

Portable Document Format

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Introduction

- Last lecture, looked at how the ideas for PDF evolved out of PostScript
- In part due to the spec of machines in 1991
- Based in part on the ‘Graph Binder’ technique

```

%Start building the page
-10 -10 translate
gsave
s24o setfont
leftmar 476 add top 18 add moveto (19)show s24 setfont (79)show
s10b setfont
(SCHEDULE E)leftmar -2.5 tshow
(Form 1040)leftmar -1.75 tshow
s6 setfont
(Department of the Treasury) leftmar -1 tshow
(Internal Revenue Service) leftmar -.3 tshow
s16b setfont
(Supplemental Income Schedule)208 -2.5 tshow
s8bc setfont
((From pensions and annuities, rents and royalties, partnerships, estates and
trusts, etc.))174 -1.3 tshow
(Attach to Form 1040) 188 -.33 tshow
(See Instructions for Schedule E (Form 1040).) 328 -.33 tshow
174 top 5 add triangle
314 top 5 add triangle
s7 setfont
(Name(s) as shown on Form 1040)leftmar 1 tshow
(Your social security number) 476 1 tshow
%draw all full horizontal lines.
0 fullrule
(Part I) leftmar top 38 sub bbox
s10b setfont
(Pension and Annuity Income.)102 3 tshow
s8 setfont
(If fully taxable, do not complete this part. Enter amount on Form 1040, line
17.)250 3 tshow
(For one pension or annuity not fully taxable, complete this part. If you have more
than one pension or annuity that is not fully taxable,)48 4 tshow
(attach a separate sheet listing each one with the appropriate data and enter
combined total of taxable parts on line 4.)48 4.8 tshow
2 fullrule
5 fullrule
s8b setfont
(1a)52 6 tshow
s8 setfont
(Did you and your employer contribute to the pension or annuity?)68 6 510 tshow
514 top 6 pica mul sub YesNoBox
s8b setfont
(b)57 7 tshow
s8c setfont
(If "yes," do you expect to get back your contribution within 3 years of the date
you receive the first payment?)68 7 510 tshow
514 top 7 pica mul sub YesNoBox
s8b setfont
(c)57 8 tshow
182 top 96 sub triangle
($.....)192 8 tshow
474 top 96 sub triangle
s8b setfont
(1d) 492 8 tshow
s8c setfont
(If "Yes," show: Your contribution)68 8 tshow
s8b setfont
(d) 288 8 tshow
s8c setfont
(Contribution received in prior years)294 8 470 tshow
s8b setfont
(2)52 9 tshow
(2)492 9 tshow
s8 setfont
(Amount received this year) 68 9 484 tshow
s8b setfont
(3)
52 10 tshow
(3)492 10 tshow
s8 setfont
(Amount on line 2 that is not taxable)68 10 484 tshow
s8b setfont
(4)52 11 tshow
(4) 492 11 tshow
s8 setfont
(Taxable part (subtract line 3 from line 2). Enter here and include in line 18
below)68 11 484 tshow
11 fullrule
(Part II) leftmar top 145 sub bbox
s10b setfont
(Rent and Royalty Income or Loss. If you need more space, attach a separate
sheet.)102 12 tshow

s8b setfont
(5a)52 13 tshow
s8c setfont
(Have you claimed expenses connected with your vacation home (or other dwelling
unit) rented to others (see Instructions?)68 13 512 tshow

```

**SCHEDULE E
(Form 1040)**

Department of the Treasury
Internal Revenue Service

Supplemental Income Schedule

(From pensions and annuities, rents and royalties, partnerships, estates and trusts, etc.)
▶ Attach to Form 1040 ▶ See Instructions for Schedule E (Form 1040).

1979

Name(s) as shown on Form 1040 _____ Your social security number _____

Part I Pension and Annuity Income. If fully taxable, do not complete this part. Enter amount on Form 1040, line 17.
For one pension or annuity not fully taxable, complete this part. If you have more than one pension or annuity that is not fully taxable, attach a separate sheet listing each one with the appropriate data and enter combined total of taxable parts on line 4.

1a Did you and your employer contribute to the pension or annuity?	<input type="checkbox"/> Yes <input type="checkbox"/> No
b If "yes," do you expect to get back your contribution within 3 years of the date you receive the first payment?	<input type="checkbox"/> Yes <input type="checkbox"/> No
c If "Yes," show: Your contribution ▶ \$.....	d Contribution received in prior years ▶ 1d _____
2 Amount received this year	2 _____
3 Amount on line 2 that is not taxable	3 _____
4 Taxable part (subtract line 3 from line 2). Enter here and include in line 18 below	4 _____

Part II Rent and Royalty Income or Loss. If you need more space, attach a separate sheet.

5a Have you claimed expenses connected with your vacation home (or other dwelling unit) rented to others (see Instructions)? Yes No

b If "yes," did you or a member of your family occupy the vacation home (or other dwelling unit) for more than 14 days during the tax year? Yes No

6a Did you elect to claim amortization (under section 191) or depreciation (under section 167(o)) for a rehabilitated certified historic structure (see instructions)? Yes No

b Amortizable basis (see Instructions) ▶ _____

(a) Property code (describe in Part V)	(b) Total amount of rents	(c) Total amount of royalties	(d) Depreciation (explain in Part VI) or depletion (attach computation)	(e) Other expenses (explain in Part VII)	(f) loss	(g) income
Property A.
Property B.
Property C.
Property D.
Property E.
7 Amounts from Form 4835..
8 Totals..	()
9 Total rent and royalty income or (loss). Combine amounts in columns (f) and (g), line 8. Enter here and include in line 18 below						9 ()

Part III Income or Losses from --		(b) Employer identification number	(c) loss	(d) income
(a) Name				
Partnerships	.....	.....	.....	.....

10 Add amounts in columns (c) and (d) and enter here		10 ()		
11 Combine amounts in column (c) and (d), line 10, and enter net income or (loss)		11 ()		
12 Additional first-year depreciation		12 ()		
13 Total Partnership income or (loss). Combine lines 11 and 12. Enter here and include in line 18 below		13 ()		
Estates or Trusts	.....	.....	.....	.....

14 Add amounts in columns (c) and (d) and enter here		14 ()		
15 Total estate or trust income or (loss). Combine amounts in columns (c) and (d), line 14. Enter here and include in line 18 below		15 ()		
Small Business Corporations	.....	.....	.....	.....

16 Add amount in columns (c) and (d) and enter here		16 ()		
17 Total small business corporation income or (loss). Combine amounts in columns (c) and (d), line 16. Enter here and include in line 18 below		17 ()		

Part IV

18 TOTAL income or (loss). Combine lines 4, 9, 13, 15, and 17. Enter here and on Form 1040, line 18. **18** _____

19 Enter your share of gross farming and fishing income applicable to Parts II and III. **19** _____ **E**

```

-10 -10 T
G
fff17 sf
522 734 M
(19)S
fff18 sf
(79)S
fff6 sf
46 748.0 M
(SCHEDULE E)S
46 739.0 M
(\(Form 1040\))S
fff8 sf
46 730 M
(Department of the Treasury)S
46 721.6 M
(Internal Revenue Service)S
fff16 sf
208 748.0 M
(Supplemental Income Schedule)S
fff13 sf
174 733.6 M
(\(From pensions and annuities, rents and royalties, partnerships, estates and trusts,
etc.\))S
188 721.96 M
(Attach to Form 1040)S
328 721.96 M
(See Instructions for Schedule E \(Form 1040\).)S
G
174 721 T
0 0 M
8 3.5 L
0 7 L
CP
F
GR
G
314 721 T
0 0 M
8 3.5 L
0 7 L
CP
F
GR
fff14 sf
46 706 M
(Name(s) as shown on Form 1040)S
476 706 M
(Your social security number)S
1 SL
N
580.0 716.0 M
46.0 716.0 L
SK
G
46 678 T
1 0 T
N
0 0 M
0 10 L
48 10 L
48 0 L
CP
F
1 SG
fff6 sf
12 2 M
(Part I)S
GR
fff6 sf
102 682 M
(Pension and Annuity Income.)S
fff9 sf
250 682 M
(If fully taxable, do not complete this part. Enter amount on Form 1040, line 17.)S
48 670 M
(For one pension or annuity not fully taxable, complete this part. If you have more than
one pension or annuity that is not fully taxable,)S
48 660.4 M
(attach a separate sheet listing each one with the appropriate data and enter combined
total of taxable parts on line 4.)S
1 SL
N
580.0 692.0 M
46.0 692.0 L
SK
1 SL
N
580.0 656.0 M
46.0 656.0 L
SK
fff10 sf
52 646 M

```

```

%Start building the page
-10 -10 translate
gsave
s24o setfont
leftmar 476 add top 18 add moveto (19)show s24 setfont
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(SCHEDULE E)leftmar -2.5 tshow
((Form 1040))leftmar -1.75 tshow
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(Department of the Treasury) leftmar -1 tshow
(Internal Revenue Service) leftmar -.3 tshow
s16b setfont
(Supplemental Income Schedule)208 -2.5 tshow
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5 fullrule
s8b setfont
(1a)52 6 tshow
s8 setfont
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514 top 6 pica mul sub YesNoBox
s8b setfont
(b)57 7 tshow
s8c setfont
(If "yes," do you expect to get back your contribution
you receive the first payment?)68 7 510 tlshow
514 top 7 pica mul sub YesNoBox
s8b setfont
(c)57 8 tshow
182 top 96 sub triangle
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474 top 96 sub triangle

```

```

-10 -10 T
G
fff17 sf
522 734 M
(19)S
fff18 sf
(79)S
fff6 sf
46 748.0 M
(SCHEDULE E)S
46 739.0 M
((Form 1040))S
fff8 sf
46 730 M
(Department of the Treasury)S
46 721.6 M
(Internal Revenue Service)S
fff16 sf
208 748.0 M
(Supplemental Income Schedule)S
fff13 sf
174 733.6 M
((From pensions and annuities, rents and royalties, partnerships, estates and trusts,
etc.))S
188 721.96 M
(Attach to Form 1040)S
328 721.96 M
(See Instructions for Schedule E (Form 1040).)S
G
174 721 T
0 0 M
8 3.5 L
0 7 L
CP
F
GR
G
314 721 T
0 0 M
8 3.5 L
0 7 L
CP
F
GR
fff14 sf
46 706 M
(Name(s) as shown on Form 1040)S
476 706 M
(Your social security number)S
1 SL
N
580.0 716.0 M
46.0 716.0 L
SK
G

```

Note how they've reduced things to single letters

PDF does the same thing with its operators -- they are generally single or double letters

Random Access

- But there is still another problem
- PostScript is linear, each page is rendered in sequence
- Not only that, we need to have rendered previous pages to ensure we are in the correct context
- Random Access to a specific page is a desirable feature

Removing the programatic operators makes the content displayable

Can see this in ghostview

Document Structuring Convention

- Adobe solved this in PostScript with the *Document Structuring Conventions*
- Uses comments to delimit each page
- Ensure that the interpreter state is reset before each page
- Software can then extract a single page based on the comments

Random Access

- But the DSC still did not allow for random access to any page
- So PDF takes a different approach
- Rather than being a sequence of operators
- PDF document is defined in as a collection of objects
- Objects are formed into structures (trees) to represent the document

(The graphical content streams are however a sequence of commands though)

PDF Objects

- Boolean
- Numbers
(Integer and Real)
- Strings
- Names
- Arrays
- Dictionaries
- Streams
- The `null` object

Very similar to those of PostScript

PDF Dictionaries

- PDF Dictionaries are functionally equivalent to PostScript Dictionaries
- Key-Value associative arrays
- But are declared rather than being built programmatically

PDF Dictionaries

- Dictionaries are begun by a <<
- And finished by >>
- Inside these operators the key is defined by a name
- Immediately followed by the value (which can be of any object type)

PDF Dictionary

```
<<  
  /Type      /Page  
  /CropBox   [ 0 0 612 792 ]  
  /MediaBox  [ 0 0 612 792 ]  
  /Rotate    0  
  /Contents  13 0 R  
  /Parent    8 0 R  
  /Resources 16 0 R  
>>
```

PDF Dictionaries are used to build up the structures in a PDF
Can also reference objects indirectly

Indirect Objects

- Objects can either be *direct*
- Or *indirect*, referenced by a unique identifier
 - An object number
 - A generation number (starts off as zero)
- Defined using the `obj/endobj` keywords

Direct objects just use their value

Object numbers usually sequential through the file (but not necessarily)

PDF Dictionary

```
12 0 obj  
(Brillig)  
endobj
```

defines a string with the object number 12 and generation number 0
Can use 12 0 R to refer to it elsewhere

Referencing an Object

- Can use the `R` keyword to reference it elsewhere: `12 0 R`
- Semantics are the same whether the object is directly or indirectly
- Although some objects *must* be indirect
- PDF is a graph not a tree

PDF Dictionary

```
<<  
  /Type      /Page  
  /CropBox   [ 0 0 612 792 ]  
  /MediaBox  [ 0 0 612 792 ]  
  /Rotate    0  
  /Contents  13 0 R  
  /Parent    8 0 R  
  /Resources 16 0 R  
>>
```

So /Contents is defined as a reference to another object called 13 0 usually a stream object

PDF streams

- Streams don't have a direct analogue in PostScript
- Used to hold binary data
- Can be read incrementally
- Used to hold the page data as *content streams*

PDF Streams

- Two parts
 - Stream data
 - Dictionary describing the stream

PDF Dictionary

```
.. dictionary ..  
stream  
data  
endstream
```

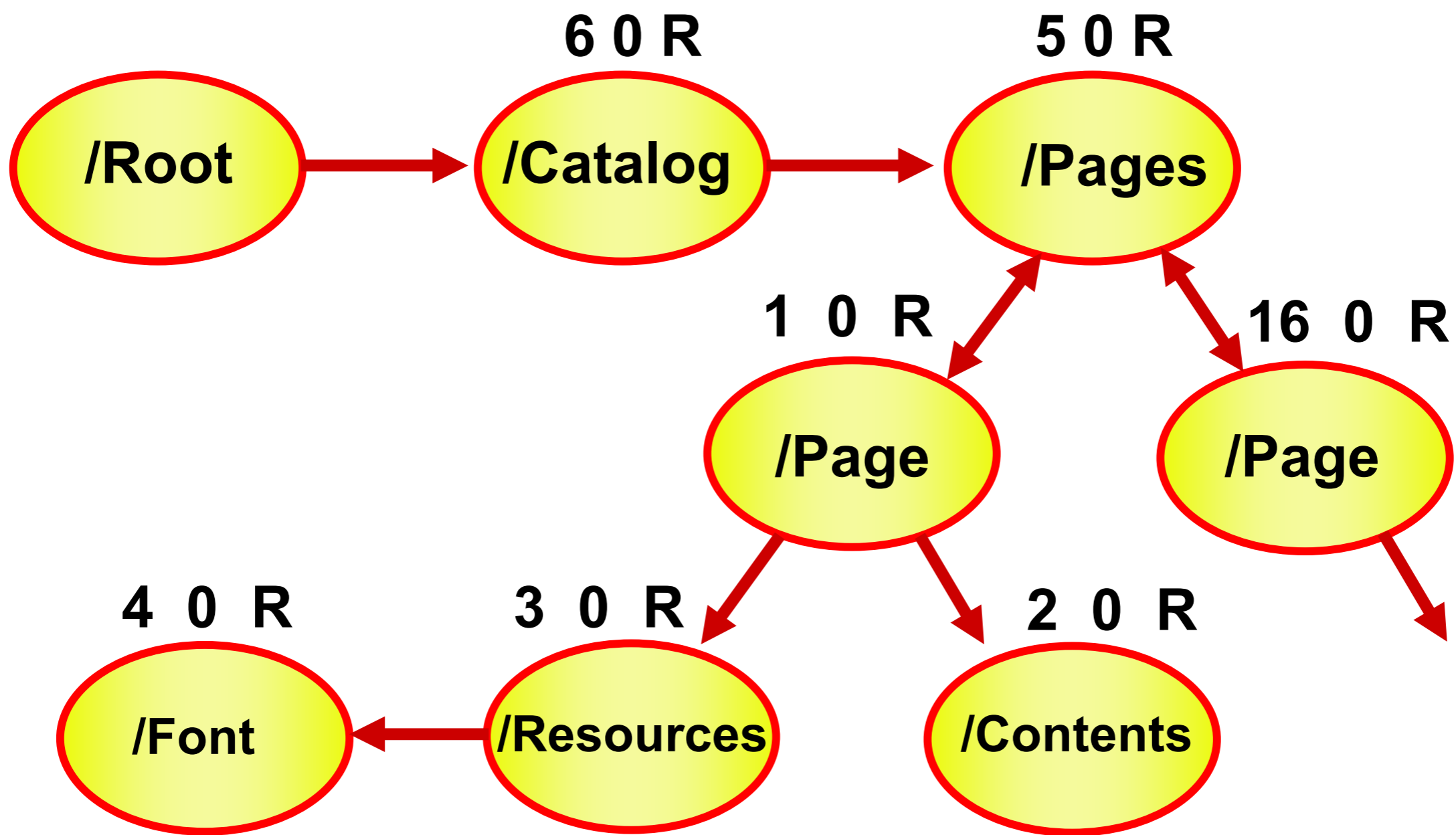
stream/endstream keywords (must be on a blank line) are used to denote the start end of a stream

Note how it starts with a dictionary -- you don't know whether you are parsing a dictionary or stream until after the end

Stream Dictionary

- Required to have a `/Length` key specifying the number of bytes (between `stream` and `endstream`)
- Can also have a `/Filter` key which describes any compression, encryption etc. applied to the stream
- **Note** `/Length` refers to encoded length of stream

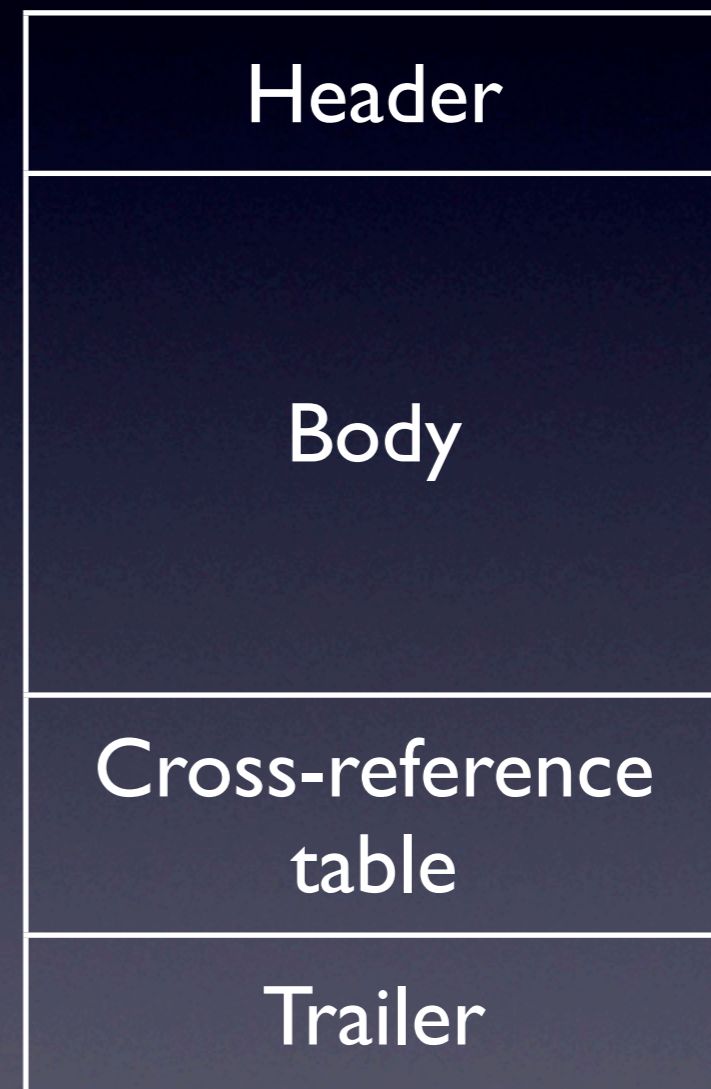
Not including any EOL before the endstream



Objects in PDF form a graph, but how are they stored in the files

PDF File Structure

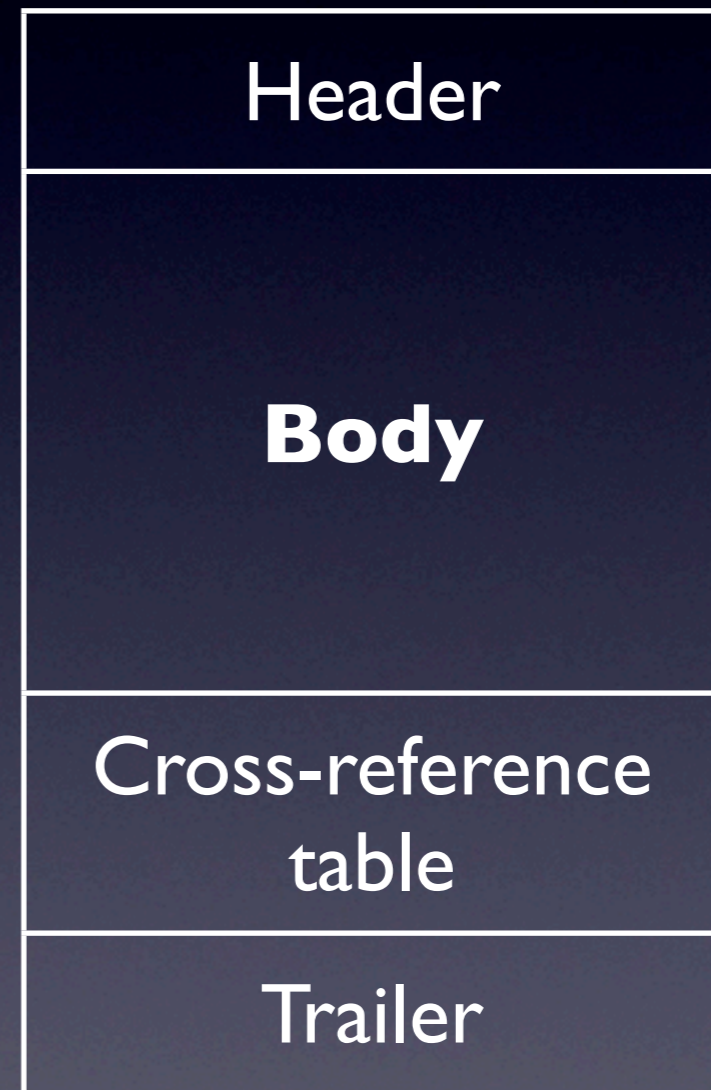
- PDF files are constructed from four parts
- The header contains the version of the PDF
`%PDF-1.4`
- Followed by four bytes of high-ASCII to force the file to be treated as binary



% used to mean start of comment

PDF Body

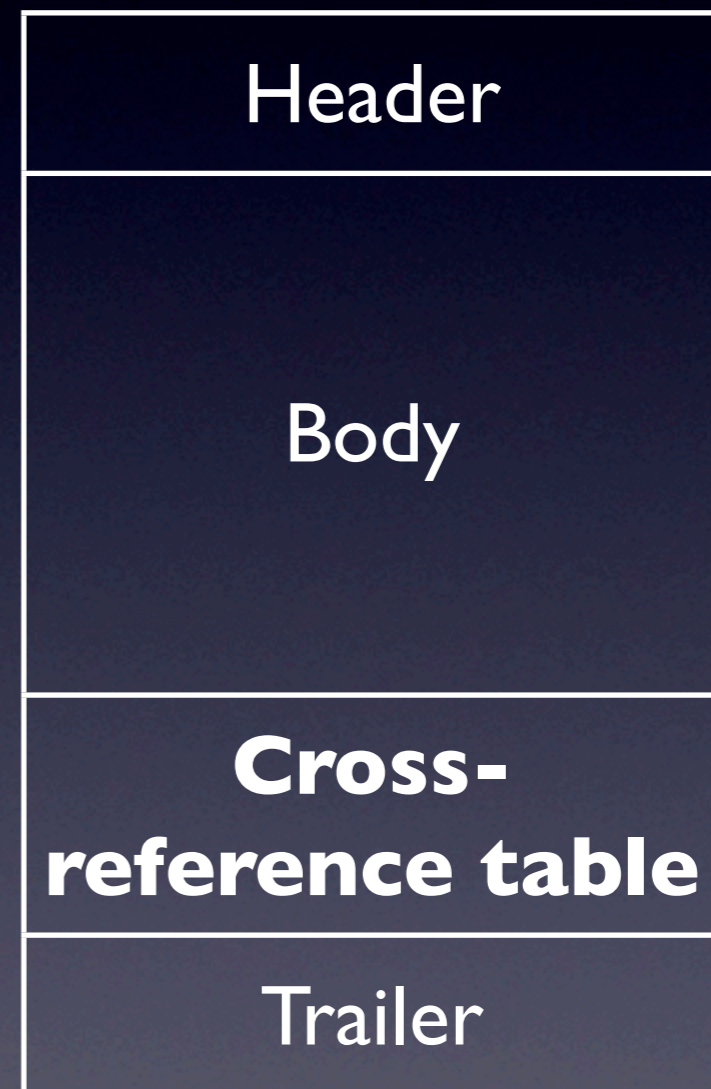
- The body contains the definition of all the COS objects in the PDF
- The indirect objects follow one after another in this section
- Direct objects are just values inside indirect ones



% used to mean start of comment

Cross-reference table

- Designed to allow quick access to any object in the file
- Maps object id to the position within the file
- Enables access to PDF without parsing all of it
- Even if bigger than memory...



% used to mean start of comment

Cross-reference table

xref ←———— marks start of xref

0 10

0000000000 65535 f

0000000513 00000 n

0000000016 00000 n

0000000146 00000 n

0000000433 00000 n

0000000362 00000 n

0000000593 00000 n

0000000240 00000 n

0000000674 00000 n

0000000723 00000 n

Cross-reference table

xref

0 10



first object number
and object count

0000000000	65535	f
0000000513	00000	n
0000000016	00000	n
0000000146	00000	n
0000000433	00000	n
0000000362	00000	n
0000000593	00000	n
0000000240	00000	n
0000000674	00000	n
0000000723	00000	n

Can have multiple cross-ref sections in the table

Cross-reference table

xref

0 10

0000000000 65535 f

0000000513 00000 n ← Entry for object #1

0000000016 00000 n

0000000146 00000 n

0000000433 00000 n

0000000362 00000 n

0000000593 00000 n

0000000240 00000 n

0000000674 00000 n

0000000723 00000 n

Object zero is special, forms a linked list of free objects in the

Cross-reference Entry

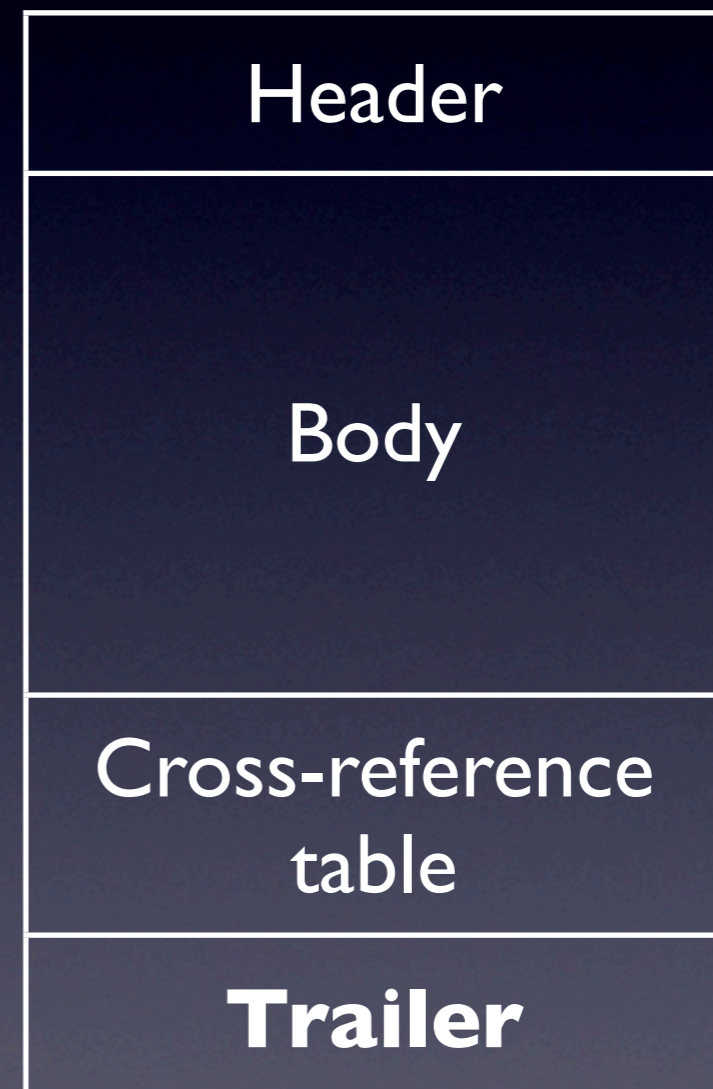
`nnnnnnnnnnn ggggg n eol`

- Always 20 bytes long
- `nnnnnnnnnnn` is a 10-byte decimal offset to the start of the object
- `ggggg` is a 5-digit generation
- `n` is keyword meaning the object is in-use

`n` can also be an `f` to mark the object as free -- but I've never seen this in use

Trailer

- Allows quick access to the xref table and certain special objects
- Consists of
 - Trailer Dictionary
 - Pointer to start of xref table
 - End of file marker



% used to mean start of comment

Trailer

```
trailer ←———— marks start of  
<< trailer  
/Size 10  
/Root 8 0 R  
/Info 9 0 R  
/ID  
[<9722da6a96465761554276269cb4b31f><9722d  
a6a96465761554276269cb4b31f>]  
>>  
startxref  
857  
%%EOF
```

Trailer

```
trailer
<<
/Size 10 ←
/Root 8 0 R
/Info 9 0 R
/ID
[<9722da6a96465761554276269cb4b31f><9722d
a6a96465761554276269cb4b31f>]
>>
startxref
857
%%EOF
```

Required, marks
the total number
of entries in the
xref table

Trailer

```
trailer
```

```
<<
```

```
/Size 10
```

```
/Root 8 0 R
```

```
/Info 9 0 R
```

```
/ID
```

```
[<9722da6a96465761554276269cb4b31f><9722d  
a6a96465761554276269cb4b31f>]
```


```
>>
```

```
startxref
```

```
857
```

```
%%EOF
```

Required,
reference to the
PDF Catalog



Trailer

```
trailer
```

```
<<
```

```
/Size 10
```

```
/Root 8 0 R
```

```
/Info 9 0 R
```

```
/ID
```

```
[<9722da6a96465761554276269cb4b31f><9722d  
a6a96465761554276269cb4b31f>]
```

```
>>
```

```
startxref
```



```
857
```

```
%%EOF
```

keyword denoting
the address of the
start of the xref

Trailer

```
trailer
<<
/Size 10
/Root 8 0 R
/Info 9 0 R
/ID
[<9722da6a96465761554276269cb4b31f><9722d
a6a96465761554276269cb4b31f>]
>>
startxref
857
%%EOF ←———— End of File Marker
```

Putting this altogether gives us a PDF like this...

```

%PDF-1.2      4 0 obj      >>
%âãïó        <<      endobj
2 0 obj      /Type /Font      8 0 obj      0000000140 00000 n
<< /Length 74 /Subtype /      <<      0000000427 00000 n
>>          Type1      /Type /Catalog      0000000356 00000 n
stream      /Name /F1      /Pages 6 0 R      0000000587 00000 n
BT          /BaseFont /      >>      0000000234 00000 n
/F1 1 Tf      Helvetica      endobj      0000000668 00000 n
36 0 0 36 300 >>      9 0 obj      0000000717 00000 n
300 Tm      <<      trailer
0 g          1 0 obj      <<
0 Tc 0 Tw      /CreationDate      /Size 10
(Hello World) /Type /Page      (D:      /Root 8 0 R
Tj          /Parent 6 0 R      20130225112108 /Info 9 0 R
ET          /Resources 3 0      )      /ID
endstream      R      /Producer      [<7b67e06cbb92
endobj      /Contents 2 0      (Acrobat      a9ae2dba172c60
3 0 obj      R      Distiller      c1b8e7><7b67e0
<<          >>      Command 3.01      6cbb92a9ae2dba
/ProcSet [/      endobj      for Solaris      172c60c1b8e7>]
PDF /Text ]      6 0 obj      \ (SPARC\ )      >>
/Font <<      <<          >>      startxref
/F1 4 0 R      /Type /Pages      endobj      851
>>          /Kids [1 0 R]      xref      %%EOF
>>          /Count 1      0 10
endobj      /MediaBox [0 0      0000000000 65535 f
          594 842]      0000000507 00000 n
          0000000016 00000 n

```

This has been tweaked to show it all on screen so some bits are missing
And the xref is wrong...
Highlight how it references other objects

Parsing PDF

- Easiest way to understand PDF is to try to parse it
- Firstly, check the version at the start of the file
- Acrobat will check for %PDF.. in the first 1K of the file or so to allow for corruption
- Then start parsing from the end of the file

Parsing PDF

- Locate the %%EOF

```
xref
0 10
0000000000 65535 f
0000000007 00000 n
0000000016 00000 n
00000000140 00000 n
00000000427 00000 n
00000000356 00000 n
00000000587 00000 n
00000000234 00000 n
00000000668 00000 n
00000000717 00000 n
trailer
<<
/Size 10
/Root 8 0 R
/Info 9 0 R
/ID [...]
>>
startxref
851
%%EOF
```

Parsing PDF

- Locate the `%%EOF`
- Walk back from this to find the `startxref`

```
xref
0 10
0000000000 65535 f
0000000000 00000 n
0000000016 00000 n
0000000140 00000 n
0000000427 00000 n
0000000356 00000 n
0000000587 00000 n
0000000234 00000 n
0000000668 00000 n
0000000717 00000 n
trailer
<<
/Size 10
/Root 8 0 R
/Info 9 0 R
/ID [...]
>>
startxref
851
%%EOF
```

Parsing PDF

- Locate the %%EOF
- Walk back from this to find the startxref
- Then read the location

```
xref
0 10
0000000000 65535 f
0000000000 00000 n
0000000016 00000 n
0000000140 00000 n
0000000427 00000 n
0000000356 00000 n
0000000587 00000 n
0000000234 00000 n
0000000668 00000 n
0000000717 00000 n
trailer
<<
/Size 10
/Root 8 0 R
/Info 9 0 R
/ID [...]
>>

startxref
851
%%EOF
```

Parsing PDF

- Locate the %%EOF
- Walk back from this to find the startxref
- Then read the location
- And seek to that location

```
xref
0 10
0000000000 65535 f
0000000000 00000 n
0000000016 00000 n
0000000140 00000 n
0000000427 00000 n
0000000356 00000 n
0000000587 00000 n
0000000234 00000 n
0000000668 00000 n
0000000717 00000 n
trailer
<<
/Size 10
/Root 8 0 R
/Info 9 0 R
/ID [...]
>>
startxref
851
%%EOF
```

Parsing PDF

- Locate the %%EOF
- Walk back from this to find the startxref
- Then read the location
- And seek to that location

```
xref
0 10
0000000000 65535 f
0000000007 00000 n
0000000016 00000 n
00000000140 00000 n
00000000427 00000 n
00000000356 00000 n
00000000587 00000 n
00000000234 00000 n
00000000668 00000 n
00000000717 00000 n
trailer
<<
/Size 10
/Root 8 0 R
/Info 9 0 R
/ID [...]
>>
startxref
851
%%EOF
```


Parsing PDF

- Locate the %%EOF
- Walk back from this to find the startxref
- Then read the location
- And seek to that location

```
xref
0 10
0000000000 65535 f
0000000507 00000 n
0000000016 00000 n
0000000140 00000 n
0000000427 00000 n
0000000356 00000 n
0000000587 00000 n
0000000234 00000 n
0000000668 00000 n
0000000717 00000 n
trailer
<<
/Size 10
/Root 8 0 R
/Info 9 0 R
/ID [...]
>>
```

Parsing PDF

- Locate the %%EOF
- Walk back from this to find the startxref
- Then read the location
- And seek to that location
- And read the xref table

```
xref
0 10
0000000000 65535 f
0000000507 00000 n
0000000016 00000 n
0000000140 00000 n
0000000427 00000 n
0000000356 00000 n
0000000587 00000 n
0000000234 00000 n
0000000668 00000 n
0000000717 00000 n
trailer
<<
/Size 10
/Root 8 0 R
/Info 9 0 R
/ID [...]
>>
```

Parsing PDF

- Now know the location of every object in the PDF body
- And can parse the trailer

```
xref
0 10
0000000000 65535 f
0000000507 00000 n
0000000016 00000 n
0000000140 00000 n
0000000427 00000 n
0000000356 00000 n
0000000587 00000 n
0000000234 00000 n
0000000668 00000 n
0000000717 00000 n
trailer
<<
/Size 10
/Root 8 0 R
/Info 9 0 R
/ID [...]
>>
```

Parsing PDF

- Now know the location of every object in the PDF body
- And can parse the trailer
- This tells us which object is the PDF catalog
- Can use the offsets in the xref table to go and parse that object

```
xref
0 10
0000000000 65535 f
0000000050 00000 n
0000000016 00000 n
0000000140 00000 n
0000000427 00000 n
0000000356 00000 n
0000000587 00000 n
0000000234 00000 n
0000000668 00000 n
0000000717 00000 n
trailer
<<
/Size 10
/Root 8 0 R
/Info 9 0 R
/ID [...]
>>
startxref
851
%%EOF
```

Now use Voyeur to walk around some of the PDF objects