**Chapter 10**

**10.1**

(a) p-type; inversion

(b) p-type; depletion

(c) p-type; accumulation

(d) n-type; inversion

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.2**

1. (i)



V



cm



or m



(ii)



V



cm



or m



1. V



so cm



(i)



V



cm



or m



(ii)



V



cm



or m



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.3**



1st approximation: Let V



Then



cm



2nd approximation:

V



Then



cm



1. V



V



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.4**

p-type silicon

(a) Aluminum gate



We have



V



Then



or

V



(b) polysilicon gate



or

V



(c) polysilicon gate



or

V



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.5**

V



V



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.6**

1. cm



1. Not possible - is always positive.



1. cm



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.7**

From Problem 10.5, V



F/cm



V



F/cm



V



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.8**

1. V



V



(b)

F/cm



(i)



V



(ii)



V



1. V



F/cm



(i)



V



(ii)



V



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.9**



where

V



Then



or

V



Now



or



We have



or

F/cm



So now



C/cm



or

cm



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.10**

V



cm



C/cm



F/cm



1. n poly gate on p-type: V



V



1. p poly gate on p-type: V



V



1. Al gate on p-type: V



V



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.11**

V



cm



C/cm



F/cm



1. n poly gate on n-type: V



V



1. p poly gate on n-type: V



V



1. Al gate on n-type: V



V



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.12**

V



The surface potential is

V



We have

V



Now



We obtain



or

cm



Then



or

C/cm



We also find



or

F/cm



Then



or

V



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.13**



F/cm



C/cm



By trial and error, let cm.



Now



V



cm



C/cm



V



Then



Then VV



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.14**



F/cm



C/cm



By trial and error, let cm



Now



V



cm



C/cm



V



Then



Then V, which is within the specified value.



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.15**

We have F/cm



C/cm



By trial and error, let cm



Now



V



cm



C/cm



V



Then



V



Then V V which meets the specification.



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.16**

1. V



F/cm



Now



V



V



cm



C/cm



Now



or V



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.17**

(a) We have n-type material under the gate, so



where

V



Then



or

cmm



(b)



For an polysilicon gate,



or

V



Now



or

C/cm



We have

C/cm



We now find



or

V



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.18**

(b)



where

V



and

V



Then



or

V



(c) For



We find



or

cmm



Now



or

C/cm



Then



or

VV



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.19**

Plot

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.20**

Plot

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.21**

Plot

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.22**

Plot

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.23**

1. For Hz (low freq),



F/cm



F/cm



Now

V



cm



Then



F/cm



(inv)F/cm



1. MHz (high freq),



F/cm (unchanged)



F/cm (unchanged)



F/cm (unchanged)



(inv)F/cm



1. V



Now



C/cm



V



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.24**

1. Hz (low freq),



F/cm



F/cm



Now

V



cm



Then



F/cm



(inv)F/cm



1. MHz (high freq),



F/cm (unchanged)



F/cm (unchanged)



F/cm (unchanged)



(inv)F/cm



1. V



Now



C/cm



Then



V



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.25**

The amount of fixed oxide charge at *x* is

C/cm



By lever action, the effect of this oxide charge

on the flatband voltage is



If we add the effect at each point, we must

integrate so that



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.26**

(a) We have



Then



or



or

V



(b)

We have



Now



or



or

V



(c)



We find



or



Now



which becomes



Then



or V



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.27**

Sketch

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.28**

Sketch

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.29**

(b)



or

V



(c) Apply V, V



For V,



n-side:



at , then



so

for



In the oxide, , so



constant. From the



boundary conditions, in the oxide



In the p-region,



at , then



At ,



So that



Since , then



The potential is



For zero bias, we can write



where are the voltage drops across



the n-region, the oxide, and the p-region,

respectively. For the oxide:



For the n-region:



Arbitrarily, set at , then



so that



At , which is the voltage



drop across the n-region. Because of

symmetry, . Then for zero bias, we



have



which can be written as



or



Solving for , we obtain



If we apply a voltage , then replace by



, so



We find



which yields

cm



Now



or

V



We also find



or

V



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.30**

(a) n-type

(b) We have

F/cm



Also



or

cmnm



(c)



or



which yields

C/cmcm



(d)



which yields

F/cm



or

pF



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.31**

(a) Point 1: Inversion

2: Threshold

3: Depletion

4: Flat-band

5: Accumulation

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.32**

We have



Now let , so



For a p-type substrate, is a



negative value, so we can write



Using the definition of threshold voltage ,



we have



At saturation



which then makes equal to zero at the



drain terminal.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.33**



mA



mA



1. Same as (b), mA



mA



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.34**



mA



mA



mA



1. Same as (c), mA



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.35**



mA



mA



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.36**

1. Assume biased in saturation region



V



Note: VV



So the transistor is biased in the saturation region.



mA



or

mA



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.37**

F/cm



A/V=1.111 mA/V



1. ,



V, V,



mA



V, V,



mA



V, V,



mA



V, V,



mA



(c) for V



V,



mA



V,



mA



V,



mA



V,



mA



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.38**



F/cm



A/V=0.961 mA/V



1. ,



V, V



mA



V, V



mA



V, V



mA



V, V



mA



(c) for V



V



mA



V



mA



V



mA



V



mA



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.39**

1. From Problem 10.37,mA/V



For V,



, V



mA



V, V



mA



V, V



mA



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.40**

Sketch

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.41**

Sketch

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.42**

We have



so that



Since , the transistor is always



biased in the saturation region. Then



where, from Problem 10.37,

mA/Vand V



Then

|  | (mA) |
| --- | --- |
| 0  1  2  3  4  5 | 0  0.336  2.67  7.22  14.0  23.0 |

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.43**

From Problem 10.38, mA/V



For V,



For V,



For V,



mA/V



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.44**



mA/V



mA



mA



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.45**

We find that V



Now



where



or

F/cm



We are given . From the graph, for



V, we have



,



then



or



or



which yields

cm/V-s



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.46**

(a)



or

V



(b)



so



which yields

A/V



(c)

V



so



or

A



(d)



or

A



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.47**



F/cm



(i)



A/V



or A/V



(ii)



1. (i)



A/V



or A/V



(ii)



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.48**

From Problem 10.37, mA/V



so mA/V



so mA/V



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.49**

From Problem 10.38, mA/V



or mA/V



or mA/V



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.50**



Now



F/cm



Then

V



1. V



(i)



cm



C/cm



V



A/V



or mA/V



For , V



For



V



1. (i) For , V



(ii) V,



V



V



(iii) V,



V



V



(iv) V,



V



V



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.51**

V



or

V



Now



V



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.52**



F/cm



V



1. V



V



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.53**

(a) poly-to-p-type V



V



also



or

cm



Now



or

C/cm



Also



or

F/cm



We find

C/cm



Then



or

V



(b) For NMOS, apply and shifts in a



positive direction, so for , we want V.



So



or



or



which yields

V



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.54**

Plot

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.55**

(a)



or

mS



Now



which yields



or

k



(b) For V, mS



Then

mS



or



which is a 12% reduction.

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.56**

(a) The ideal cutoff frequency for no overlap

capacitance is,



or

GHz



(b) Now



where



We find



or

F



Also



or

S



Then



or

F



Now



or

F



We now find



or

GHz



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**10.57**

(a) For the ideal case



or

GHz



(b) With overlap capacitance (using the

values from Problem 10.56),



We find



or

S



We have



or

F



Then



or

GHz



\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_