

WHAT DOES A NEW THINKPAD ULTRABOOK REALLY GIVE YOU? THE THINKPAD X1 CARBON VS. THINKPAD X220



Ultrabooks are a new category of computer—lighter and thinner than a traditional notebook computer but with comparable battery life and performance. Lenovo, whose ThinkPad X Series of business notebooks has been a leader in keyboard comfort and usability, introduced the new super-light ThinkPad X1 Carbon Ultrabook. This Ultrabook boasts a new keyboard design, the ThinkPad Precision Keyboard.

Principled Technologies (PT) wanted to find out if you really can improve on what the industry has called the best keyboard experience on a notebook. To do so, we had a group of impartial users in our lab evaluate the keyboard experience with ThinkPad X1 Carbon Ultrabook and with a previous-generation Lenovo ThinkPad notebook. We also compared the two systems' battery life and graphics performance.

The ThinkPad X1 Carbon excelled in every category we tested, including user experience—80 percent of users preferred the ThinkPad Precision Keyboard to the X220 notebook's keyboard. The ThinkPad X1 Carbon also delivered 20 percent longer battery life and performance generally comparable to, and in some cases better than, that of the ThinkPad X220 notebook system.

These findings make the Lenovo ThinkPad X1 Carbon an ideal choice for the user who would like to embrace extreme portability and keyboard usability while still enjoying long battery life and excellent performance.



PUTTING THE SYSTEMS TO THE TEST

About the Lenovo ThinkPad X1 Carbon Ultrabook

Lenovo has this say about its new Ultrabook: “The ThinkPad X1 Carbon is a stylish, no-compromise thin and light system with superior performance, battery, communication, and entertainment features.”

How does the Lenovo ThinkPad X1 Carbon Ultrabook compare to a previous-generation ThinkPad notebook?

We brought in a number of impartial users to compare the keyboard experience of the Lenovo ThinkPad X1 Carbon Ultrabook with the previous generation keyboard found on the X220 notebook. ThinkPad has long been touted in the industry for having the best keyboard, but with this change to a new design we wanted to ask the question, “Can you really improve on the ThinkPad Keyboard?” Each participant had their say on the overall experience and quality the old and new keyboard offered.

We also tested the performance of both systems using industry-standard benchmarks, and found that the ThinkPad X1 Carbon Ultrabook provided performance that was comparable to that of a full-fledged notebook running normal voltage processors. In addition to those advantages, the X1 Carbon’s battery lasted considerably longer—roughly 4.5 hours versus the ThinkPad X220’s 3.5 hours.

For detailed system configuration information, see [Appendix A](#). For detailed steps on how we tested, see [Appendix B](#) and [Appendix C](#).

USERS PREFER THE THINKPAD X1 CARBON KEYBOARD

Figure 1 summarizes how our study participants rated the keyboards of the two systems. As the predominance of winning checkmarks in the column of the ThinkPad X1 Carbon suggest, they overwhelmingly preferred the newer ThinkPad Precision Keyboard. (For detailed results of the keyboard evaluation, see [Appendix D](#).)

	ThinkPad X1 Carbon New ThinkPad Precision Keyboard	ThinkPad X220 Previous Generation Keyboard	Notes
Overall ranking	✓		Eight of 10 participants preferred the X1 Carbon ThinkPad Precision Keyboard to the previous-generation notebook keyboard.
Action of the keys	✓		On average, participants-preferred the action on the X1 Carbon ThinkPad Precision Keyboard, which they rated as “on the crisp and snappy side.”

	ThinkPad X1 Carbon New ThinkPad Precision Keyboard	ThinkPad X220 Previous Generation Keyboard	Notes
Distance the keys move downward	✓		Participants rated the distance the keys move downward as being better on X1 Carbon ThinkPad Precision Keyboard.
The touch and feel of the keyboard	✓		Overall, participants rated the touch and feel of the previous-generation notebook keyboard average, and those of the X1 Carbon ThinkPad Precision Keyboard excellent.
The texture on the tops of the keys	✓		Participants, on average, rated the X1 Carbon ThinkPad Precision Keyboard texture as just right. They rated both as having an acceptable texture, with the ThinkPad Precision Keyboard earning a slightly higher rating than the previous-generation notebook keyboard.
Overall typing experience	✓		On average, participants liked the typing experience on the X1 Carbon ThinkPad Precision Keyboard more than on the previous-generation notebook keyboard.
Satisfaction level if you had just purchased this laptop	✓		On average, our participants said they would have been much more satisfied with the X1 Carbon ThinkPad Precision Keyboard than with the previous-generation notebook keyboard if they purchased them.
Satisfaction level if the laptop had been purchased for you	✓		If the laptop had been purchased for them, participants said they would have been slightly more satisfied with the X1 Carbon ThinkPad Precision Keyboard.

Figure 1: The results of our keyboard study, as rated by those who tested the systems.

BATTERY LIFE

In Lenovo's internal testing, MobileMark 2007 (the previous version) showed that the ThinkPad X1 Carbon delivered 8.2 hours of battery life. MobileMark 2007 puts a lighter load on the system than MobileMark 2012.¹

We tested the batteries of the two notebook systems using the latest BAPCo MobileMark® 2012 benchmark to simulate battery life during office productivity and media creation applications. Figure 2 compares the battery life scores of the systems. The Lenovo ThinkPad X1 Carbon Ultrabook battery life was roughly an hour longer than that of the Lenovo ThinkPad X220 during the MobileMark 2012 test. (For complete MobileMark 2012 results, see [Appendix E](#).)

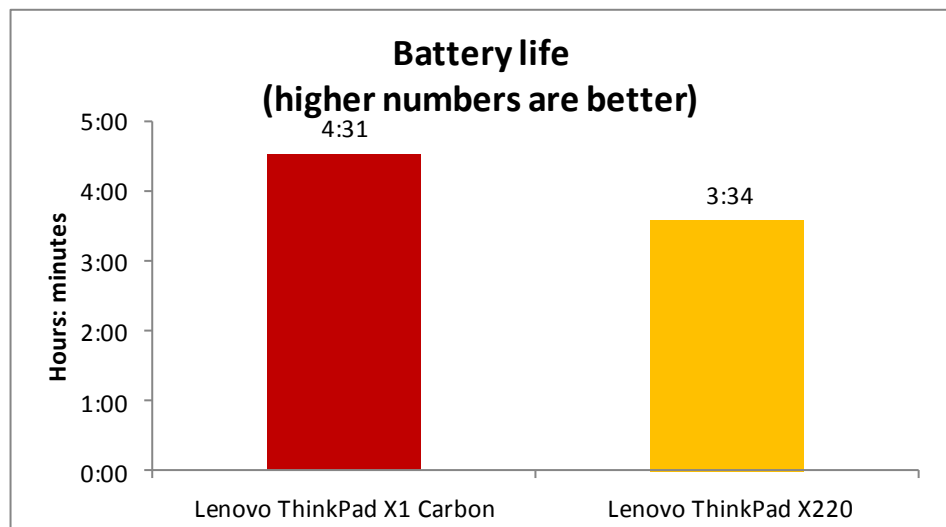


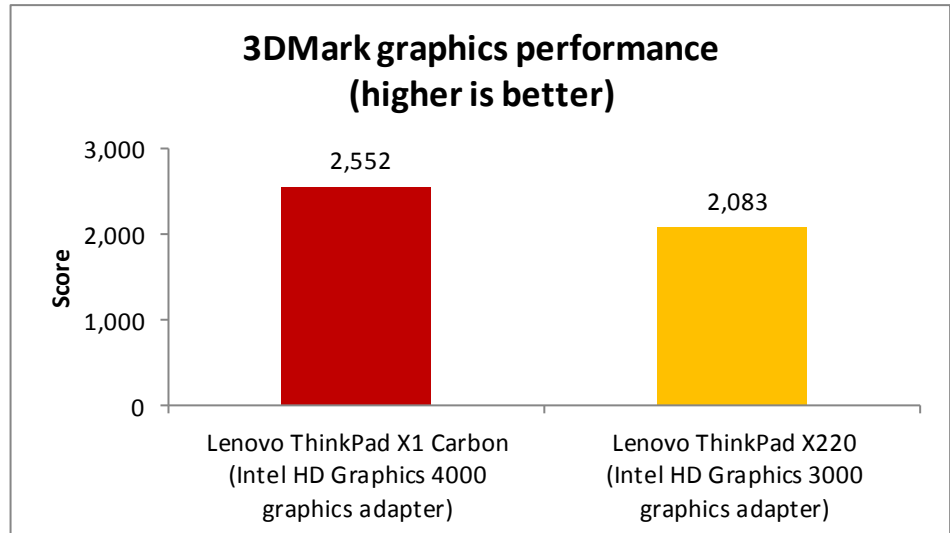
Figure 2: Battery life times for the Lenovo ThinkPad X1 Carbon and the Lenovo ThinkPad X220 we tested.

GRAPHICS PERFORMANCE

We tested the graphics performance of the two systems using the industry-standard 3DMark Vantage 1.1.0 benchmark. On this benchmark, the Intel HD Graphics 4000 graphics adapter in the Lenovo ThinkPad X1 Carbon delivered 18.4 percent better graphics performance than the Intel HD Graphics 3000 graphics adapter in the Lenovo ThinkPad X220.

¹ <http://www.lenovo.com/psref/pdf/psref430.pdf> Note: The reference to the 8.2-hour claim appears on pages 215 and 216. The fact that the claim is based on MobileMark 2007 appears on page 229.

Figure 3: 3DMark graphics performance benchmark results for the Lenovo ThinkPad X1 Carbon and the Lenovo ThinkPad X220 we tested.



3DMark Vantage 1.1.0 performance			
	Lenovo ThinkPad X1 Carbon	Lenovo ThinkPad X220	Percentage difference
3DMark Score	2,552	2,083	18.4%
Graphics Score	2,071	1,653	20.2%

Figure 4: Median 3DMark graphics performance benchmark results for the two systems. Higher numbers are better.

THE BENCHMARKS WE USED

In this section, we present a brief overview of the benchmarks we used in our testing.

BAPCo MobileMark 2012

MobileMark 2012 is an industry-standard benchmark that provides a battery life rating and a performance rating based on common office scenarios. In our tests, we focus solely on the battery life rating. MobileMark 2012 uses applications and workloads specific to mobile systems. These include office activities like file and document management, data processing, and rich content creation. This module provides a score for battery life of the tested applications.

MobileMark 2012 includes the following applications with their corresponding tasks:

- ABBYY® FineReader Pro 11
- Adobe® Acrobat® Pro X
- Adobe Flash® Player 11
- Adobe Photoshop® CS5 Extended 12.04

- Adobe Photoshop Elements 10
- Adobe Premiere® Pro CS 5.5
- CyberLink PowerDVD Ultra 11
- Microsoft® Excel® 2010 SP1
- Microsoft Internet Explorer® 9
- Microsoft Outlook® 2010 SP1
- Microsoft PowerPoint® 2010 SP1
- Microsoft Windows Media Player
- Microsoft Word 2010 SP1
- Mozilla® Firefox® 10.0.2
- WinZip® Pro 16

MobileMark 2012 measures system battery life in minutes. It records system battery life at the start of the benchmark and repeats the workload until the system battery life is depleted, or until the system powers down due to low battery life.

MobileMark 2012 records a timestamp once per minute. At the end of the benchmark, it compares the beginning timestamp to the final (last recorded) timestamp. MobileMark 2012 derives its system battery life rating as the number of minutes between the start and end timestamps.

For more information on this benchmark, see

<http://www.bapco.com/products/mobilemark2012/index.php>.

Futuremark® 3DMark Vantage

Futuremark 3DMark Vantage is a benchmark designed to rate the performance of DirectX® 10 gaming PCs. It includes two graphics tests, two CPU tests, and six feature tests. The benchmark reports both graphics and CPU scores, as well as an overall 3DMark score to rate overall gaming performance.

For more information on 3DMark Vantage, see

<http://www.3dmark.com/3dmarkvantage/>.

IN CONCLUSION

In our tests, we found that the newly designed ThinkPad Precision Keyboard on the lightweight Lenovo ThinkPad X1 Carbon Ultrabook delivered an experience that 8 out of 10 users preferred to the already popular ThinkPad X series notebook keyboard experience.

The Lenovo ThinkPad X1 Carbon Ultrabook also delivered comparable or better performance to a previous-generation Lenovo ThinkPad notebook and longer battery life—almost an extra hour.

These factors combine to make the Lenovo ThinkPad X1 Carbon Ultrabook an excellent choice for those ready who want the extreme portability of an ultra-lightweight system and an outstanding keyboard experience without sacrificing long battery life and excellent performance.

APPENDIX A: DETAILED SYSTEM CONFIGURATION

Figure 5 presents detailed configuration information for the two systems we tested.

System	Lenovo ThinkPad X1 Carbon	Lenovo ThinkPad X220
General		
Number of processor packages	1	1
Number of cores per processor	2	2
Number of hardware threads per core	2	2
System power management policy	Energy Saver	Energy Saver
Processor power-saving option	Enhanced Intel® SpeedStep® Technology	Enhanced Intel SpeedStep Technology
System dimensions (length x width x height)	13" x 8-7/8" x 3/4"	12" x 8-1/8" x 1-3/8"
System weight	2 lbs. 15 oz.	3 lbs. 5 oz.
CPU		
Vendor	Intel	Intel
Name	Core™ i5	Core i7
Model number	3427U	2620M
Stepping	E1	D2
Socket type and number of pins	Socket 988B rPGA	Socket 988B rPGA
Core frequency (GHz)	1.80	2.70
L1 cache	32 KB + 32 KB (per core)	32 KB + 32 KB (per core)
L2 cache	512 KB (256 KB per core)	512 KB (256 KB per core)
L3 cache	3 MB	4 MB
Platform		
Vendor	Lenovo	Lenovo
Motherboard model number	344423U	428624U
Motherboard chipset	Intel QS77	Intel QM67
BIOS name and version	Lenovo G6ET21WW (1.00) (05/30/2012)	Lenovo 8DET63WW (1.33) (07/19/2012)
Memory module(s)		
Vendor and model number	N/A – Integrated into motherboard	1 x Micron 16JSF51264HZ-1G4D1, 1 x Elpida EBJ41UF8BCS0-DJ-F
Type	PC3-10600	PC3-10600
Speed (MHz)	1,333	1,333
Speed running in the system (MHz)	1,333	1,333
Timing/Latency (tCL-tRCD-tRP-tRASmin)	9-9-9-24	9-9-9-24
Size (MB)	4,096	8,192

System	Lenovo ThinkPad X1 Carbon	Lenovo ThinkPad X220
Number of memory module(s)	N/A – Integrated into motherboard	2
Chip organization (single-sided/double-sided)	N/A – Integrated into motherboard	Double-sided
Channel (single/dual)	Dual	Dual
Hard disk		
Vendor and model number	SanDisk SD5SG2128G1052E	Hitachi HTS725032A7E630
Number of disks in system	1	1
Size (GB)	128	320
Buffer size (MB)	N/A	32
RPM	N/A	7,200
Type	SATA 6.0 Gb/s	SATA 6.0 Gb/s
Controller	Intel 7 Series Chipset Family SATA AHCI Controller	Intel 6 Series/C200 Series Chipset Family SATA Storage Controller
Driver	Intel 11.2.0.1006 (05/30/2012)	Intel 9.2.0.1011 (09/10/2010)
Operating system		
Name	Windows® 7 Professional x64	Windows 7 Professional x64
Build number	7601	7601
Service Pack	1	1
File system	NTFS	NTFS
Kernel	ACPI x64-based PC	ACPI x64-based PC
Language	English	English
Microsoft DirectX version	DirectX 11	DirectX 11
Graphics		
Vendor and model number	Intel HD Graphics 4000	Intel HD Graphics 3000
Type	Integrated	Integrated
Chipset	Intel HD Graphics 4000	Intel HD Graphics 3000
BIOS version	2124.1	2089.0
Total available graphics memory (MB)	1,696	1,696
Dedicated video memory (MB)	64	64
System video memory (MB)	0	0
Shared system memory (MB)	1,632	1,632
Resolution	1,600 x 900 x 32-bit	1,366 x 768 x 32-bit
Driver	Intel 8.15.10.2696 (03/19/2012)	Intel 8.15.10.2769 (05/25/2012)
Sound card/subsystem		
Vendor and model number	Realtek High Definition Audio	Conexant 20672 Smart Audio HD
Driver	Realtek 6.0.1.6617 (04/17/2012)	Conexant 8.32.23.2 (10/03/2011)
Ethernet		
Vendor and model number	N/A	Intel 82579LM Gigabit Network Connection

System	Lenovo ThinkPad X1 Carbon	Lenovo ThinkPad X220
Driver	N/A	Intel 11.15.16.0 (01/11/2012)
Wireless		
Vendor and model number	Intel Centrino Advanced-N 6205S	Intel Centrino Advanced-N 6205
Driver	Intel 15.1.0.18 (02/20/2012)	Intel 14.3.0.6 (10/27/2011)
Modem		
Vendor and model number	H5321 gw Mobile Broadband Modem	N/A
Driver	Ericsson AB 7.0.0.1 (09/01/2011)	N/A
Optical drive(s)		
Vendor and model number	N/A	N/A
Type	N/A	N/A
USB ports		
Number	2	3
Type	1 x USB 2.0, 1 x USB 3.0	2 x USB 2.0, 1 x USB 3.0
Other	Media card reader, Mini DisplayPort	Media card reader, DisplayPort
IEEE 1394 ports		
Number	0	0
Monitor		
LCD type	HD+ LED WXGA	HD LED WXGA
Screen size	14.0"	12.5"
Refresh rate	50 Hz	50 Hz
Battery		
Type	N/A - Integrated	Lenovo 0A36282
Size (length x width x height)	N/A - Integrated	8-1/8" x 2-1/8" x 7/8"
Rated capacity	(45.8Wh)	5,200mAh / 11.1V (57Wh)
Weight	N/A - Integrated	11 oz.

Figure 5: System configuration information.

APPENDIX B: MEASURING KEYBOARD PREFERENCE

To obtain data about participant preferences on the typing experience of the two systems' keyboards, we asked 10 testers—5 men and 5 women from the PT staff—to type on those systems.

We placed each system in a conference room, on a table with a partition that concealed each participant from the other system.

A proctor read test instructions to participants and also observed the test. Testers had full view of the system being reviewed during the test to allow them the full user experience.

After finishing the typing tasks at a given station, the participant completed a paper form, using a nine-point rating scale to indicate his or her perception of the keyboard's feel. The form also contained a field where participants could record optional comments.

Participant profile

- 5 men and 5 women
- Users of notebook computers with a range of experience
- Basic touch-typing skills

Task list

1. Type a standard sentence that contains all the letters of the English alphabet: *The quick brown fox jumped over the lazy sleeping dog.*
2. Press Enter.
3. Choose from a set of five texts and transcribe the text for the duration of the test.
4. Switch to any of the remaining texts at any time during the test.
5. Continue transcription until 5 minutes has elapsed.

Test monitor role

- Read initial instructions to test participants.
- Observe tests to ensure participants follow test procedures.
- Collect ratings forms and enter data into results spreadsheet.
- Prepare the test stations for the next participant.

Competitive keyboard comparison

Subjects arrived at PT test labs and were asked to wait in a dedicated area. Once both subjects for a session arrived, they were escorted to the testing area.

Introduction

Subjects were asked to sit at one of the two notebooks. The proctor explained the expectations for the study. Key highlights:

- Subjects would provide feedback on the typing experience of each keyboard.
- Subjects would perform a basic transcription exercise:
 - Transcribing text from print into a Notepad file on the notebook.
 - Duration: 5 minutes.
- The proctor would ask the subjects to type at a comfortable typing speed.
- The proctor would ask the subjects to ignore errors or mistyping. Editing with the touchpad or using backspace will be discouraged.

- It was understood that touch typists may perform corrections automatically. Single backspaces are acceptable, but not backing up through an entire word or area in the document.
- The proctor would ask if there are any questions, at this point.
- The proctor would ask the subjects to adjust their chairs and document holders to comfortable positions.
- Five printed texts would be provided. The subjects could choose any of them to start with, and could change texts during the typing experience.

Typing/rating exercise

1. Once the subjects were comfortable, the proctor counted down to zero, and started the timer for 5 minutes.
2. At the completion of the 5-minute period, the subjects were given a questionnaire to rate the typing experience.
3. The proctor explained how the 9-point Likert scale should be filled out.
4. The proctor explained that there are no correct or incorrect answers, and that this was simply an opportunity for the subject to provide his or her opinion on the typing exercise.
5. The proctor encouraged questions from the subject if anything was unclear. All answers to a question were provided to the entire group.

Ranking exercise

After both notebooks had been used and rated, the subjects performed a forced ranking exercise, ranking the most and least preferred typing experience.

The opportunity for additional written feedback regarding the preference was provided for on the questionnaire, along with the opportunity for verbal feedback to the proctor.

The proctor thanked the subjects for their participation, and released them.


Notebook keyboard evaluation questionnaire

Subject# _____

Notebook _____


Please use the scales on the following pages to evaluate the typing experience of the notebook you just used. Each scale has nine segments, with a pair of opposing adjectives at each end of the scale (e.g., fast—slow). Mark each scale with an “X” in the slot you feel most accurately represents your feeling, attitude, or opinion in response to the statement or question.

For example:

Slow  Fast

The closer to one or the other of the adjectives on the scales you make the mark, the more you indicate that adjective applies to your typing experience.

1. How would you rate the touch of the keys on this keyboard?

Too light  Too heavy

Just
right

2. The key action (the way the keys feel when they are pressed down) on this keyboard is:

Soft & mushy  Crisp & snappy

Unacceptable  Acceptable

3. In general, the distance the keys move downward when they are pressed is:

Too short  Too long

Unacceptable  Acceptable

4. Overall, how would you rate the touch and feel of this keyboard:

Poor

Excellent

5. Overall, the sound of this keyboard is:

Too noisy

Too quiet

Just
right

Unacceptable

Acceptable

6. The distance (spacing) from key to key is:

Too close

Too far apart

Just
right

Unacceptable

Acceptable

7. Overall, how did you like the typing experience on this notebook:

Disliked it

Liked it

8. If you had just purchased this notebook, how satisfied would you have been with the typing experience:

Very dissatisfied

Very satisfied

9. If your employer had just provided this laptop to you, how satisfied would you have been with it:

Very dissatisfied

Very satisfied

APPENDIX C: MEASURING SYSTEM PERFORMANCE

Measuring battery life with MobileMark 2012

Avoiding antivirus software conflicts

MobileMark 2012 is not compatible with any virus-scanning software, so we uninstalled any such software present on the notebook PCs before we installed the benchmark.

Avoiding pre-installed software conflicts

MobileMark 2012 installs the following applications, which its test scripts employ:

- ABBYY FineReader Pro 11
- Adobe Acrobat Pro X
- Adobe Flash Player 11
- Adobe Photoshop CS5 Extended 12.04
- Adobe Photoshop Elements 10
- Adobe Premiere Pro CS 5.5
- CyberLink PowerDVD Ultra 11
- Microsoft Excel 2010 SP1
- Microsoft Internet Explorer
- Microsoft Outlook 2010 SP1
- Microsoft PowerPoint 2010 SP1
- Microsoft Windows Media Player
- Microsoft Word 2010 SP1
- Mozilla Firefox 10.0.2
- WinZip Pro 16

If any of these applications are already on the system under test, they could cause problems with the benchmark due to software conflicts. To avoid any such issues, before we installed the benchmark, we uninstalled all conflicting pre-installed software applications, including different versions of any of the programs MobileMark 2012 uses.

Adjusting display brightness and power settings

The brightness of a notebook's display affects its battery life. Therefore, BAPCo requires that before you test with MobileMark 2012 you do the following step: make sure the brightness of the notebook's monitor is greater than or equal to 150 nits on a completely white screen while the notebook is unplugged and running on battery power. The measurement follows the standards from the Video Electronics Standards Association (www.vesa.org).

We complied with this standard for all the tests we ran by setting the notebook PC's brightness as close to 150 nits as we could without going below that brightness level. We used the following procedure before we started each test. Note: This procedure assumes we began with the notebook plugged into the power supply.

1. To create a completely blank, white screen, open Microsoft Paint by clicking Start→All Programs→Accessories→Paint.
2. Press Ctrl+W to open the Resize and Skew dialog.
3. Under Horizontal and Vertical enter 200, and click OK.
4. Click the View tab.
5. Click Full screen to view a white screen.
6. Wait 45 minutes to allow the screen to warm.
7. Unplug the notebook from the power supply, and measure the display's brightness using a luminance meter in the center of the screen. (We used the Gossen Mavolux 5032C.)
8. If the reading is below or significantly greater than 150 nits, use the notebook's keyboard screen-brightness-adjustment keys to bring the display as close to 150 nits as possible, then retest.
9. Allow the notebook to run on battery power for 10 minutes, re-measure the display, and adjust the brightness up or down as necessary.
10. Verify that the notebook saved the brightness setting by plugging in the system, unplugging it, and taking another reading.

Note: If the notebook did not save this setting, use its power management application(s) to set the brightness appropriately, and save that setting. If saving the settings is ineffective, use the keyboard brightness setting keys to adjust the screen to bring the display as close to 150 nits as possible. Next, note how many times you pressed the button to achieve the desired brightness. After unplugging the system under test, use the keyboard to set the desired brightness by pressing the brightness button as many times as you previously noted to return the screen to the correct brightness level.

Using the MobileMark built-in Configuration Tool

This tool supports three levels of configuration:

1. Only makes changes that are REQUIRED in order for the benchmark to run.
2. Additionally, makes changes that are RECOMMENDED for repeatable results.
3. Additionally, makes changes that help ensure best results.

The Configuration tool makes the following configuration changes at each of the three levels:

Level 1 - Required

- Disables User Account Control (UAC)
- Disables Windows Update
- Disables System Sleep and Hibernate
- Sets Screen Dimming Timeout (2 minutes)
- Disables Low Battery Actions
- Disables Network Proxies
- Disables Autorun for Optical Drive

Level 2 - Recommended

- Create BAPCo power scheme
- Set Power Plan Type to balanced
- Disables Windows Firewall
- Disables Windows Sidebar/Gadgets

- Disables Windows Pop-ups
- Disables Incoming Remote Desktop Connections
- Disables Windows Error Reporting
- Disables Screen Saver and Monitor Timeout
- Sets CPU Adaptive Mode
- Disables Desktop Slideshow
- Disables Disk Defrag

Level 3 - Optional

- Sets Hard Disk Timeout
- Disables Windows Defender
- Disables System Restore
- Ignores Laptop Lid Close
- Sets Maximum Display Brightness
- Disables Adaptive Brightness

Installing MobileMark 2012 and configuring the system for testing

1. Verify that the wireless adapter is enabled and connected to a wireless router that is not connected to the Internet.
2. Insert the MobileMark 2012 Install DVD into the notebook PC's DVD drive.
3. When the Autoplay menu appears, click Run MobileMark2012_Setup.exe.
4. At the Welcome screen, click Next.
5. Enter the serial number, and click Next.
6. Accept the license agreement, and click Next.
7. At the Choose Components screen, select Full, and click Next.
8. At the Choose Install Location screen, accept the default location of C:\Program Files (x86)\BAPCo\MobileMark2012, and click Next.
9. At the Choose Start Menu Folder screen, click Install.
10. Insert Disc 2 when prompted.
11. At the InstallShield Wizard Complete screen, click Finish.
12. Launch MobileMark 2012.
13. Click Configuration and choose all options.
14. Click Apply, and restart the computer when prompted.
15. Adjust the screen brightness to no less than 150 nits:
 - a. Click the Windows start button, and type `power options` in the Windows Start Search box.
 - b. Click Change plan settings.
 - c. Click Change advanced power settings.
 - d. Expand the Display option, and change the Display brightness on battery and plugged in to the correct percentage that produces no less than 150 nits.

Note: If you are unable to save these settings, please see the Displaying Brightness section above.

Conditioning the battery

1. Plug the AC power adapter into the notebook PC, and completely charge the battery.
2. Install MobileMark 2012, following the steps we outlined in the Installing MobileMark 2012 section earlier in this section.
3. Double-click the MobileMark 2012 icon on the desktop.

4. Click the Office Productivity icon.
5. Type `System Conditioning` as the name for this test in the Project Name, check the box next to conditioning, and click Continue.
6. If MobileMark 2012 lists no problems or warnings, click Continue. If it does list any problems or warnings, close MobileMark 2012, and correct the problem(s) before proceeding.
7. When prompted, unplug the AC power adapter. The Office Productivity test begins immediately.
8. The test is complete when the notebook PC has fully depleted its battery and is no longer operational when running on battery power.
9. Plug the AC power adapter into the notebook PC, and completely charge the battery.

Measuring battery life with MobileMark 2012

We performed the following steps to run the MobileMark 2012 Office Productivity benchmark:

1. Double-click the MobileMark 2012 icon on the desktop.
2. Select the Office Productivity test by clicking the Office Productivity icon.
3. Enter a name for this test in the Project Name field, and click Continue.
4. If MobileMark 2012 lists no problems or warnings, click Continue. If it does list any problems or warnings, close MobileMark 2012, and correct the problem(s) before proceeding.
5. When prompted, unplug the AC power adapter. The test begins immediately.
6. The Office Productivity test is complete when the notebook PC has fully depleted its battery and is no longer operational when running on battery power.

We executed the MobileMark 2012 Office Productivity test three times on the system and took the median battery life run as the representative score for that test.

Getting the MobileMark 2012 results

After each MobileMark Productivity 2012 test completed, we plugged the AC power adapter into the notebook PC and turned on the system. MobileMark 2012 started automatically after the system booted, then analyzed the test scores and opened the Test Results Viewer with the results from the last test.

To submit these results to BAPCo, we saved the test results by performing the following steps:

1. Click Save.
2. Enter a name and select FDR to save the results as an FDR file.
3. Click Save again, and select PDF to save the results as a PDF file.
4. Browse to the Documents directory where the result FDR and PDF files were saved.

Measuring graphics performance with 3DMark Vantage 1.1.0

Installing and patching 3DMark Vantage

1. Download the 3DMark_Vantage_v110_installer.exe Windows package from <http://www.futuremark.com/benchmarks/3dmarkvantage/download/>.
2. Install 3DMark Vantage 1.1.0 with the default options by double-clicking the 3DMark_Vantage_v110_installer.exe file.
3. At the Welcome screen, click Next.
4. At the License Agreement screen, click I accept the terms of the license agreement, and click Next.

5. At the Setup Type screen, click Express, and click Next.
6. At the Ready to Install the Program screen, click Install.
7. When the 3DMark Vantage Read Me page appears in your Web browser, review the document, and click Close when you are finished.
8. At the Setup Complete screen, click Finish.
9. Launch 3DMark Vantage 1.1.0 by double-clicking on the 3DMark Vantage desktop icon. Enter the registration code, and click Register.
10. Exit 3DMark Vantage 1.1.0.

Running 3DMark Vantage 1.1.0

For Performance-level results:

1. Reboot the system, and wait 2 minutes.
2. Double-click the 3DMark Vantage desktop icon to launch the benchmark.
3. To close the Important Information window, click Close.
4. Click Run Benchmark.
5. When the benchmark run completes, take a screenshot of the results, and record the 3DMark, GPU, and CPU scores.
6. Perform steps 1 through 5 two more times, and report the median of the three runs.

APPENDIX D: DETAILED RESULTS OF KEYBOARD EVALUATION

In this section, we present the detailed results of our keyboard evaluation, where 10 participants spent time exploring the two keyboards then completed the Notebook keyboard evaluation questionnaire included in Appendix B.

About the participants

We had half the participants work with the X1 initially and the other half work with the X220 initially.

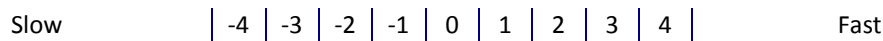
- Participant A – Worked with the Lenovo ThinkPad x220 first
- Participant B - Worked with the Lenovo ThinkPad X1 Carbon first
- Participant C - Worked with the Lenovo ThinkPad x220 first
- Participant D - Worked with the Lenovo ThinkPad X1 Carbon first
- Participant E - Worked with the Lenovo ThinkPad x220 first
- Participant F - Worked with the Lenovo ThinkPad x220 first
- Participant G - Worked with the Lenovo ThinkPad x220 first
- Participant H - Worked with the Lenovo ThinkPad X1 Carbon first
- Participant I - Worked with the Lenovo ThinkPad X1 Carbon first
- Participant J - Worked with the Lenovo ThinkPad X1 Carbon first

About the rating scale

Participants completed the Notebook keyboard evaluation questionnaire included in Appendix B. The questionnaire uses a nine-point Likert scale, with questions that use the following format:



Figures 7 and 8 present the participants' responses, translating the position where they placed the mark as follows:



Participants also had the opportunity to type in written answers to several questions about the two keyboards.

Evaluation of the keyboard on the Lenovo ThinkPad x220

Participant	A	B	C	D	E	F	G	H	I	J
<i>How would you rate the touch of the keys on this keyboard?</i>										
<i>Too light -- Too heavy</i>	-1	3	2	0	0	0	0	1	-1	0
<i>The key action (the way the keys feel when they are pressed down on this keyboard is:</i>										
<i>Soft & mushy -- Crisp & snappy</i>	-1	-3	2	3	-1	2	2	-3	-1	1
<i>Unacceptable -- Acceptable</i>	3	-2	0	3	3	4	-1	-2	2	3
<i>In general, the distance the keys move downward when they are pressed is:</i>										
<i>Too short -- Too long</i>	3	2	3	0	-1	1	1	2	0	0
<i>Unacceptable -- Acceptable</i>	-1	1	-2	3	3	4	2	-2	0	3
<i>Overall, how would you rate the touch and feel of this keyboard:</i>										
<i>Poor -- Excellent</i>	-1	-1	-1	2	1	3	2	-2	-2	3
<i>Overall, the sound of this keyboard is:</i>										
<i>Too noisy -- Too quiet</i>	-1	-2	-2	-1	-1	-1	-2	0	1	-1
<i>Unacceptable -- Acceptable</i>	0	2	-2	3	2	3	-1	2	0	3
<i>The distance (spacing) from key to key is</i>										
<i>Too close -- Too far apart</i>	-2	-3	-1	-1	-1	0	2	-3	4	0
<i>Unacceptable -- Acceptable</i>	0	-2	2	2	3	4	-1	-3	-4	3
<i>Overall, how did you like the typing experience on this notebook:</i>										
<i>Disliked it -- Liked it</i>	-1	-2	-2	2	2	-2	-1	-3	-3	3
<i>If you had just purchased this notebook, how satisfied would you have been with the typing experience?</i>										
<i>Very dissatisfied -- Very satisfied</i>	-3	-2	-2	1	2	-1	-1	-2	-3	3
<i>If your employer had just provided this laptop to you, how satisfied would you have been with it?</i>										
<i>Very dissatisfied -- Very satisfied</i>	-3	-1	0	2	3	3	2	-2	-1	3
Ranking										
<i>Rank the order of the keyboards (1 = your favorite, 2 = your least favorite)</i>	2	2	2	1	2	2	2	2	2	1

Figure 6: User responses to the keyboard on the Lenovo ThinkPad x220.

Evaluation of the ThinkPad Precision Keyboard on the Lenovo ThinkPad X1 Carbon

Participant	A	B	C	D	E	F	G	H	I	J
<i>How would you rate the touch of the keys on this keyboard?</i>										
<i>Too light -- Too heavy</i>	2	1	0	1	0	0	0	1	2	1
<i>The key action (the way the keys feel when they are pressed down on this keyboard is:</i>										
<i>Soft & mushy -- Crisp & snappy</i>	2	3	1	-2	3	0	-1	0	4	3
<i>Unacceptable -- Acceptable</i>	4	-1	3	-2	4	0	4	3	-4	3
<i>In general, the distance the keys move downward when they are pressed is:</i>										
<i>Too short -- Too long</i>	1	-2	1	2	0	1	0	0	-4	0
<i>Unacceptable -- Acceptable</i>	3	-1	3	-2	4	0	4	4	-4	3
<i>Overall, how would you rate the touch and feel of this keyboard:</i>										
<i>Poor -- Excellent</i>	1	2	4	-1	4	0	3	3	-1	2
<i>Overall, the sound of this keyboard is:</i>										
<i>Too noisy -- Too quiet</i>	-1	0	2	0	0	-2	-1	0	0	-1
<i>Unacceptable -- Acceptable</i>	1	4	3	0	4	0	3	4	4	3
<i>The distance (spacing) from key to key is</i>										
<i>Too close -- Too far apart</i>	0	0	0	2	0	1	1	2	3	3
<i>Unacceptable -- Acceptable</i>	4	4	4	-2	4	0	3	2	-2	-3
<i>Overall, how did you like the typing experience on this notebook:</i>										
<i>Disliked it -- Liked it</i>	2	2	4	-2	4	1	4	3	-2	1
<i>If you had just purchased this notebook, how satisfied would you have been with the typing experience?</i>										
<i>Very dissatisfied -- Very satisfied</i>	2	2	3	-1	3	3	4	3	-1	2
<i>If your employer had just provided this laptop to you, how satisfied would you have been with it?</i>										
<i>Very dissatisfied -- Very satisfied</i>	2	3	3	0	4	4	4	3	0	3
Ranking										
<i>Rank the order of the keyboards (1 = your favorite, 2 = your least favorite)</i>	1	1	1	2	1	1	1	1	1	2

Figure 7: User responses to the ThinkPad Precision Keyboard on the Lenovo ThinkPad X1 Carbon.

APPENDIX E: COMPLETE MOBILEMARK 2012 SCORES

Figure 8 presents the battery life results for the systems in detail.

MobileMark 2012 battery life			
	Lenovo ThinkPad X1 Carbon	Lenovo ThinkPad X220	Percentage difference
Performance Qualification score	121	131	-8.3%
Battery Life score (mm)	271	214	21.0%
Battery Life score (hh:mm)	4:31	3:34	21.0%

Figure 8: Detailed battery life results for the two systems.

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