

SESSION THREE

Bond Math



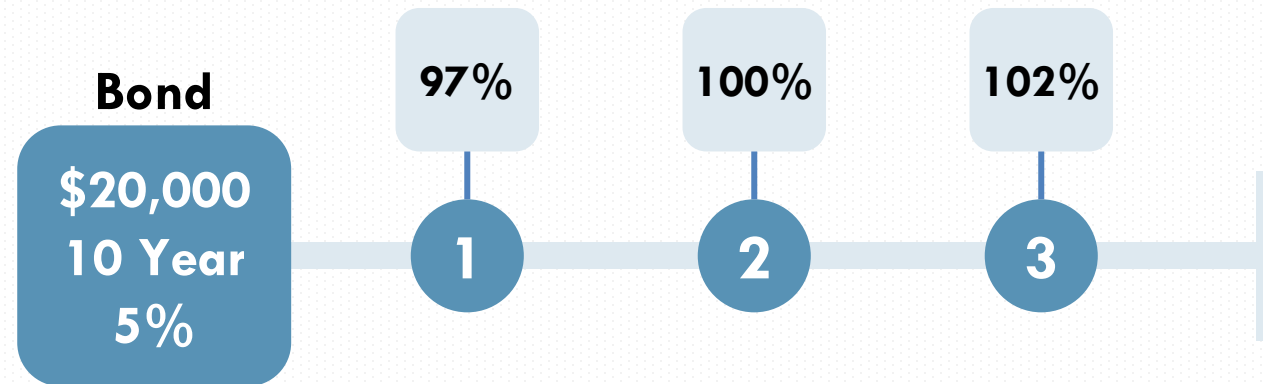
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What is a Bond Price?

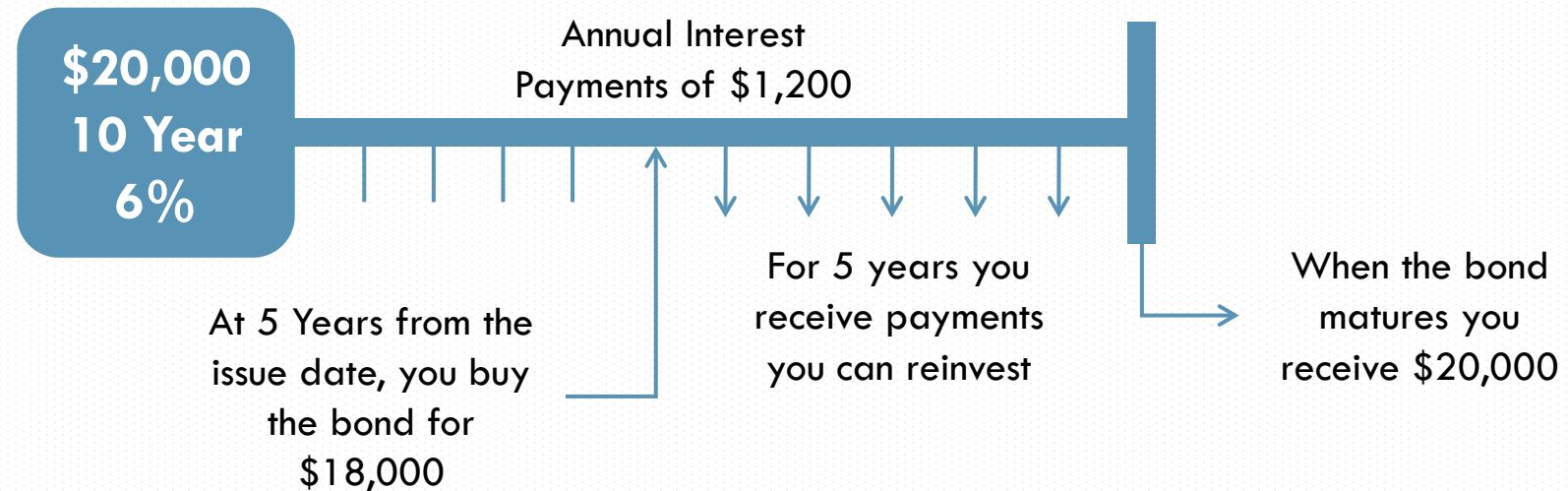
- The price investors are willing to pay to buy a bond which changes with daily market movements
- Price is expressed as a percentage (i.e. 97%, 102%) of the face value (i.e. \$20,000)



- 1) Price = $0.97 \times \$20,000$ or \$19,400
- 2) Price = $1.00 \times \$20,000$ or \$20,000
- 3) Price = $1.02 \times \$20,000$ or \$20,400

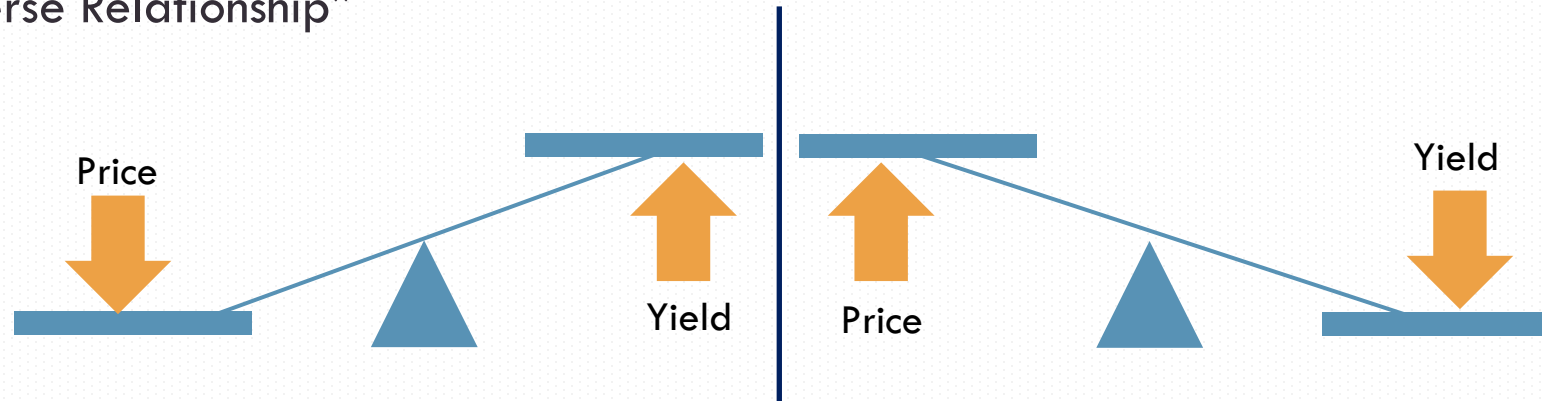
What is a Bond Yield?

- Yield is the return on a bond/investment, expressed as an annual percentage
- A 6% yield means that the bond/investment averages 6% return each year
- A bond yield is based on coupon payments the investor receives over time and the price paid to buy the bond



What is the Relationship Between a Bond Price & its Yield?

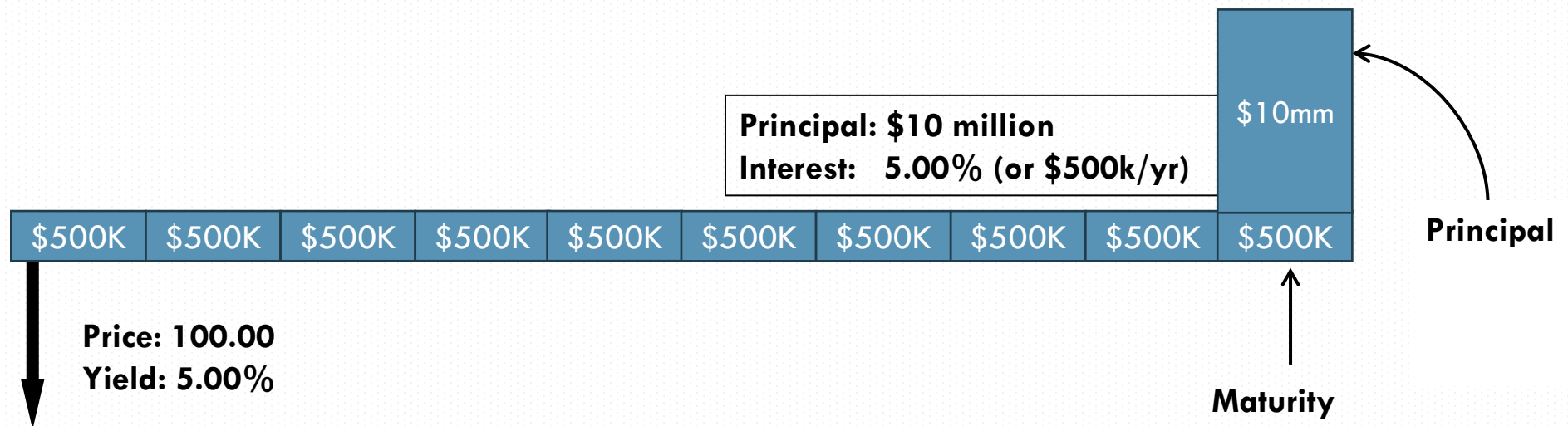
- One goes up & the other goes down
- “Inverse Relationship”



- Factors impacting price & yield
 - Current market & economic conditions
 - Inflation
 - Risk of the bond’s repayment, i.e., its credit rating

Terminology

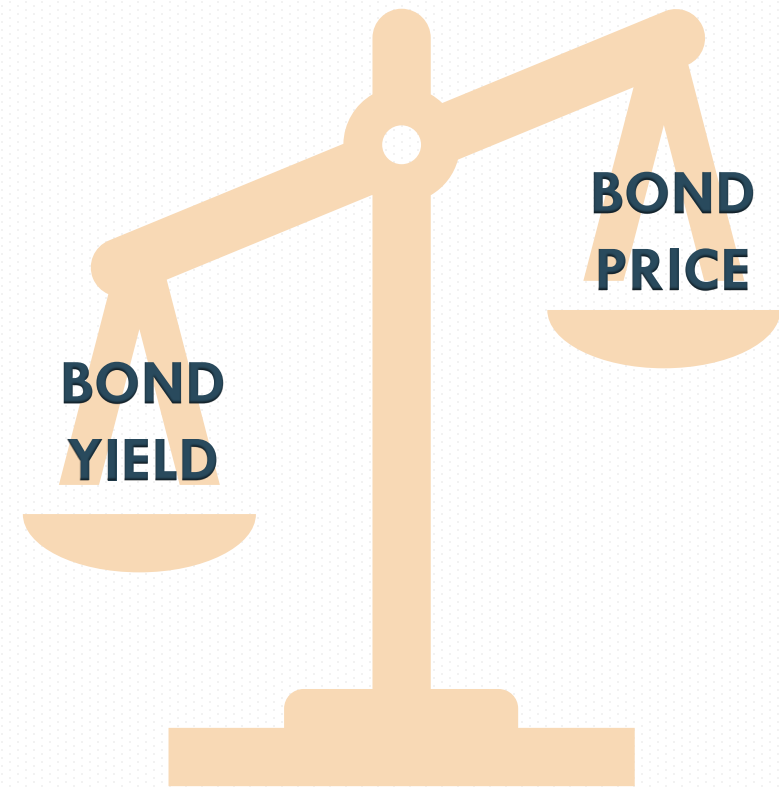
- A Bond is evidence of a loan to the issuer from the purchaser of that bond
Buyer = “lender” or “investor” or “purchaser” Seller = “borrower” or “issuer”
- Par Amount = “Principal” or “face amount” of the loan
- Maturity date = Repayment date of loan
- Nominal or Coupon rate = Interest rate paid periodically on the loan
- Price = Amount a lender will lend in consideration of future receipt of principal and interest payments
- Yield = Single rate that sets the present value of the principal and interest payments equal to the price



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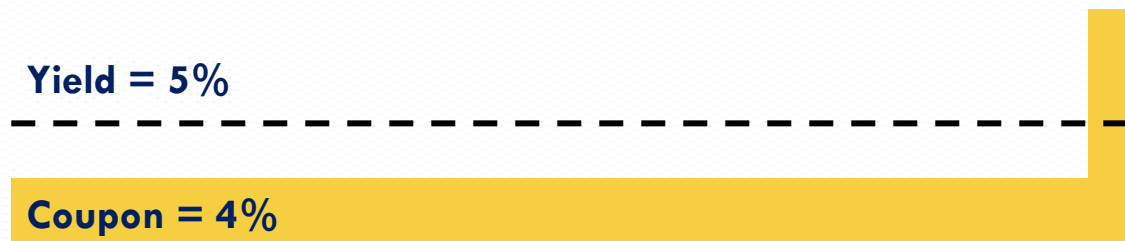
Coupons, Yields & Price

- Coupon is the interest rate assigned to a bond, typically paid semi-annually
- Yield is the return on the bond, if held to maturity
- Relationships between coupon and yield determines the price on a bond
- If coupon = yield, par bond (price = 100%)
- If coupon > yield, premium bond (price >100%)
- If coupon < yield, discount bond (price <100%)
- Prices & Yields move in opposite directions



Discount vs. Premium Bonds

- Original Issue Discount Bonds (OIDs)



Discount Bond	
Coupon	4%
Price	97.277%
Yield	5%

- Original Issue Premium Bonds (OIPs)



Premium Bond	
Coupon	4%
Price	102.829%
Yield	3%

Which of the following is INCORRECT:

A bond where coupon = yield is a par bond.

0%

A bond where coupon > yield is a discount bond.

0%

A bond where coupon > yield is a premium bond.

0%

Bond Cash Flows

- Bonds have two cash flows
 - Stream of interest (coupon) payments
 - Lump sum face value (principal) payment at maturity
- Knowing a bond's cash flows, you can calculate its price
- Consider a \$1,000 bond paying 4% interest and maturing in 3 years
 - Interest cash flows (coupon payments) of \$40 in years 1 through 3
 - Plus the principal of \$1,000 in year 3
- When an investor buys a bond, he/she is buying its cash flows

Coupon 4%	
Year	Cash Flow
1	40.00
2	40.00
3	1,040.00
Total	1,120.00

Time Value of Money

- When an investor buys a bond, he/she is buying its cash flows, which occur at different times, so to determine a bond's price need to consider the Time Value of Money
- A dollar received today is worth more than a dollar received in the future
- Likewise, a dollar received in the future is worth less than a dollar received today



Present Value (PV)

- To measure the time value of money, we can calculate the value today (present value or PV) of a cash flow happening in the future
- PV is opportunity cost of delayed cash flows
- Use of Present Values allows the comparison of cash flows received and/or paid in different periods
- PV is used to
 - Calculate the price of a bond
 - Estimate dollars needed today to fill a project construction fund
 - Estimate amount needed today to set aside in escrow for a Refunding
 - Calculate different types of yields (i.e. arbitrage yield, true interest cost)

Construction Date	Draw Schedule	PV @ 4.0% (to 7/1/2025)
7/1/2026	\$10,000,000	\$9,615,385
7/1/2027	\$20,000,000	\$18,491,124
7/1/2028	\$40,000,000	\$35,559,854
7/1/2029	\$5,000,000	\$4,274,021

Bond Valuation – Calculating the Price

- The PV of a bond's cash flows is its price
- Consider a bond with a coupon = 4%
 - If the current market yield is 4%, then the value of the bond is \$1,000
 - However, if the current market yield is 3%, then the value of the bond is greater than \$1,000 and the bond will sell at a premium price
 - If the current market yield is 5%, then the value of the bond is less than \$1,000 and the bond will sell as a discounted price

	A	B	C
Coupon	4%	4%	4%
Market Yield	4%	3%	5%
Price	100.000 (par)	102.829 (prem.)	97.277 (disc)

Year	Cash Flow	PV of Cash Flow	PV of Cash Flow	PV of Cash Flow
1	40.00	\$38.46	\$38.83	\$38.10
2	40.00	36.98	37.70	36.28
3	1,040.00	924.56	951.75	898.39
	1,120.00	Price = \$1,000.00	Price = \$1,028.29	Price = \$972.77

Bond Yields

Date	Debt Service	PV Factor	Present Value to 08/30/2023 @ 3.7816819113%
10/1/2023	226,455.00	0.996779154	225,725.62
4/1/2024	1,314,900.00	0.978281409	1,286,342.22
10/1/2024	2,079,900.00	0.960126935	1,996,968.01
4/1/2025	1,295,775.00	0.942309364	1,221,020.92
10/1/2025	2,100,775.00	0.924822442	1,942,843.87
4/1/2026	1,275,650.00	0.907660035	1,157,856.52
10/1/2026	2,120,650.00	0.890816119	1,889,109.20
4/1/2027	1,254,525.00	0.874284784	1,096,812.12
10/1/2027	2,144,525.00	0.858060230	1,840,131.61
4/1/2028	1,232,275.00	0.842136763	1,037,744.08
10/1/2028	2,167,275.00	0.826508796	1,791,271.85
4/1/2029	1,208,900.00	0.811170846	980,624.44
10/1/2029	2,188,900.00	0.796117529	1,742,621.66
4/1/2030	1,184,400.00	0.781343565	925,423.32
10/1/2030	2,214,400.00	0.766843769	1,698,098.84
4/1/2031	1,158,650.00	0.752613053	872,015.11
10/1/2031	2,238,650.00	0.738646424	1,653,570.82
4/1/2032	1,131,650.00	0.724938981	820,377.20
10/1/2032	2,266,650.00	0.711485914	1,612,689.55
4/1/2033	1,103,275.00	0.698282502	770,397.63
10/1/2033	43,938,275.00	0.685324113	30,111,959.36
	75,846,455.00		56,673,603.95

- Yield is the single **interest rate** that sets the present value of a stream of **cash flows** (debt service payments) equal to the **price** (a target value that may vary)
- PV is also used to calculate certain yields
 - Arbitrage Yield
 - True Interest Cost (TIC)
- TIC calculation is often used to determine winner of a competitive bond sale

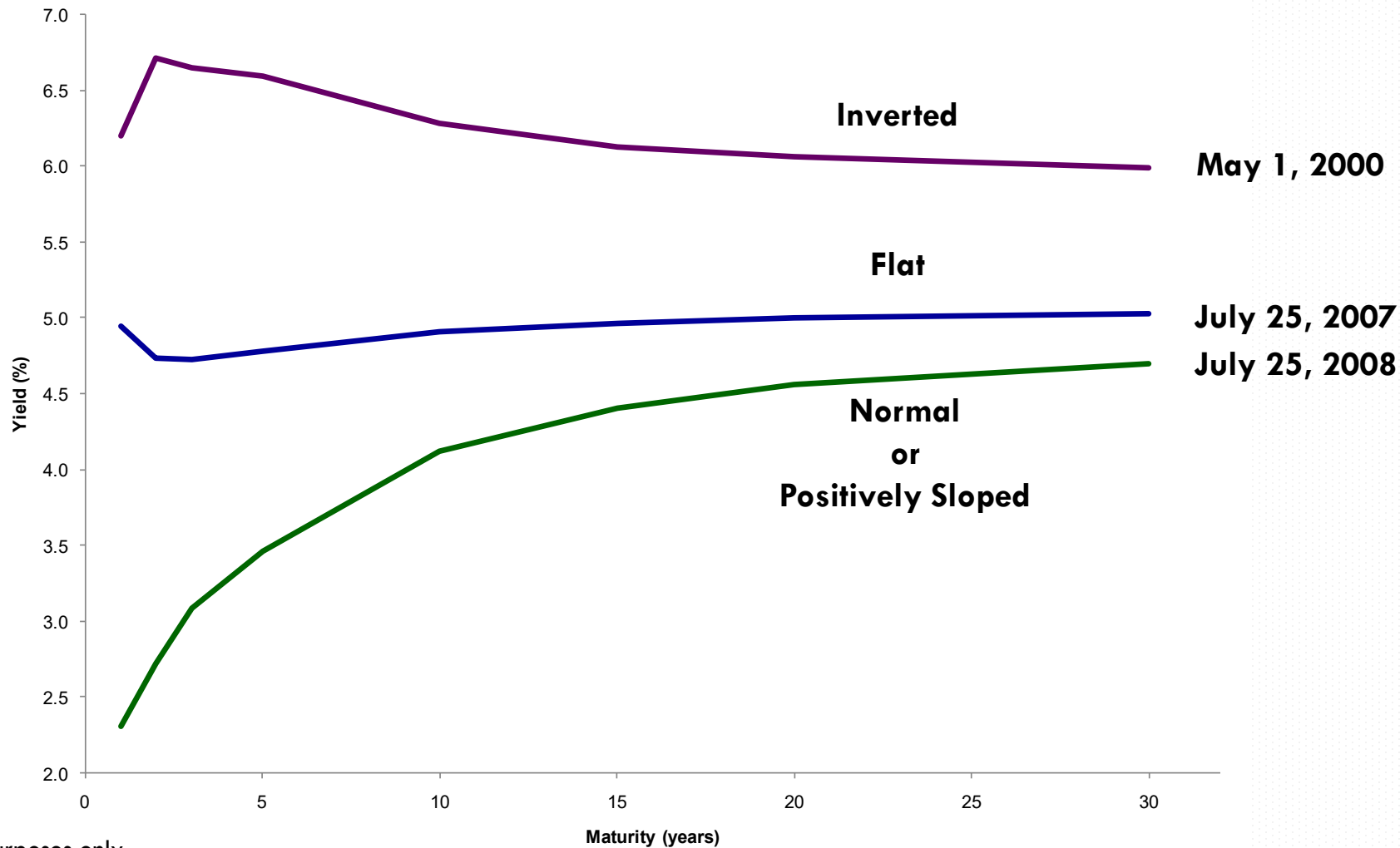
$$\text{Present Value} = \frac{1}{(1 + \text{rate})^{\text{number of periods}}}$$

Proceeds Summary

Delivery date	8/30/2023
Par Value	51,300,000.00
Premium (Discount)	5,373,603.95
Target for yield calculation	56,673,603.95

Chart provided for illustrative purposes only.

Types of Yield Curves



For illustrative purposes only.

Coupon/Yield Relationships

- For a given coupon, the price an investor is willing to pay for a bond is inversely related to the yield

	Original Issue Discount (OID)	Par Bond	Original Issue Premium (OIP)
General Rule	Coupon < Yield ↓ Price < 100	Coupon = Yield ↓ Price = 100	Coupon > Yield ↓ Price > 100
Example (20-year bond)*	Coupon = 4.00% Yield = 5.00% Price = 87.448	Coupon = 5.00% Yield = 5.00% Price = 100.000	Coupon = 6.00% Yield = 5.00% Price = 112.551

*Assumes settlement date of 1/1/2025 and final maturity of 1/1/2045

Issuer/Investor Preferences

- Given the same proceeds and present value of debt service, you would think an issuer would be essentially indifferent between issuing OID, Par, or OIP Bonds

	OID	Par	OIP
Par Amount	55,860,000	50,000,000	42,565,000
Coupon	3.000%	3.75%	5.000%
Yield	3.750%	3.75%	3.750%
Price	89.513%	100.000%	117.478%
Proceeds	50,001,962	50,000,000	50,004,511

Retail investors are typically less sensitive to coupon

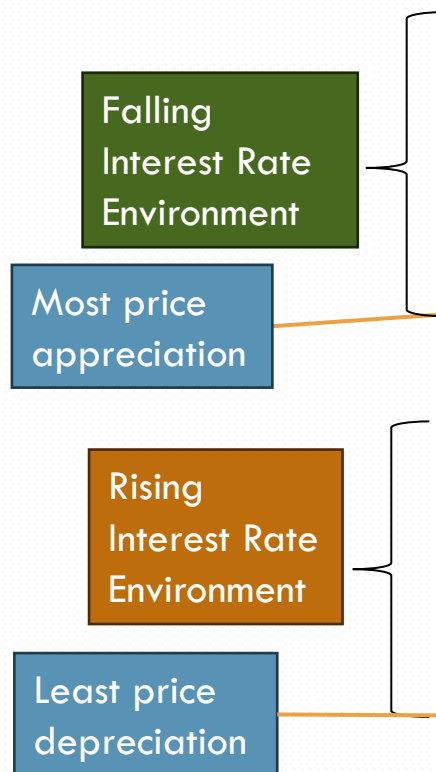
- Typically, “buy and hold”
- Less sensitive to market discount rules
- Retail-only order periods allow par bonds to be pre-sold
- Demand is strongest in years 1 - 10 and 20

Institutional investors are NOT indifferent to coupon

- Interest rate views (price protection, coupon reinvestment, duration, and convexity management)
- Possible tax implications (market discount rule)
- Cash flow needs (replace refunded higher coupon bonds)

Price Volatility

- Premium bonds provide price protection against rising interest rates
- Discount bonds provide opportunity for investors to enhance their return in falling rate environment



Price Volatility			
	OID	Par	OIP
Purchase Date	1/1/25	1/1/25	1/1/25
Maturity	1/1/45	1/1/45	1/1/45
Coupon	3.000%	3.750%	5.000%
Yield	3.750%	3.750%	3.750%
Price	89.513%	100.000%	117.478%
Purchase Date	4/1/25	4/1/25	4/1/25
Maturity	1/1/45	1/1/45	1/1/45
Coupon	3.000%	3.750%	5.000%
Yield	3.000%	3.000%	3.000%
Price	100.000%	111.111%	129.636%
% Price Change	11.716%	11.111%	10.349%
Purchase Date	4/1/25	4/1/25	4/1/25
Maturity	1/1/45	1/1/45	1/1/45
Coupon	3.000%	3.750%	5.000%
Yield	4.500%	4.500%	4.500%
Price	80.503%	90.248%	106.490%
% Price Change	(10.066%)	(9.752%)	(9.353%)

Pricing Callable Bonds

- Depending on the type of bond an investor holds, the call option an issuer holds may affect the yield that the investor expects

	Par	Discount	Premium
Settlement Date	10/1/2025	10/1/2025	10/1/2025
Maturity	10/1/2045	10/1/2045	10/1/2045
Call	10/1/2035	10/1/2035	10/1/2035
Price*	100	87.448	112.551
Coupon	5.000%	4.000%	6.000%
Yield (to Maturity)	5.000%	5.000%	5.000%
Yield (to Call)	5.000%	5.660%	4.432%**

*to maturity
 **Yield to worst

- If a callable premium bond is called, the investor receives a lower yield than originally represented (“yield to worst”)

Pricing of Callable Premium Bonds

- MSRB rules require issuers to sell OIPs at the price and yield that constitutes the worst case for the investor (i.e., lower yield, higher price)
- A higher coupon premium bond has a better chance of being called, but a bigger “kick” to maturity if it is not called

Delivery Date	10/1/25
Maturity Date	10/1/45
Coupon	6.000%
Price to Maturity (PTM)	112.551
YTM	5.000%
Call Date	10/1/35
Call Price	100.000
Yield to Worst (at call date)	4.432%
Price to Call (PTC)	112.556
Yield to Maturity (YTM)	5.000%

($\Delta = .57\% = \text{“Kick to Maturity”}$)

Issuer's best case (bonds called) / Investor's worst case

Issuer's worst case (bonds not called) / Investor's best case

Pricing of Callable Premium Bonds -(cont. 2 of 2)

- Callable premium bonds are usually denoted with an asterisk or footnote when priced to a date other than the final maturity date

<u>Maturity (October 1)</u>	<u>Principal Amount</u>	<u>Interest Rate</u>	<u>Yield</u>	<u>Price</u>
2024	\$765,000	5.000%	3.120%	101.989
2025	805,000	5.000	3.030	103.950
2026	845,000	5.000	2.920	106.093
2027	890,000	5.000	2.900	108.034
2028	935,000	5.000	2.870	110.010
2029	980,000	5.000	2.860	111.873
2030	1,030,000	5.000	2.850	113.704
2031	1,080,000	5.000	2.900	115.037
2032	1,135,000	5.000	2.930	116.405
2033	1,190,000	5.000	3.010	117.197
2034	1,250,000	5.000	3.070	116.629 ^c
2035	1,315,000	5.000	3.160	115.783 ^c
2036	1,380,000	5.000	3.250	114.944 ^c
2037	1,445,000	5.000	3.350	114.020 ^c
2038	1,520,000	5.000	3.490	112.742 ^c
2039	1,595,000	5.000	3.640	111.392 ^c
2040	1,675,000	5.000	3.730	110.591 ^c
2041	1,760,000	5.000	3.810	109.885 ^c
2042	1,845,000	5.000	3.890	109.184 ^c
2043	1,940,000	5.000	3.930	108.835 ^c

^c – Priced to the October 1, 2033 par call date.

Bond Pricing Reports for Callable Premium Bonds

Bond Component	Maturity Date	Amount	Rate	Yield	Price	Yield to Maturity	Call Date	Call Price
Serial Bond:								
	10/1/2024	765,000	5.000%	3.120%	101.989			
	10/1/2025	805,000	5.000%	3.030%	103.950			
	10/1/2026	845,000	5.000%	2.920%	106.093			
	10/1/2027	890,000	5.000%	2.900%	108.034			
	10/1/2028	935,000	5.000%	2.870%	110.010			
	10/1/2029	980,000	5.000%	2.860%	111.873			
	10/1/2030	1,030,000	5.000%	2.850%	113.704			
	10/1/2031	1,080,000	5.000%	2.900%	115.037			
	10/1/2032	1,135,000	5.000%	2.930%	116.405			
	10/1/2033	1,190,000	5.000%	3.010%	117.197			
	10/1/2034	1,250,000	5.000%	3.070%	116.629 C	3.206%	10/1/2033	100.000
	10/1/2035	1,315,000	5.000%	3.160%	115.783 C	3.397%	10/1/2033	100.000
	10/1/2036	1,380,000	5.000%	3.250%	114.944 C	3.561%	10/1/2033	100.000
	10/1/2037	1,445,000	5.000%	3.350%	114.020 C	3.713%	10/1/2033	100.000
	10/1/2038	1,520,000	5.000%	3.490%	112.742 C	3.876%	10/1/2033	100.000
	10/1/2039	1,595,000	5.000%	3.640%	111.392 C	4.030%	10/1/2033	100.000
	10/1/2040	1,675,000	5.000%	3.730%	110.591 C	4.130%	10/1/2033	100.000
	10/1/2041	1,760,000	5.000%	3.810%	109.885 C	4.213%	10/1/2033	100.000
	10/1/2042	1,845,000	5.000%	3.890%	109.184 C	4.290%	10/1/2033	100.000
	10/1/2043	1,940,000	5.000%	3.930%	108.835 C	4.336%	10/1/2033	100.000
		25,380,000						

For illustrative purposes only.

Callable premium bonds must be represented to investors in the Official Statement using which yield option?

The lowest possible yield achieved between the bond's first optional redemption date and its maturity ...

0%

The highest possible yield achieved between the bond's first optional redemption date and its maturity ...

0%

A 0% yield.

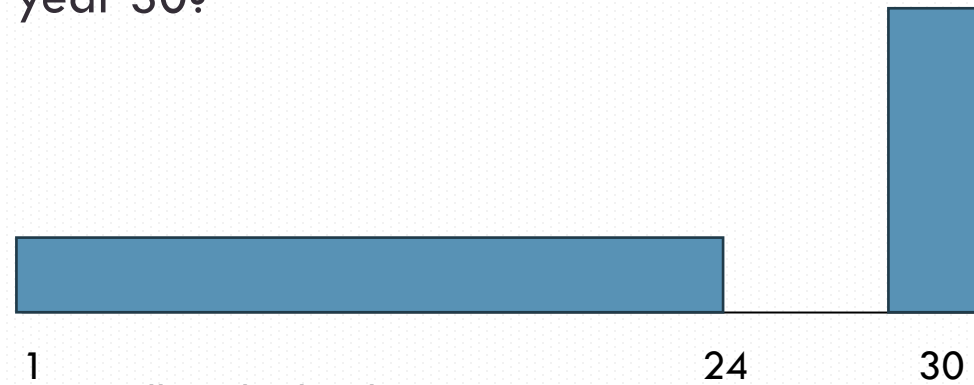
0%

Offering yields are not shown on the Official Statement.

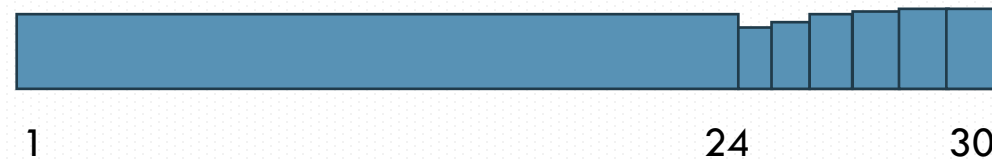
0%

Mandatory Redemption Provisions

- What are the implications if you are selling 30-year bonds and investors are only interested in years 1 - 24 and year 30?



- Debt service structure will not be level
- Yields may have to increase in order to interest buyers in years 25-29 (increased cost to issuer)
- To mitigate this, underwriters may spread out the 30-year maturity amount amongst the 25 - 30-year maturities as mandatory sinking funds. All maturities will be priced to the 30-year maturity.



Mandatory Redemption Provisions -(cont. 2 of 2)

\$11,310,000 – 5.250% Term Bonds due October 1, 2048; Yield: 4.070%; Price: 109.678 ¢;
CUSIP†: 84049M CB2

\$14,610,000 – 5.250% Term Bonds due October 1, 2053; Yield: 4.150%; Price: 108.986 ¢;
CUSIP†: 84049M CC0

Mandatory Sinking Fund Redemption. The Bonds maturing on October 1, 2048 and October 1, 2053 (the "Term Bonds") shall be subject to redemption in part by lot from sinking account payments made by the Authority, at a redemption price equal to the principal amount thereof to be redeemed with accrued interest thereon to the redemption date, without premium, in the aggregate respective principal amounts and on the respective dates as set forth in the following tables; provided, however, if some but not all of the Term Bonds of a maturity have been redeemed pursuant to the optional and extraordinary redemption provisions of the Indenture, each future sinking account payment with respect to such Term Bonds will be reduced on a pro rata basis (as nearly as practicable) in integral multiples of \$5,000, so that the total amount of sinking account payments with respect to such Term Bonds to be made subsequent to the optional and extraordinary redemption provisions of the Indenture shall be reduced by an amount equal to the principal amount of the Term Bonds so redeemed, all as shall be designated pursuant to written notice filed by the Authority with the Trustee:

Bonds Maturing on October 1, 2048

Redemption Date (October 1)	Principal Amount to be Redeemed
2044	\$2,035,000
2045	2,145,000
2046	2,255,000
2047	2,375,000
2048*	2,500,000

* maturity



Optional Redemption Provisions

- Call Option: The right, but not the obligation, to buy an asset at a given price
- Municipal bond issuers utilize call options to provide themselves flexibility to repay bonds prior to their stated maturity, i.e., through a refinancing/refunding

Optional Redemption. The Bonds maturing on or after October 1, 2034, shall be subject to redemption prior to their respective maturity dates on any date on or after October 1, 2033, as a whole or in part, from prepayments of Base Rental made at the option of the City under the Sublease on any date with respect to which such prepayment have been made. The Bonds called for optional redemption shall be redeemed at a redemption price equal to 100 percent of the principal amount of the Bonds to be redeemed, without premium, plus accrued interest thereon to the date of redemption.

Bond Statistics - Offsets in Calculations Differ

	TIC	All-In TIC	Arbitrage Yield
Par Value	51,300,000.00	51,300,000.00	51,300,000.00
+ Accrued Interest			
+ Premium (Discount)	5,373,603.95	5,373,603.95	5,373,603.95
- Underwriter's Discount	-258,636.70	-258,636.70	
- Cost of Issuance Expense		-248,000.00	
Target Value	56,414,967.25	56,166,967.25	56,673,603.95
Target Date	8/30/2023	8/30/2023	8/30/2023
Yield	4.344711%	4.381522%	3.781682%

For illustrative purposes only.

Definitions

- **True Interest Cost (TIC):**
Rate, compounded semi-annually, necessary to discount the amounts payable on the respective principal and interest payment dates to the purchase price received for the new issue securities. TIC computations produce a figure slightly different from the net interest cost ("NIC") method since TIC considers the time value of money while NIC does not.
- **All-In True Interest Cost (AIC):**
Discount rate, assuming semiannual compounding and a 30/360-day calendar, which is the net present value (NPV) of all payments of principal, interest, and future expenses equal to the par amount of bonds plus accrued interest plus premium less original issue discount less insurance premium less costs of issuance less other up front expenses, as applicable. The cashflows can be discounted to either the delivery date or the dated date.
- **Arbitrage Yield:**
"Arbitrage" refers to the difference between the interest rate at which bonds are issued, a.k.a. the Arbitrage Yield, and the interest rate at which bond proceeds are invested, a.k.a. the Investment Yield. If the Investment Yield exceeds the Arbitrage Yield, the dollar difference in earnings is "positive arbitrage" and must be rebated to the IRS unless certain exceptions are met. Common exceptions are for "small issuers" and for issuers who meet certain "spend-down" requirements. Conversely, if the Investment Yield is less than the Arbitrage Yield, the dollar difference in earnings is "negative arbitrage" and no rebate is owed.

Definitions -(cont. 2 of 2)

- **Net Interest Cost (NIC):**

A method of computing the interest expense to the issuer of bonds, which may serve as the basis of award in a competitive sale. NIC takes into account any premium or discount applicable to the issue, as well as the dollar amount of coupon interest payable over the life of the issue. NIC does not take into account the time value of money (as would be done in other calculation methods, such as the “true interest cost” (TIC) method). The term “net interest cost” refers to the overall rate of interest to be paid by the issuer over the life of the bonds. (Disadvantage: No consideration for time value of money)

$$\frac{\text{Total coupon interest payments} + \text{premium(discount)}}{\text{Bond Years}}$$

- **Average Coupon:**

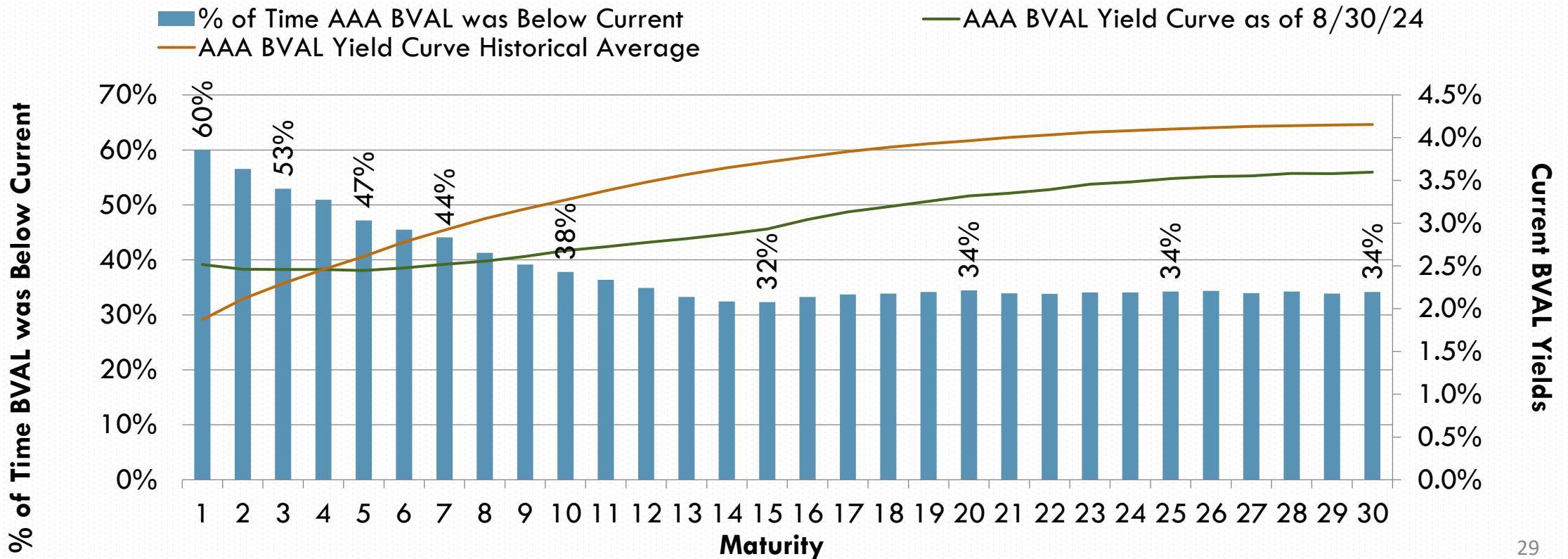
A calculation of the total interest cost for a bond issue expressed as a percentage. The average coupon is equal to the total interest payments of an issue divided by bond year dollars.

$$\frac{\text{Annual Interest}}{\text{Principal Outstanding}}$$

Tax-Exempt Borrowing Rates – Historical Context

- On the short end of the yield curve, “AAA” rated Bloomberg Valuation Service (“BVAL”) rates have risen significantly above 30-year averages, while the long end is below the historical average

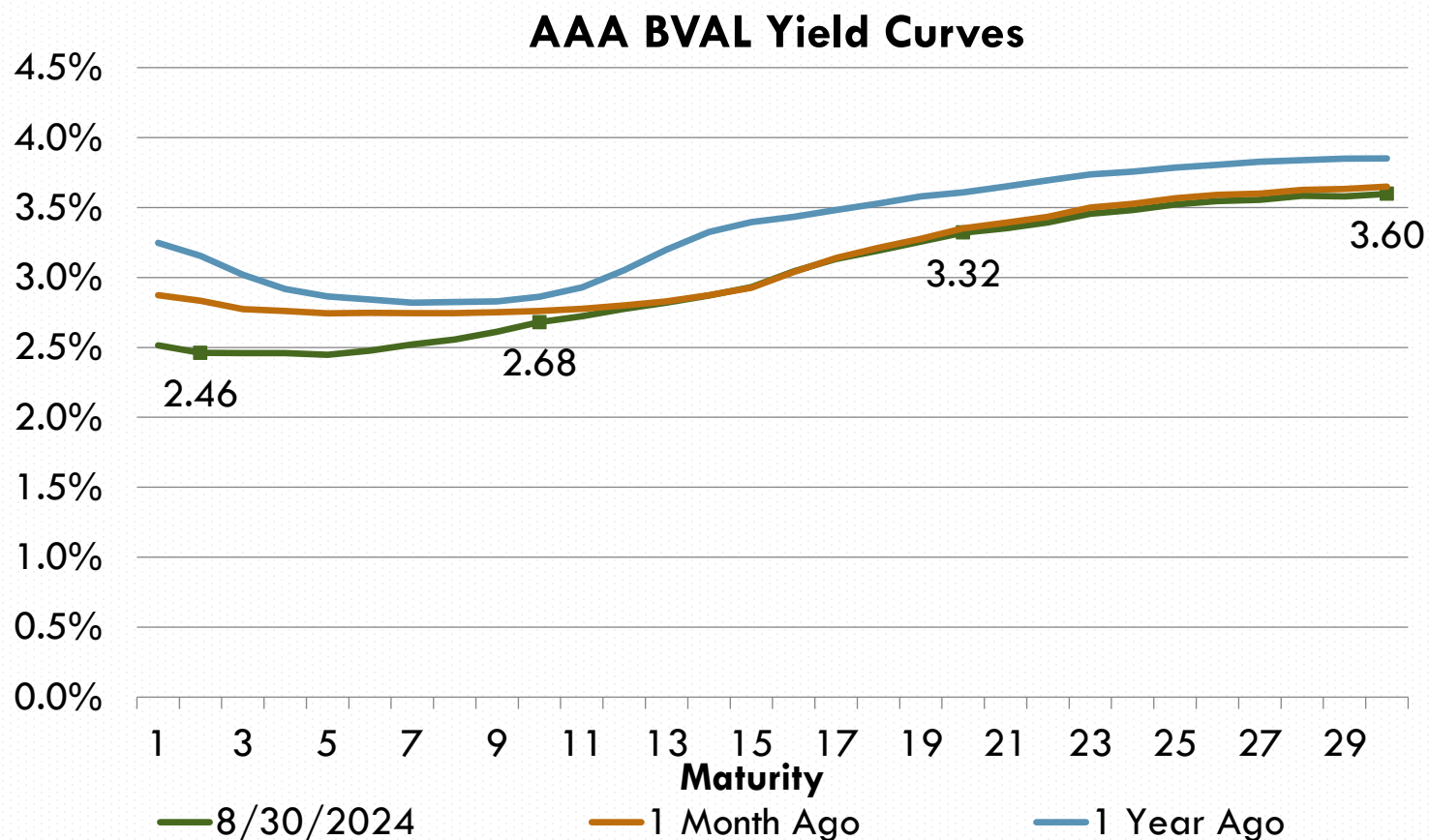
AAA BVAL Yield Curve



Source: Bloomberg as of August 30, 2024.

Tax-Exempt Borrowing Rates

- Expectations of a Federal Reserve rate cut have caused rates to decrease across all maturities over the past year



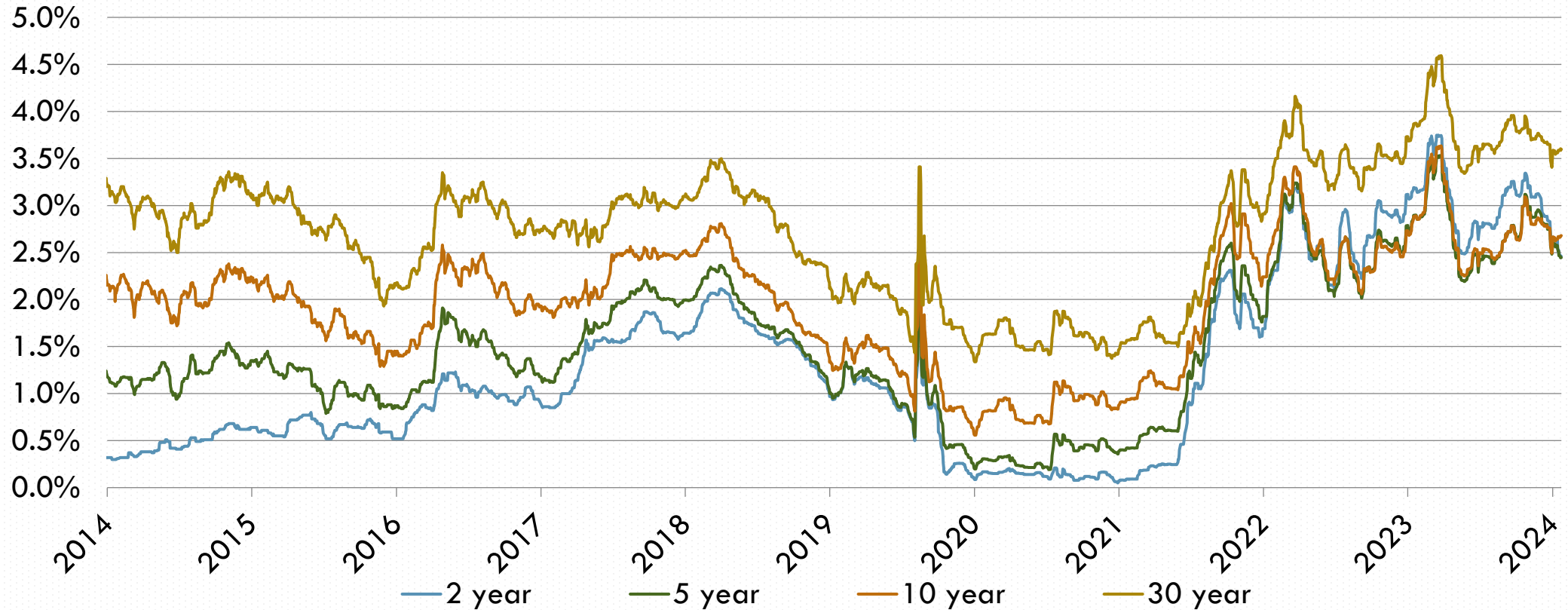
Term (Years)	BVAL 8/30/2024	Δ From 7/30/2024	Δ From 8/30/2023
1	2.52%	-36 bps	-73 bps
2	2.46%	-37 bps	-69 bps
3	2.46%	-32 bps	-56 bps
4	2.46%	-30 bps	-46 bps
5	2.45%	-30 bps	-42 bps
6	2.48%	-27 bps	-37 bps
7	2.52%	-22 bps	-30 bps
8	2.56%	-19 bps	-27 bps
9	2.61%	-14 bps	-22 bps
10	2.68%	-8 bps	-18 bps
11	2.72%	-5 bps	-21 bps
12	2.77%	-3 bps	-28 bps
13	2.82%	-1 bps	-38 bps
14	2.87%	0 bps	-45 bps
15	2.93%	1 bps	-46 bps
16	3.04%	0 bps	-39 bps
17	3.13%	-1 bps	-35 bps
18	3.19%	-2 bps	-34 bps
19	3.26%	-2 bps	-32 bps
20	3.32%	-3 bps	-29 bps
21	3.35%	-4 bps	-30 bps
22	3.39%	-4 bps	-30 bps
23	3.46%	-4 bps	-28 bps
24	3.48%	-4 bps	-27 bps
25	3.52%	-4 bps	-26 bps
26	3.55%	-4 bps	-26 bps
27	3.55%	-4 bps	-27 bps
28	3.58%	-4 bps	-26 bps
29	3.58%	-5 bps	-27 bps
30	3.60%	-5 bps	-25 bps

Source: Bloomberg as of August 30, 2024.

Historical AAA BVAL

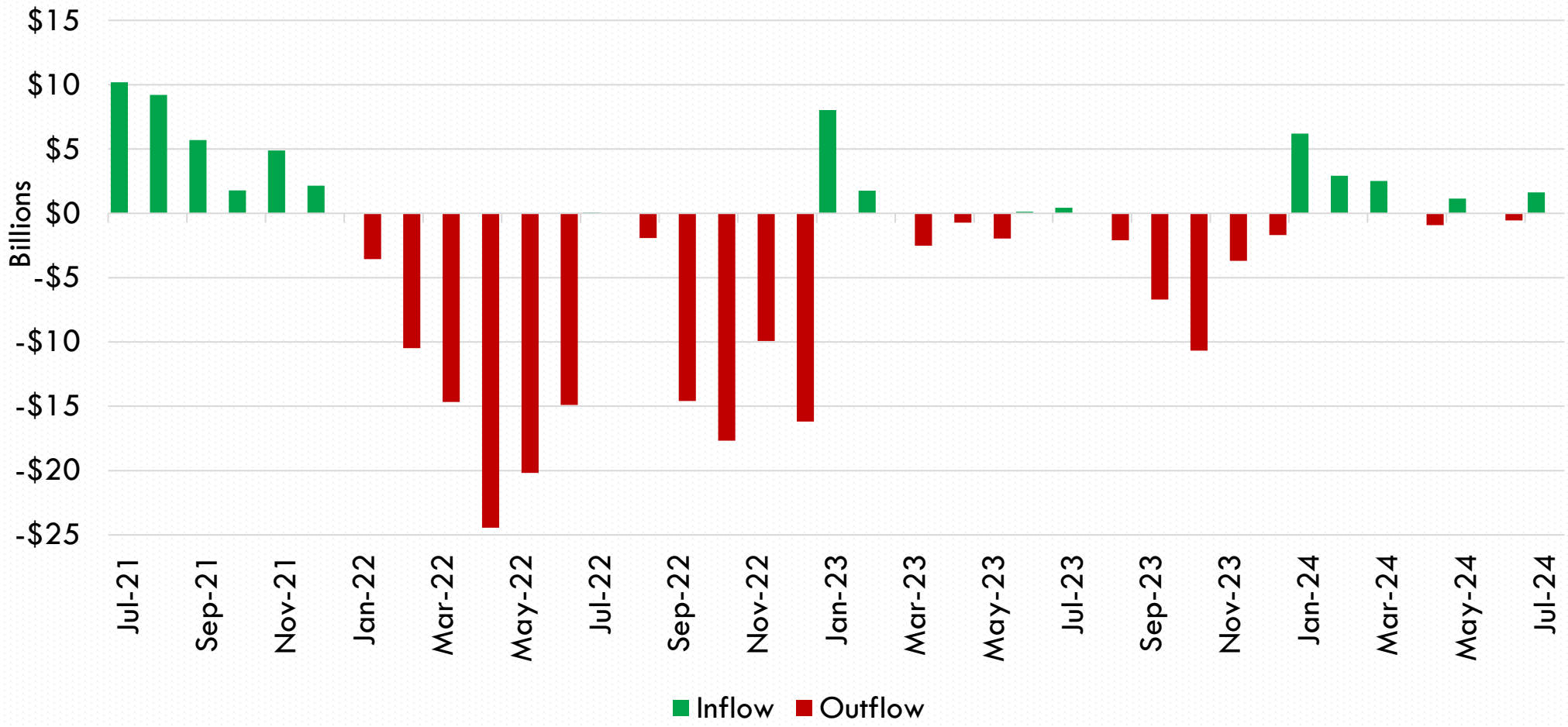
- Rates have experienced volatility over the past YEAR, but are significantly below their peaks in October 2023

Historical BVAL Rates



Source: Bloomberg as of August 30, 2024.

Total Monthly Fund Flows



Source: Investment Company Institute as of August 28, 2024.

United States Bond Yield Forecasts

- U.S. Treasury yield curve is still inverted
- The market currently expects decreased interest rates over the next few years

WORLD BOND YIELD FORECASTS SEPTEMBER 3, 2024

Rate	Yields	Q3 24	Q4 24	Q1 25	Q2 25	Q3 25	Q4 25	Q1 26	Q2 26	Q3 26	Q4 26
United States											
US 30-Year	4.12 %	4.19 %	4.13 %	4.08 %	4.02 %	3.98 %	3.98 %	3.95 %	3.95 %	3.99 %	3.99 %
US 10-Year	3.83 %	3.98 %	3.93 %	3.87 %	3.82 %	3.75 %	3.73 %	3.62 %	3.62 %	3.65 %	3.66 %
US 5-Year	3.64 %	3.86 %	3.78 %	3.69 %	3.61 %	3.51 %	3.47 %	3.36 %	3.38 %	3.43 %	3.41 %
US 2-Year	3.86 %	4.10 %	3.90 %	3.71 %	3.54 %	3.38 %	3.27 %	3.14 %	3.14 %	3.21 %	3.21 %
US 3-Month Term SOFR	5.01 %	5.02 %	4.63 %	4.23 %	3.89 %	3.58 %	3.35 %	3.29 %	3.17 %	3.12 %	3.12 %
Fed Funds Rate - Upper Bound	5.50 %	5.25 %	4.75 %	4.35 %	4.00 %	3.75 %	3.60 %	3.40 %	3.30 %	3.25 %	3.20 %
Fed Funds Rate - Lower Bound	5.25 %	4.98 %	4.52 %	4.11 %	3.76 %	3.51 %	3.37 %	3.16 %	3.05 %	3.00 %	2.97 %
2 Year - 10 Year Spread	-0.03 %	-0.12 %	0.02 %	0.16 %	0.27 %	0.37 %	0.46 %	0.48 %	0.48 %	0.43 %	0.45 %



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