20. An investor paid \$95 for a bond with face value \$100 maturing in six months. On which day will the bond value pass \$98, provided the interest rate remains constant?

21. Consider the coupon bond in Example 4.20. For any $t \in [0, 1)$, find a formula for $V(t)$. Use a graphing calculator to sketch $V(t)$ for $0 \leq t < 1$. Then, sketch the entire graph of the price of the coupon bond as a function of time, for all $t \in [0, 5]$.

22. A bond with face value 100 and annual coupons of \$8 maturing after 3 years is trading at par. Find the implied continuous compounding rate.

23. The cash prices of 6-month and 1-year Treasury bills are 94.0 and 89.0. A 1.5-year bond that will pay coupons of \$4 every 6 months currently sells for \$94.84. A 2-year bond that will pay coupons of \$5 every 6 months currently sells for \$97.12. Use the bootstrap method to calculate the 6-month, 1-year, 1.5-year, and 2-year zero rates.

24. Suppose zero interest rates with continuous compounding are given by

Maturity (years)	1	2	3	4	5
Rate (% per annum)	2.0	3.0	3.7	4.2	4.6

    (a) Calculate forward interest rates for the second through fifth year.

    (b) Value an FRA where you will pay 5% for the third year on \$1 million.

25. Portfolio A consists of a 1-year zero-coupon bond with a face value of \$2,000 and a 10-year zero-coupon bond with a face value of \$6,000. Portfolio B consists of a 5.95-year zero-coupon bond with a face value of \$5,000. The current yield on all bonds is 10% per annum.

    (a) Show that both portfolios have the same duration.

    (b) Show that the percentage changes in the values of the two portfolios for a 0.1% per annum increase in yields are the same.

    (c) What are the percentage changes in the values of the two portfolios for a 5% per annum increase in yields?