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Most bonds are traded between interest dates. Most bonds sell at a premium or discount. Often, U.S. accounting rules require that such premiums or discounts be amortized via the "interest" method -- a compound-interest approach.[1] Even (rather than compound-interest) calculation of the interest that the buyer prepaid.

Similarly, even under compound-interest amortization, when the end of an accounting year falls between interest-payment dates it is common to allocate total interest for the overlapping interest period straight-line between the part of that period that occurred before, and the part that occurred after, the year end. These practices can generate three kinds of confusing phenomena: (1) except by coincidence, the total amortization of premium or discount will not "add up" or "come out even" -- it will not equal that premium or discount, (2) the first interest period's amortization of premium or discount may be negative -- may increase those amounts that it should reduce -- and (3) the relative sizes of different periods' interest charges may be the reverse of what one would reasonably expect. All three confusions may be avoided by more consistent interest allocations.[2]

Textbook and handbook discussions of bonds issued between interest dates usually consider only straight-line amortization of premium or discount, in which amortizations do add up properly and negative amortizations do not occur, and never concern themselves about inconsistent interest-charge sizes. That is to say, most textbooks and handbooks dodge the difficult, interesting aspects of such bond issues. Moreover (without naming names), when they <u>do</u> consider these topics their discussions are sometimes erroneous.

What follows begins by assuming that, like most people, you have forgotten much of what you once knew about bond calculations. Sophisticated readers may wish to skim the next two sections.

Bonds Issued on an Interest Date[3]

We will begin with a simple illustration. On June 30 of Year 1 a buyer purchases $100,000 par value of bonds that mature on 12/31/2, acquiring them from the issuer. These bonds pay interest at a coupon rate of 8 percent per semi-annual interest though the true annual compound interest rate is (1.08 * 1.08) - 1 = 16.64%). We simplify further by assuming that the "effective" or "yield" rate on these bonds (the interest rate that the market demands for investments of this kind) is known to be 7 percent per semi-annual period (or "14 percent" annually). Finally, for brevity we will perform all calculations in terms of months, treat all months as being of equal lengths, and disregard that in non-leap years the period January 1 through June 30 is three days shorter than the period July 1 through December 31.

<Figure 1 about here>

There are many ways to calculate the issue price of these bonds, all of which give the same results (except for possible rounding errors). We may begin with the time diagram in Figure 1. This shows the rights to receive cash that the buyer purchased, and the dates upon which each of these rights becomes effective. The issue date is indicated by the letter I.

The buyer has the right to receive $100,000 * 8% = $8,000 at the end of 6 months, another $8,000 at the end of the second semi-annual interest period, and $108,000 at the end of the third period. The bonds' issue price will equal the present value of these rights, discounted at the 7% effective rate. These present values are:

```
$8,000 * (1/1.07) ......................  =  $   7,476.64
$8,000 * (1/1.07) * (1/1.07) ...........  =      6,987.51
$108,000 * (1/1.07) * (1/1.07) * (1/1.07) =     88,160.17
                                             ------------
    Issue price of bonds ................    $ 102,624.32
                                             ============
```

-- or, in more compressed notation (where the caret, ^, signifies Y-to-the-Xth-power exponentiation, as when 2 ^ 3 = 8 and 2 ^ -3 = 1/8):

```
$8,000 * (1.07 ^ -1)      =  $    7,476.64
$8,000 * (1.07 ^ -2)      =       6,987.51
$108,000 * (1.07 ^ -3)    =      88,160.17
                              ------------
   Issue price of bonds      $ 102,624.32
                              ============
```

We could, of course, have made these calculations from published tables of the discounted present values of single payments. But if the effective rate is an uneven one (say, 6 and 15/16ths percent instead of 7 percent) this can be inconvenient. Since any business- or science-oriented pocket calculator allows one to make exponential calculations (and with greater accuracy than most such tables provide), such published tables are like slide rules -- obsolete and unnecessary.

Alternative Calculations

There are many alternative ways to make these calculations. For instance, textbooks often perceive such bonds as the one in Figure 1 to offer two rights: the right to receive a single (balloon) payment of $100,000 in 3 periods, and the right to receive a 3-period annuity of $8,000 per period. As these textbooks will tell you, the formula for the present value of any end-of-period annuity is:

A * (1 - {[1 + R] ^ -N}) / R

-- where A is the periodic payment ($8,000), R is the periodic effective rate (7%), and N is the number of periods (3). This gives us:

```
$100,000 * (1.07 ^ -3) ........ =  $  81,629.79
$8,000 * [1 - (1.07 ^ -3)] / .07 =     20,994.53
                                   ------------
   Issue price of bonds            $ 102,624.32
                                   ============
```

Another approach to bond calculations results from considering the reason for there being premiums or discounts. These occur because the amount of interest that the bonds pay (here, $8,000 per period) differs from the amount of interest that the market demands, as reflected by the effective rate ($100,000 * 7% = $7,000 per period). The difference between the two is an annuity of superior or inferior interest over the bonds' life, and may be treated like any other annuity.

<Figure 2 about here>

Since our example's coupon rate exceeds its effective rate, there is a 3-period annuity of $8,000 - $7,000 = $1,000 superior interest that is reflected in Figure 2. Using the same annuity formula as before, on the issue date this superior-interest annuity was worth $1,000 * (1- [1.07 ^ -3]) / .07 = $2,624.32. Since the 8% coupon rate exceeds the rate that the market required, this $2,624.32 is a premium that the market is willing to pay for superior interest. The total issue price will be the sum of this premium and what the bonds would sell for were there <u>not</u> an interest superiority -- that is to say, the sum of the premium and the bonds' par value: $2,624.32 + $100,000.00 = $102,624.32.

Issue Prices of Bonds Issued Between Interest Dates

<Figures 3 and 4 about here>

We will use this interest superiority or inferiority approach to calculate issue prices of bonds that are issued between interest dates. Let us begin by modifying our example so that instead of buying the $100,000 of bonds on 6/30/1 the buyer purchases them on 10/31/1. We then have the situation that is reflected in Figures 3 and 4.

In our last calculation the issue price was the sum of two things: the premium for interest superiority and the par value. Now it will be the sum of three things: premium, par value and compensation to the seller for the 4 months' interest between 6/30/1 and 10/31/1. As before, we could make the calculation that follows in terms of the exact number of days between 6/30/1 and 10/31/1 (123 out of the 184 days in the second half of the year). But for simplicity we will make monthly calculations instead.

Most reference sources describe the same, two-step procedure for calculating this grand total of par value, premium and prepaid interest (which we will call the "gross issue price"):[4]

<Figure 5 about here>

1. First, we calculate what the bonds' issue price would have been had they been issued just before the first interest payment on 12/31/1. This is done in Figure 5. Since that

payment is to be received immediately, its present value is 100%:

12/31/1 Interest payment (8,000 * [1.07 ^ -0])	$ 8,000.00
Maturity value (100,000 * [1.07 ^ -2]) .	87,343.87
6/30/2 and 12/31/2 interest payments (8,000 * {1 - [1.07 ^ -2]} / .07) ...	14,464.15
Pro-forma issue price as of 12/31/1	$ 109,808.02

<Figure 6 about here>

2. Next, as is reflected in Figure 6, we discount this $109,808.02 back 2 months, or 2/6ths of an interest period, to determine the present value of these bonds at the <u>actual</u>, 10/31/1, issue date: $109,808.02 * (1.07 ^ -[2/6]) = $107,359.25.[5] This is the gross issue price before deducting prepaid interest (before deducting the compensation to the seller for the first 4 months, 7/1/1 through 10/31/1, of the 12/31/1 interest payment).

At first one might believe that this prepaid interest equals 4/6ths of the $8,000, 12/31/1 payment, or $5,333.33. But such a straight-line calculation would be inconsistent with the compound-interest approach that we must use elsewhere. Instead of the ratio of prepaid interest to total interest being 4/6, it really should be that of 4 months' <u>compound</u> interest to 6 months' <u>compound</u> interest.

To determine this ratio, we first find the monthly effective rate, M, that is equivalent to a 7% semi-annual rate:

M = (1.07 ^ [1/6]) - 1 = 0.01134026012

Using a calculator, you may verify the correctness of this calculation by observing that (1+M) * (1+M) * (1+M) * (1+M) * (1+M) * (1+M) = 1.07 (often plus or minus a small difference due to cumulative rounding errors). Similarly, 4 months' compound interest at the effective rate will be:

```
[(1+M) ^ 4] - 1  =  0.04613849949
                 =  ({1.07 ^ [1/6]} - 1) ^ 4
                 =  (1.07 ^ [4/6]) - 1
```

Therefore, the ratio of prepaid interest to total semi-annual interest should be:

```
({1.07 ^ [4/6]} - 1) / ({1.07 ^ [6/6]} - 1)
                            =  ({1.07 ^ [4/6]} - 1) / .07
```

(which readers may recognize as being the same as the formula for the future value of a fractional-period annuity). Using this relationship, we conclude that on 10/31/1 the buyer prepaid:

```
$8,000 * ({1.07 ^ [4/6]} - 1) / .07  =  $5,272.97
```

of interest.

We may now use this formula to verify our earlier calculation of the gross issue price. Since the buyer will own these bonds for only 2 and 2/6ths = 14/6ths interest periods, the present value of the superior-interest annuity should be calculated as:

```
$1,000 * (1 - {1.07 ^ -[14/6]}) / .07  =  $2,086.28
```

and we have:

Par value	$ 100,000.00
Premium	2,086.28
Prepaid interest	5,272.97
Gross issue price at 10/31/1	$ 107,359.25

-- the same gross issue price that we calculated earlier by following standard industry practices.

The internally consistent net issue price then is:

Gross issue price	$ 107,359.25
Less prepaid interest	5,272.97
Internally consistent net issue price (equals par value plus premium) .	$ 102,086.28

However, although standard industry practice is to calculate the same gross issue price that we have, it does not calculate the same net issue price. For the usual convention is to calculate book prepaid interest straight-line, whether or not one amortizes premium or discount straight-line. Thus, the conventional figure for book prepaid interest would be $8,000 * 4 months / 6 months = $5,333.33, and the conventional net issue price would be:

Gross issue price	$ 107,359.25
Less prepaid interest	5,333.33
Conventional net issue price	$ 102,025.92

This promiscuous mingling of compound-interest and straight-line calculations has peculiar consequences that we will soon examine.

A General Formula

The general formula for the gross issue price is:

$$G = M + (\{M \ast C - M \ast E\} \ast \{1 - [(1+E)^{-(L - \{A/N\})}]\} / E) + (M \ast C \ast \{[(\{1+E\}^{\{A/N\}}) - 1] / E\})$$

-- where:

- A = The number of months for which the buyer prepaid interest
- C = The periodic (annual or semi-annual) coupon rate.
- E = The periodic (annual or semi-annual) effective rate.
- G = The gross issue price.
- L = The life of the bond, in whole interest periods (rounded upwards).
- M = The bond's maturity (par) value.
- N = The number of months (6 or 12) in an interest period.

This looks ferocious. But it is easily evaluated step-by-step, as we did above, on any "scientific" or business calculator equipped with a Y-to-the-Xth-power key. Also, such calculations are easily programmed.

Just as there are many ways to calculate the gross issue price of a bond that is issued on an interest date, so there are many alternative algorithms for between-interest-dates calculations. But they all yield the same gross issue price, give or take rounding differences.[6]

Calculation of Effective Rate from Gross Issue Price

Until now, our discussion has made a major simplification, by assuming that we know the effective rate and use it to calculate the gross issue price. In the real world, usually the reverse is true: We know the gross issue price ($107,359.25), the maturity value, the coupon rate, the life of the bonds and the number of interest payments per year; we must use these to calculate the effective rate (yield).

There is no formula for doing this directly. Instead, we must use an iterative (trial and error) approach. Once again there are many such approaches. The one that we will illustrate has the virtue of being easily understood, but is both too slow and too unsystematic for general use.

Since the bonds were issued at a premium, the semi-annual effective rate must be less than the coupon rate. As an arbitrary guess, let us first suppose that it was 6.5%. We use the procedure described earlier (or the last section's formula), and calculate that if the effective rate really were 6.5% then the gross issue price would have been $108,430.75. This is greater than the actual gross issue price of $107,359.25, so we know that our estimated effective rate is too low (because the lower the effective rate is, the higher the issue price will be).

Therefore, we must choose a higher effective rate for our second iteration, say 7.5%. This results in a trial gross issue price of $106,303.99, which is too low. But now we know that the true effective rate lies somewhere between 6.5% and 7.5%. If our next iteration split the difference and used a trial rate of 7%, the resulting trial gross issue price would equal the real gross issue price, and we could stop iterating, knowing that 7% was the correct answer.

A computer may be programmed to make similar iterations: starting with an estimated effective rate, then adjusting that estimate up or down depending on whether the calculated gross issue price is higher or lower than the true gross issue price, and using some such rule as "split the difference" to ensure that the estimated rate eventually will converge to (home-in on) the true effective rate. However, most such procedures converge annoyingly slowly if one implements them on a microcomputer.

There is a very rapid algorithm for making such calculations, the Newton-Raphson approach. Unfortunately, it is tedious to explain and requires a working understanding of the calculus to appreciate.[7] For present purposes, the main thing to recognize is that effective rates can be accurately estimated from gross issue prices by successive, trial-and-error uses of the way of calculating gross issue prices that we described earlier.

We conclude this section by emphasizing again that all ways of figuring gross issue prices and effective rates that are used in practice would yield the same $107,359.25 gross issue price and 7% effective rate that we have calculated. There is no disagreement over such amounts (except, of course, that often calculations and results would be modified to reflect numbers of days instead of numbers of months).

Amortization Calculations

We must consider one more thing before discussing confusions that can arise in accounting for bonds issued between interest dates: How to calculate compound-interest amortization of premium or discount. This is done as follows for each interest period:

1. Take the beginning-of-period carrying (book) value of the bond.

2. Multiply it by the effective rate, to determine the interest revenue or expense for the period.

3. Compare this revenue or expense with the period's interest receivable or payable (as figured at the coupon rate).

4. The difference between the two is the period's amortization of premium or discount.

<Figure 7 about here>

Figure 7 shows these calculations for Figure 1's and 2's bonds that were issued on an interest date. The carrying value at the beginning of the first interest period was the $102,624.32 issue price. Interest revenue or expense for the first period is $102,624.32 * 7% = $7,183.70. Since the semi-annual interest receivable or payable is $8,000.00, the first period's amortization of premium is $8,000.00 - $7,183.70 = $816.30, for a new, second-period beginning balance of $102,624.33 - $816.30 = $101,808.03. (However, reworking these calculations with less rounded figures, we get an issue price of $102,624.316044, a first-period interest expense or revenue of $102,624.316044 * .07 = $7,183.702123, a first-period amortization of $8,000 - $7,183.702123 = $816.297877, and a first-period ending balance of $102,624.316044 - $816.297877 = $101,808.0181. Therefore, Figure 8 reports this ending balance as $101,808.02.) Subsequent periods' calculations work in exactly the same way.

<Figure 8 about here>

When bonds are issued between interest dates, amortization calculations become only slightly more complicated. Figure 8 shows these calculations for Figure 3's through 6's bonds that were issued between interest dates, under the assumption that accountants use the same internally consistent $5,272.97 figure for book prepaid interest that we did when calculating the $107,359.25 gross issue price:

Internally consistent net issue price	$ 102,086.28
Internally consistent prepaid interest	5,272.97

Gross issue price	$ 107,359.25
	============

Since the buyer is entitled to a return on all of its investment (including any temporary investment in prepaid interest), that gross issue price is also the bonds' beginning carrying value. But because the bondholders' investment was for only 2 months of the first period, we calculate compound-interest revenue and expense to be:

$107,359.35 * ({1.07 ^ [2/6]} - 1) = $2,448.77

Since book prepaid interest is $5,272.97, the bondholders' first-period share of interest <u>receivable</u> is $8,000.00 - $5,272.97 = $2,727.03. Comparing this with the interest revenue gives an amortization of $2,727.03 - $2,448.77 = $278.26, for a second-period beginning carrying value of $101,808.02:

Gross issue price		$ 107,359.25
Prepaid interest	$ 5,272.97	
First period's amortization	278.26	5,551.23
	----------	------------
Beginning carrying value for second period ..		$ 101,808.02
		============

-- which is the same amount as in Figure 7. One would <u>expect</u> these amounts to be identical since, after the first interest payment, the two <u>situations</u> are identical.

Amortizations That Do Not Come Out Even[8]

<Figure 9 about here>

However, there is no requirement that accountants allocate interest in the way that we have allocated it thus far. For instance, accountants know what the gross issue price and the maturity value are. The difference between the two, $107,359.25 - $100,000.00 = $7,359.25, consists of prepaid interest and premium. Widespread practice calculates the book prepaid interest portion by a simple straight-line allocation that we mentioned earlier: $8,000 * 4 months / 6 months = $5,333.33. This is done in Figure 9. The buyer's portion of the first period's interest receivable shrinks to \$8,000.00 - \$5,333.33 = \$2,666.67.

A parallel calculation of the first period's interest revenue or expense then yields \$107,359.25 * 7% * 2/6 = \$2,505.05, and the first period's premium amortization shrinks to \$2,666.67 - \$2,505.05 = \$161.62, for an end-of-first-period carrying value of \$107,359.25 - \$5,333.33 - \$161.62 = \$101,864.30. The second period's interest revenue or expense becomes \$101,864.30 * 7% = \$7,130.50, and so forth.

<Figure 10 about here>

Unfortunately, as Figure 9's end-of-third-period carrying value shows, the premium on these bonds does not become completely amortized (\$100,064.44 - \$100,000.00 = \$64.44 is too great an amount merely to be a rounding error). Nor, as Figure 10 demonstrates, does it remedy matters to base calculation of the first period's interest revenue or expense on the bonds' <u>net</u> issue price: (\$107,359.25 - \$5,333.33) * 7% * 2/6 = \$2,380.60, etc.

Indeed, if bonds are issued between interest dates, book prepaid interest is calculated straight-line, premium or discount is amortized according to the compound-interest approach, and interest is allocated straight-line within interest periods, then premium or discount amortization will <u>never</u> "add up," except by coincidence. Instead, accountants must plug (fudge) the final interest revenue or expense to make things come out even. In practice, accountants do so routinely.

<Figure 11 about here>

There *is* one way to avoid this sort of sloppiness, while still making straight-line calculations of book prepaid interest and otherwise allocating interest within periods straight-line: Calculate the *first* period's interest revenue or expense in the same, compound-interest, way that we calculated it earlier: \$107,359.25 * ({1.07 ^ [2/6]} - 1) = \$2,448.77. As Figure 11 illustrates, premium or discount amortization then adds up (subject, of course, to possible rounding errors).

What this boils down to is (1) calculating the gross issue price by the compound-interest approach, (2) calculating book prepaid interest straight-line, (3) calculating the first interest revenue or expense compound-interest style, then (4) making all subsequent allocations straight-line. Delicacy restricts us to calling this procedure "eclectic." To the best of our knowledge, things are never calculated this eclectic way in practice -- that is to say, if accountants mix compound-interest amortization of premium or discount with straight-line calculation of book prepaid interest and straight-line allocations within interest periods, they accept any consequent inaccuracy in premium or discount amortization rather than go to the trouble (and additional inconsistency) of making a compound-interest calculation of the first period's interest revenue or expense. Finally, before continuing, we emphasize that this coupling of compoundinterest and straight-line calculations is different from the straight-line amortization of premium and discount that is discussed in Appendix A.

Negative Amortization

<Figures 12 through 14 about here>

Figure 12 gives the first 3 periods' amounts for a situation that is identical to the one in Figure 9, except that the bonds' issue and maturity dates are now 9/30/1 and 6/30/21. As you can see, under conventional, straight-line calculation of book prepaid interest, compound-interest amortization of premium or discount and conventional, straight-line allocation within interest payment periods, the first period's amortization can be in the wrong direction -- in this case increasing the premium.

Moreover, this incongruity cannot be avoided by our earlier eclectic device to make amortization come out even: by making a compound-interest calculation of the first period's interest revenue or expense. This is just what Figure 13 does, yet the first period's amortization is still negative. Only by calculating both book prepaid interest and premium or discount amortization straight-line (as in Appendix A) or both compound-interest (as in Figure 8) can we be sure of avoiding any possibility of negative amortization. Figure 14 does this for the compound-interest alternative.

<Figures 15 and 16 about here>

Figure 12's example of negative amortization was a conservative one. Figure 15 is more dramatic. And, as Figure 16 demonstrates, there even can be pathological situations in which amortization is never in the right direction.

Inconsistent Interest Charges

<Figure 17 about here>

We will consider one last potential confusion that can result from inconsistently coupling compound-interest amortization of premium or discount with straight-line allocation of interest within interest periods, and will demonstrate that it can arise even when book prepaid interest is calculated by the compound-interest approach. This incongruity is easiest seen when bonds are issued at a discount, so Figure 17 is the same as Figure 14 except that:

1. The annual effective rate is 18% (instead of 14%),

2. The bonds were issued on 6/30/1 and mature on 8/31/2, and

3. Although the company calculated book prepaid interest in an internally consistent, compound-interest way, when it closed its books at 12/31/1 it expediently accrued interest for the 4 months, 9/1/1 through 12/31/1, via straight-line allocation of the appropriate figures for the complete 9/1/1 through 2/28/2 interest period.

For the first accounting period (7/1/1 through 8/31/1), interest receivable or payable is $8,000 - $5,256.37 = $2,743.63 and interest revenue or expense is $103,232.44 * ({1.09 ^ [2/6]} - 1) = $3,008.45, yielding $3,008.45 - $2,743.63 = $264.82 of discount amortization. For the second period (9/1/1 through 12/31/1), allocated interest receivable or payable is $8,000.00 * 4/6 = $5,333.33 and allocated interest revenue or expense is $98,240.89 * 9% * 4/6 = $5,894.45 -- while for the third period (1/1/2 through 2/28/2) allocated interest receivable or payable is $8,000.00 * 2/6 = $2,666.67 and allocated interest revenue or expense is $98,240.89 * 9% * 2/6 = $2,947.23.

Now, whenever bonds are issued at a discount and book prepaid interest is calculated in an internally consistent way, the carrying value of the bonds will increase period by period. Since the compound-interest amortization approach bases its interest revenue and expense calculations on these carrying values, interest revenue and expense should also increase period by period over the bonds' life. Yet, if we compare the $3,008.45 interest revenue or expense for the two-month first period (7/1/1 through 8/31/1) with the $2,947.23 figure for the two-month third period (1/1/2 through 2/28/2), interest revenue or expense has decreased.

As was true of book prepaid interest, the way to avoid such paradoxes is to allocate interest within periods via compound-interest ratios, instead of by straight-line ratios. For the second period (four months) this gives us:

```
$8,000.00 * ({1.09 ^ [4/6]} - 1) / .09  ....  =  $5,256.37
$98,240.89 * .09 *({1.09 ^ [4/6]} - 1) / .09
   =  $98,240.89 * (1.09 ^ [4/6])  .........  =  $5,809.40
```

and for the third period (two months):

```
$8,000.00 - $5,256.37  =  $2,743.63
$8,841.68 - $5,809.40  =  $3,032.28
```

<Figure 18 about here>

This is done in Figure 18, whose compound-interest allocations within interest-payment periods are consistent with its compound-interest calculations of book prepaid interest and compound-interest discount amortizations. Once again, making all three kinds of calculations straight-line, as in Appendix A, also escapes these difficulties.[9]

Summary

Calculations for bonds issued between interest dates are only slightly harder to make than ones for bonds issued on interest dates. When programmed on a computer, or even on a programmable calculator,[10] they are almost trivial.

The real difficulties here are man-made, and result from expedient attempts to simplify compound-interest calculations by use of somewhat incompatible straight-line allocations. However, since this has no consequences save the generation of confusion, we expect these inconsistencies to persist.

Appendix A

Straight-Line Amortization of Premium or Discount

A company may amortize bond premium or discount straight-line whenever the results do not materially differ from those that would occur under compound-interest amortization. Companies that do this also allocate interest straight-line within periods. We will illustrate such calculations with the data from the example in Figures 17 and 18.

<Figure 19 about here>

The gross issue price will still be $103,232.44, but the company will calculate book prepaid interest as $8,000.00 * 4/6 = $5,333.33. The net issue price will be $103,232.44 - $5,333.33 = $97,899.11, for a discount at issue of $100,000.00 - $97,899.11 = $2,100.89. The buyer will hold these bonds for 14 months, so discount amortization for the first, 2-month period will be $2,100.89 * 2/14 = $300.13, and the first period's interest revenue or expense will be $8,000.00 - $5,333.33 + $300.13 = $2,966.80. The carrying value at the end of the first period will be $97,899.11 + $300.13 = $98,199.24. Figure 19 gives the remaining details.

Since these calculations are consistently straight-line, they encounter none of the difficulties that we earlier experienced from mingling straight-line and compound-interest calculations.

Appendix B

Assumptions Made by This Paper's Amortization Calculations

1. The company closes its books once per year, each December 31st.

2. All transactions occur at the ends of equal-length months.

3. If a company calculates book prepaid interest by the compound-interest approach but allocates interest and the like straight-line within interest-payment periods, it does the latter by first subtracting the book prepaid interest from the total interest for the period, then dividing the remainder straight-line (rather than by dividing the total interest straight-line then subtracting the prepaid interest from the first portion).

4. Although rounded amounts are reported in the Figures, these amounts are calculated from <u>un</u>rounded balances (the consequence is that rounding errors appear as occasional penny discrepancies within an accounting period's calculations, rather than as larger, cumulative discrepancies).

Notes

<1> See AICPA Professional Standards, 4111.14. The alternative, straight-line, amortization approach is briefly discussed in Appendix A.

<2> Until he abandoned accounting theory for micro-computers, one of us often argued that all allocations, such as these within-period interest allocations, are dreadfully arbitrary; see, for instance, A. L. Thomas, The Allocation Problem: Part Two (Sarasota, Fla.: American Accounting Association, 1974). But even when we are arbitrary, it may be best to be consistent. What follows is an instance.

<3> Technically, the next several sections describe valuation techniques that are valid only for bonds with two or more coupon payments remaining. But bonds with just one coupon payment (or no coupon payments, in the case of zero-coupon bonds) are easily handled by parallel calculations involving discounting single cash flows.

<4> See, for instance:

R. Cissell, H. Cissell, and D. C. Flaspohler, Mathematics of Finance, 5th ed. (Boston: Houghton Mifflin Company, 1978), pp. 279-82.

E. B. Greynolds, Jr., J. S. Aronofsky and R. J. Frame, Financial Analysis Using Calculators: Time Value of Money (New York: McGraw-Hill, 1980).

S. Homer and M. L. Leibowitz, Inside the Yield Book: New Tools for Bond Market Strategy (Englewood Cliffs, N. J.: Prentice-Hall, 1972).

P. M. Hummel and C. L. Seebeck, Mathematics of Finance, 3rd ed. (New York: McGraw-Hill Book Company, 1971), pp. 125-32.

B. M. Spence, J. Y. Graudenz, and J. J. Lynch, Jr., Standard Securities Calculation Methods (New York: Securities Industry Association, Inc., 1973), p. 38.

<5> Readers are warned that different computer and calculator programs are inconsistent with each other here. One of us has had occasion to compare outputs from many such programs. Few report the same gross issue price for a bond issued between interest dates; their treatments of fractional interest rates (such as our 1.Ø7 ^ -[2/6]) are a major reason for these inconsistencies. For a complete discussion (including a description of the effects of different daycount methods) see Spence, Graudenz and Lynch, op. cit.

<6> See Greynolds, Aronofsky and Frame, op. cit., pp. 337-4Ø.

<7> For more details, see Greynolds, Aronofsky and Frame, op. cit., pp. 343-44. Readers are invited to request single copies of a documented Microsoft BASIC bond calculations program (with error trapping, formatted output, and various user convenience features) from Arthur L. Thomas, 1642 Indiana,

Lawrence, Kansas 66044.

<8> See Appendix B for the technical assumptions made in the next several sections.

<9> As a demonstration of this consistency, please note that the third period's discount amortization now equals the first period's discount amortization times one plus the effective rate: $264.82 * 1.09 = $288.65. This is exactly what we should expect, given the simple exponential formula upon which the compound-interest approach to amortization is based.

<10> Greynolds, Aronofsky and Frame, op. cit., passim.

Figure 1
Rights to Receive Cash from a Bond Issued on an Interest Date

```
I            8,000        8,000        108,000
^              ^            ^             ^
|-------------|-------------|-------------|
^             ^             ^             ^
6/30/1     12/31/1       6/30/2       12/31/2
```

Figure 2
An Annuity of Superior Interest

```
I            1,000        1,000        1,000
^              ^            ^            ^
|-------------|-------------|-------------|
^             ^             ^             ^
6/30/1     12/31/1       6/30/2       12/31/2
```

Figure 3
Rights to Receive Cash from a Bond Issued Between Interest Dates

```
I       8,000                    8,000                     108,000
^         ^                        ^                           ^
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
^       ^       ^       ^       ^       ^       ^       ^
10/31/1 12/31/1 2/28/2  4/30/2  6/30/2  8/31/2 10/31/2 12/31/2
```

Figure 4
Superior Interest from a Bond Issued Between Interest Dates

```
I       1,000                    1,000                     1,000
^         ^                        ^                         ^
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
^       ^       ^       ^       ^       ^       ^       ^
10/31/1 12/31/1 2/28/2  4/30/2  6/30/2  8/31/2 10/31/2 12/31/2
```

Figure 5
Same as Figure 3, Except That the
Bond Was Issued Just Before the First Interest Payment

```
 I                                                 100,000
8,000                  8,000                        8,000
  ^                      ^                            ^
  |---|---|---|---|---|---|---|---|---|---|---|---|
  ^       ^       ^       ^       ^       ^       ^
12/31/1 2/28/2  4/30/2  6/30/2  8/31/2  10/31/2 12/31/2
```

Figure 6
Discounting of Figure 5's Bond to its Real Issue Date

```
   I                          109,808.02
   ^                              ^
   |------------|------------|
   ^                              ^
10/31/1                       12/31/1
```

Figure 7
Amortization of Premium on a Bond Issued on an Interest Date

Period	Beginning-of-Period Book Value	Interest Receivable or Payable	Interest Revenue or Expense	Amortization of Premium	End-of-Period Book Value
1	102,624.32	8,000.00	7,183.70	816.30	101,808.02
2	101,808.02	8,000.00	7,126.56	873.44	100,934.58
3	100,934.58	8,000.00	7,065.42	934.58	100,000.00

Figure 8
Amortization of Premium on a Bond Issued Between Interest Dates,
With Mutually Consistent Compound-Interest Calculation
of Both Book Prepaid Interest and Amortization of Premium

Period	Beginning-of-Period Book Value	Interest Receivable or Payable	Interest Revenue or Expense	Amortization of Premium	End-of-Period Book Value
1	107,359.25	2,727.03	2,448.77	278.26	101,808.02
2	101,808.02	8,000.00	7,126.56	873.44	100,934.58
3	100,934.58	8,000.00	7,065.42	934.58	100,000.00

Figure 9
Amortization of Premium on a Bond Issued Between Interest Dates,
With Straight-Line Calculation of Book Prepaid Interest,
And Compound-Interest Amortization of Premium
(First-Period Calculations Based on the Gross Issue Price)

Period	Beginning-of-Period Book Value	Interest Receivable or Payable	Interest Revenue or Expense	Amortization of Premium	End-of-Period Book Value
1	107,359.25	2,666.67	2,505.05	161.62	101,864.30
2	101,864.30	8,000.00	7,130.50	869.50	100,994.80
3	100,994.80	8,000.00	7,069.64	930.36	100,064.44

Figure 10
Same as Figure 9, Except That the First Period's
Calculations are Based on the Net Issue Price

Period	Beginning-of-Period Book Value	Interest Receivable or Payable	Interest Revenue or Expense	Amortization of Premium	End-of-Period Book Value
1	102,025.92	2,666.67	2,380.60	286.07	101,739.85
2	101,739.85	8,000.00	7,121.79	878.21	100,861.64
3	100,861.64	8,000.00	7,060.31	939.69	99,921.95

Figure 11
Same as Figure 9, Except With Compound-Interest
Calculation of the First Period's Interest Revenue or Expense

Period	Beginning-of-Period Book Value	Interest Receivable or Payable	Interest Revenue or Expense	Amortization of Premium	End-of-Period Book Value
1	107,359.25	2,666.67	2,448.77	217.90	101,808.02
2	101,808.02	8,000.00	7,126.56	873.44	100,934.57
3	100,934.57	8,000.00	7,065.42	934.58	100,000.00*

* Adjusted to eliminate one cent cumulative rounding error.

Figure 12
A Case of Negative Amortization

Maturity value: $100,000.00
Semi-annual coupon rate: 8%
Issue date: 9/30/1
Maturity date: 6/30/21
Number of interest payments per year: 2
Method for calculating book prepaid interest: straight-line
Premium amortization method: compound-interest
Allocation method within interest-payment periods: straight-line
Semi-annual effective rate: 7%
Gross issue price: $117,231.23
Book prepaid interest: $4,000.00

Period	Beginning-of-Period Book Value	Interest Receivable or Payable	Interest Revenue or Expense	Amortization of Premium	End-of-Period Book Value
1	117,231.23	4,000.00	4,103.09	-103.09	113,334.32
2	113,334.32	8,000.00	7,933.40	66.60	113,267.72
3	113,267.72	8,000.00	7,928.74	71.26	113,196.47
...	...	...	...	...	...

Figure 13
Same as Figure 12, But With Compound-Interest
Calculation of the First Period's Interest Revenue or Expense

Period	Beginning-of-Period Book Value	Interest Receivable or Payable	Interest Revenue or Expense	Amortization of Premium	End-of-Period Book Value
1	117,231.23	4,000.00	4,033.70	-33.70	113,264.93
2	113,264.93	8,000.00	7,928.55	71.45	113,193.48
3	113,193.48	8,000.00	7,923.54	76.46	113,117.02
...	...	...	...	...	...

Figure 14
Same as Figure 13, Except With Mutually Consistent Calculation
of Both Book Prepaid Interest and Amortization of Premium

Period	Beginning-of-Period Book Value	Interest Receivable or Payable	Interest Revenue or Expense	Amortization of Premium	End-of-Period Book Value
1	117,231.23	4,067.65	4,033.70	33.95	113,264.93
2	113,264.93	8,000.00	7,928.55	71.46	113,193.47
3	113,193.47	8,000.00	7,923.54	76.46	113,117.02
...	...	...	...	...	...

Figure 15
Another Case of Negative Amortization

Maturity value: $10,000,000
Semi-annual coupon rate: 7.5%
Issue date: 4/30/1
Maturity date: 12/31/40
Number of interest payments per year: 2
Method for calculating book prepaid interest: straight-line
Premium amortization method: compound-interest
Allocation method within interest-payment periods: straight-line
Semi-annual effective rate: 6.75%
Gross issue price: $11,599,408
Book prepaid interest: $500,000

Period	Beginning-of-Period Book Value	Interest Receivable or Payable	Interest Revenue or Expense	Amortization of Premium	End-of-Period Book Value
1	11,599,408	250,000	260,987	-10,987	11,110,394
2	11,110,394	750,000	749,952	48	11,110,346
3	11,110,346	750,000	749,948	52	11,110,294
...	...	...	...	...	...

Figure 16
A Radical Instance of Negative Amortization

Maturity value: $100,000.00
Annual coupon rate: 16%
Issue date: 6/30/1
Maturity date: 12/31/2
Number of interest payments per year: 1
Method for calculating book prepaid interest: straight-line
Discount amortization method: compound-interest
Annual effective rate: 16%
Gross issue price: $107,703.30
Book prepaid interest: $8,000.00

Period	Beginning-of-Period Book Value	Interest Receivable or Payable	Interest Revenue or Expense	Amortization of Premium	End-of-Period Book Value
1	107,703.30	8,000.00	8,616.26*	616.26	100,319.56
2	100,319.56	16,000.00	16,051.13	51.13	100,370.69

* 107,703.30 * 16% * 6/12 = 8,616.26.

Figure 17
Mutually Consistent Compound-Interest Calculation of Book Prepaid Interest and Discount Amortization, Coupled With Straight-Line Allocation of Interest Within Periods

Maturity value: $100,000.00
Semi-annual coupon rate: 8%
Issue date: 6/30/1
Maturity date: 8/31/2
Number of interest payments per year: 2
Method for calculating book prepaid interest: compound-interest
Premium amortization method: compound-interest
Allocation method within interest-payment periods: straight-line
Semi-annual effective rate: 9%
Gross issue price: $103,232.44
Book prepaid interest: $5,256.37

Period	Beginning-of-Period Book Value	Interest Receivable or Payable	Interest Revenue or Expense	Amortization of Discount	End-of-Period Book Value
1	103,232.44	2,743.63	3,008.45	264.82	98,240.89
2	98,240.89	5,333.33	5,894.45	561.12	98,802.01
3	98,802.01	2,666.67	2,947.23	280.56	99,082.57
4	99,082.57	8,000.00	8,917.43	917.43	100,000.00

Figure 18
Same as Figure 17, Except That Allocation of Interest Within Periods is Compound-Interest

Period	Beginning-of-Period Book Value	Interest Receivable or Payable	Interest Revenue or Expense	Amortization of Discount	End-of-Period Book Value
1	103,232.44	2,743.63	3,008.45	264.82	98,240.89
2	98,240.89	5,256.37	5,809.40	553.03	98,793.92
3	98,793.92	2,743.63	3,032.28	288.66	99,082.57
4	99,082.57	8,000.00	8,917.43	917.43	100,000.00

Figure 19
Same as Figure 16, Except That All Calculations are Straight-Line

Period	Beginning-of-Period Book Value	Interest Receivable or Payable	Interest Revenue or Expense	Amortization of Discount	End-of-Period Book Value
1	103,232.44	2,666.67	2,966.80	300.13	98,199.24
2	98,199.24	5,333.33	5,933.57	600.25	98,799.49
3	98,799.49	2,666.67	2,966.79	300.13	99,099.62
4	99,099.62	8,000.00	8,900.38	900.38	100,000.00

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