>	F <sub>1</sub>	F <sub>4</sub>
E <sub>2</sub>	V <sub>2</sub>	V <sub>3</sub>	E <sub>1</sub>	E <sub>3</sub>	E <sub>11</sub>	E <sub>10</sub>	F <sub>1</sub>	F <sub>6</sub>
E <sub>3</sub>	V <sub>3</sub>	V <sub>4</sub>	E <sub>2</sub>	E <sub>4</sub>	E <sub>12</sub>	E <sub>11</sub>	F <sub>1</sub>	F <sub>3</sub>
E <sub>4</sub>	V <sub>4</sub>	V <sub>1</sub>	E <sub>3</sub>	E <sub>1</sub>	E <sub>9</sub>	E <sub>12</sub>	F <sub>1</sub>	F <sub>5</sub>
E <sub>5</sub>	V <sub>5</sub>	V <sub>6</sub>	E <sub>8</sub>	E <sub>6</sub>	E <sub>9</sub>	E <sub>10</sub>	F <sub>2</sub>	F <sub>4</sub>
E <sub>6</sub>	V <sub>6</sub>	V <sub>7</sub>	E <sub>5</sub>	E <sub>7</sub>	E <sub>12</sub>	E <sub>9</sub>	F <sub>2</sub>	F <sub>5</sub>
E <sub>7</sub>	V <sub>7</sub>	V <sub>8</sub>	E <sub>6</sub>	E <sub>8</sub>	E <sub>11</sub>	E <sub>12</sub>	F <sub>2</sub>	F <sub>3</sub>
E <sub>8</sub>	V <sub>8</sub>	V <sub>5</sub>	E <sub>7</sub>	E <sub>5</sub>	E <sub>10</sub>	E <sub>11</sub>	F <sub>2</sub>	F <sub>6</sub>
E <sub>9</sub>	V <sub>1</sub>	V <sub>6</sub>	E <sub>1</sub>	E <sub>5</sub>	E <sub>6</sub>	E <sub>4</sub>	F <sub>4</sub>	F <sub>5</sub>
E <sub>10</sub>	V <sub>5</sub>	V <sub>2</sub>	E <sub>5</sub>	E <sub>1</sub>	E <sub>2</sub>	E <sub>8</sub>	F <sub>4</sub>	F <sub>6</sub>
E <sub>11</sub>	V <sub>3</sub>	V <sub>8</sub>	E <sub>3</sub>	E <sub>7</sub>	E <sub>8</sub>	E <sub>2</sub>	F <sub>3</sub>	F <sub>6</sub>
E <sub>12</sub>	V <sub>7</sub>	V <sub>4</sub>	E <sub>7</sub>	E <sub>3</sub>	E <sub>4</sub>	E <sub>6</sub>	F <sub>3</sub>	F <sub>5</sub>

- look up vertex  $v_5$  in vertex table and find edge  $E_5$
- look up edge  $E_5$  in edge table and since  $v_5=VSTART(E_5)$ , next edge is  $ENCCW(E_5)=E_{10}$
- look up edge  $E_{10}$  in edge table and since  $v_5=VSTART(E_{10})$ , next edge is  $ENCCW(E_{10})=E_8$
- look up edge  $E_8$  in edge table and since  $v_5=VEND(E_8)$ , next edge is  $ENCW(E_8)=E_5$ ; now, we are done!