# ANSI E1.48 – 2014 (R2019)

## A Recommended Luminous Efficiency Function for Stage and Studio Luminaire Photometry

Photo/2013-5000r2a

Approved as an American National Standard by the ANSI Board of Standards Review on 1 February 2019.
This is a reaffirmation of the 2014 edition.

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# 1 Introduction (not normative)

## 1.1 Problem

The problem this Standard attempts to address is that many light meters, whether hand-held or part of a goniophotometer or other apparatus, use a photopic luminous efficiency function, V(λ), that does not accurately match the response of the human eye. They give meter readings for stage and studio luminaires with significant extreme blue and red output as having lower luminous output than they appear to have to the human viewer. Therefore, we recommend a luminosity efficiency function that more closely approximates the response of the human eye for use with meters measuring the illuminance of stage and studio luminaires.

## 1.2 Background

Quite often the photopic luminous efficiency function, V(λ), used by light meters is the one commonly called "CIE 1924," which is, as the name suggests, more than 80 years old. There also are more recent luminosity functions, such as CIE 2004, published in ISO 23539:2005(E), Photometry - The CIE System Of Physical Photometry, which is cited by IES LM-79-08, Approved Method for the Electrical and Photometric Measurements of Solid-State Lighting Products. However, even this most recent standard for the photopic luminous efficiency function does not agree with the most recent published research on the human perception of light as a function of wavelength. This disagreement can lead to low meter readings —readings that do not match what a person's eyes are telling him when he looks at the output of a stage and studio luminaire.

The error is small with continuous spectrum sources such as incandescent lamps when producing nominally white light, but the error can be significant with luminaires that use narrow-band sources or that use filters on continuous spectrum white sources to produce intensely colored light. For example, a luminaire using red, green, and blue LEDs with outputs centered at 660, 525, and 470 nm will have the output of the red and blue LEDs under-reported by 11% and 47% per CIE 1924 and by 9% and 43% per CIE 2004 compared to the V(λ) function recommended in this Standard. In both cases, these differences are significant. An error also will be found with heavily filtered output from a continuous source. The transmission through a congo blue gel will be almost entirely above 660 nm and below 500 nm, which are the extreme ends of the spectrum where CIE 1924 and CIE 2004 most deviate from the V(λ) function recommended here. Figure 1 shows the CIE 1924 function and the V(λ) function recommended in this Standard. The increased sensitivity with this Standard's function can be seen clearly.

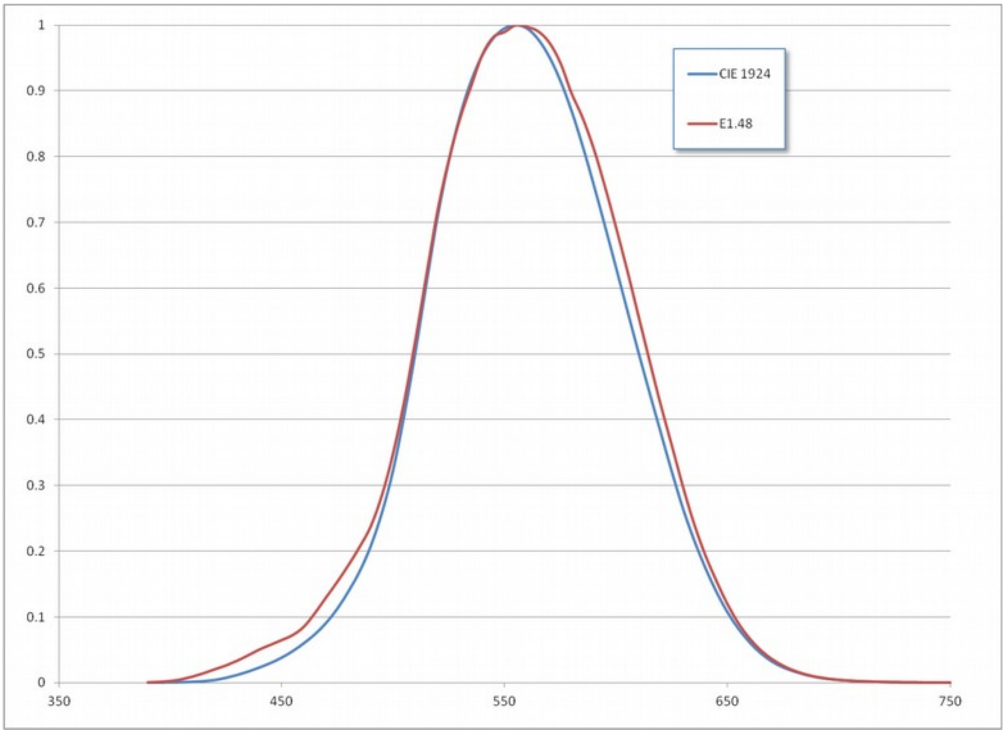

Figure 1

Industries that use primarily white light from continuous or near-continuous sources are perhaps not materially affected by the inaccurate V(λ) functions embodied in common light meters. However, the entertainment industry, which uses narrow-band emitters and intensely colored light, is seriously affected. Published luminaire performance data can be off by 50%, simply because the meters used to measure the light output conformed to an inaccurate photopic luminous efficiency function.

Photometry differs from most other measurement sciences in that nothing is absolute, instead everything is referred back to the human eye and the theoretical "standard observer." You can't have a standard lumen in quite the same way as you have a standard kilogram or a standard metre, Instead, the standards are based on statistical studies of many people in an attempt to produce an acceptable average for human vision. The photopic luminous efficiency function, V(λ), is a means of presenting the data from that accepted average standard observer in a usable form. Most light meters are designed to mimic the response of the human eye, not that of a video camera or other light sensor.

**1.3 Solution**
The solution we propose is to specifically recommend the use of a photopic luminous efficiency function, V(λ), that better matches the response of the human eye than the common historical V(λ) function, when measuring the output of stage and studio luminaires, particularly when measuring those for which it is known or believed that 20% or more of the output power is at wavelengths shorter than 500 nm.

The photopic luminous efficiency function, V(λ), specified here is based on research done with human subjects in the last decade. It has been offered to the CIE (Commission Internationale de l'Éclairage) for adoption as an international standard, but that adoption is still pending as this E1.48 standard is being written.

## 2 Scope (normative)

This Standard shall apply to all stage and studio luminaires, but particularly to those for which it is known or believed that 20% or more of the output power is at wavelengths shorter than 500 nm.

# 3 Requirements (normative)

### 3.1 Measurement

Meters of any type that measure the output of a stage or studio luminaire shall have a photopic luminous efficiency function, V(λ), that matches the values given in the following table:

**Luminous Efficiency Function V(λ)**

| λ nm | V |
|---|---|
| 390 | 4.14616E-04 |
| 391 | 5.02833E-04 |
| 392 | 6.08499E-04 |
| 393 | 7.34444E-04 |
| 394 | 8.83739E-04 |
| 395 | 1.05965E-03 |
| 396 | 1.26553E-03 |
| 397 | 1.50475E-03 |
| 398 | 1.78049E-03 |
| 399 | 2.09557E-03 |
| 400 | 2.45219E-03 |
| 401 | 2.85222E-03 |
| 402 | 3.29912E-03 |
| 403 | 3.79747E-03 |
| 404 | 4.35277E-03 |
| 405 | 4.97172E-03 |
| 406 | 5.66101E-03 |
| 407 | 6.42161E-03 |
| 408 | 7.25031E-03 |
| 409 | 8.14017E-03 |
| 410 | 9.07986E-03 |
| 411 | 1.00561E-02 |
| 412 | 1.10646E-02 |
| 413 | 1.21052E-02 |
| 414 | 1.31801E-02 |
| 415 | 1.42938E-02 |
| 416 | 1.54500E-02 |
| 417 | 1.66409E-02 |
| 418 | 1.78530E-02 |
| 419 | 1.90702E-02 |
| 420 | 2.02737E-02 |

| λ nm | V |
|---|---|
| 421 | 2.14481E-02 |
| 422 | 2.26004E-02 |
| 423 | 2.37479E-02 |
| 424 | 2.49125E-02 |
| 425 | 2.61211E-02 |
| 426 | 2.73992E-02 |
| 427 | 2.87499E-02 |
| 428 | 3.01691E-02 |
| 429 | 3.16514E-02 |
| 430 | 3.31904E-02 |
| 431 | 3.47791E-02 |
| 432 | 3.64149E-02 |
| 433 | 3.80957E-02 |
| 434 | 3.98184E-02 |
| 435 | 4.15794E-02 |
| 436 | 4.33710E-02 |
| 437 | 4.51718E-02 |
| 438 | 4.69542E-02 |
| 439 | 4.86872E-02 |
| 440 | 5.03366E-02 |
| 441 | 5.18761E-02 |
| 442 | 5.33222E-02 |
| 443 | 5.47060E-02 |
| 444 | 5.60634E-02 |
| 445 | 5.74339E-02 |
| 446 | 5.88511E-02 |
| 447 | 6.03081E-02 |
| 448 | 6.17864E-02 |
| 449 | 6.32657E-02 |
| 450 | 6.47235E-02 |
| 451 | 6.61475E-02 |

| λ nm | V |
|---|---|
| 452 | 6.75726E-02 |
| 453 | 6.90493E-02 |
| 454 | 7.06328E-02 |
| 455 | 7.23834E-02 |
| 456 | 7.43596E-02 |
| 457 | 7.65938E-02 |
| 458 | 7.91144E-02 |
| 459 | 8.19535E-02 |
| 460 | 8.51482E-02 |
| 461 | 8.87266E-02 |
| 462 | 9.26601E-02 |
| 463 | 9.68972E-02 |
| 464 | 1.01375E-01 |
| 465 | 1.06014E-01 |
| 466 | 1.10738E-01 |
| 467 | 1.15511E-01 |
| 468 | 1.20312E-01 |
| 469 | 1.25116E-01 |
| 470 | 1.29896E-01 |
| 471 | 1.34630E-01 |
| 472 | 1.39331E-01 |
| 473 | 1.44023E-01 |
| 474 | 1.48737E-01 |
| 475 | 1.53507E-01 |
| 476 | 1.58364E-01 |
| 477 | 1.63320E-01 |
| 478 | 1.68376E-01 |
| 479 | 1.73537E-01 |
| 480 | 1.78805E-01 |
| 481 | 1.84182E-01 |
| 482 | 1.89656E-01 |

| λ nm | V |
|---|---|
| 483 | 1.95210E-01 |
| 484 | 2.00826E-01 |
| 485 | 2.06483E-01 |
| 486 | 2.12183E-01 |
| 487 | 2.18028E-01 |
| 488 | 2.24159E-01 |
| 489 | 2.30730E-01 |
| 490 | 2.37916E-01 |
| 491 | 2.45871E-01 |
| 492 | 2.54602E-01 |
| 493 | 2.64076E-01 |
| 494 | 2.74249E-01 |
| 495 | 2.85068E-01 |
| 496 | 2.96484E-01 |
| 497 | 3.08501E-01 |
| 498 | 3.21139E-01 |
| 499 | 3.34418E-01 |
| 500 | 3.48354E-01 |
| 501 | 3.62960E-01 |
| 502 | 3.78228E-01 |
| 503 | 3.94136E-01 |
| 504 | 4.10658E-01 |
| 505 | 4.27760E-01 |
| 506 | 4.45399E-01 |
| 507 | 4.63540E-01 |
| 508 | 4.82138E-01 |
| 509 | 5.01143E-01 |
| 510 | 5.20497E-01 |
| 511 | 5.40139E-01 |
| 512 | 5.60021E-01 |
| 513 | 5.80097E-01 |
| 514 | 6.00317E-01 |
| 515 | 6.20626E-01 |
| 516 | 6.40940E-01 |
| 517 | 6.61077E-01 |
| 518 | 6.80813E-01 |

| λ nm | V |
|---|---|
| 519 | 6.99904E-01 |
| 520 | 7.18089E-01 |
| 521 | 7.35159E-01 |
| 522 | 7.51182E-01 |
| 523 | 7.66314E-01 |
| 524 | 7.80735E-01 |
| 525 | 7.94645E-01 |
| 526 | 8.08207E-01 |
| 527 | 8.21382E-01 |
| 528 | 8.34070E-01 |
| 529 | 8.46171E-01 |
| 530 | 8.57580E-01 |
| 531 | 8.68241E-01 |
| 532 | 8.78306E-01 |
| 533 | 8.87991E-01 |
| 534 | 8.97521E-01 |
| 535 | 9.07135E-01 |
| 536 | 9.16995E-01 |
| 537 | 9.26929E-01 |
| 538 | 9.36673E-01 |
| 539 | 9.45948E-01 |
| 540 | 9.54468E-01 |
| 541 | 9.61983E-01 |
| 542 | 9.68439E-01 |
| 543 | 9.73829E-01 |
| 544 | 9.78152E-01 |
| 545 | 9.81411E-01 |
| 546 | 9.83667E-01 |
| 547 | 9.85208E-01 |
| 548 | 9.86381E-01 |
| 549 | 9.87536E-01 |
| 550 | 9.89023E-01 |
| 551 | 9.91081E-01 |
| 552 | 9.93491E-01 |
| 553 | 9.95917E-01 |
| 554 | 9.98021E-01 |

| λ nm | V |
|---|---|
| 555 | 9.99461E-01 |
| 556 | 9.99993E-01 |
| 557 | 9.99756E-01 |
| 558 | 9.98984E-01 |
| 559 | 9.97912E-01 |
| 560 | 9.96774E-01 |
| 561 | 9.95736E-01 |
| 562 | 9.94711E-01 |
| 563 | 9.93553E-01 |
| 564 | 9.92116E-01 |
| 565 | 9.90255E-01 |
| 566 | 9.87860E-01 |
| 567 | 9.84932E-01 |
| 568 | 9.81504E-01 |
| 569 | 9.77603E-01 |
| 570 | 9.73261E-01 |
| 571 | 9.68476E-01 |
| 572 | 9.63137E-01 |
| 573 | 9.57106E-01 |
| 574 | 9.50254E-01 |
| 575 | 9.42457E-01 |
| 576 | 9.33690E-01 |
| 577 | 9.24289E-01 |
| 578 | 9.14671E-01 |
| 579 | 9.05233E-01 |
| 580 | 8.96361E-01 |
| 581 | 8.88307E-01 |
| 582 | 8.80846E-01 |
| 583 | 8.73645E-01 |
| 584 | 8.66376E-01 |
| 585 | 8.58720E-01 |
| 586 | 8.50430E-01 |
| 587 | 8.41505E-01 |
| 588 | 8.32011E-01 |
| 589 | 8.22015E-01 |
| 590 | 8.11587E-01 |

| λ nm | V |
|---|---|
| 591 | 8.00787E-01 |
| 592 | 7.89652E-01 |
| 593 | 7.78205E-01 |
| 594 | 7.66473E-01 |
| 595 | 7.54479E-01 |
| 596 | 7.42247E-01 |
| 597 | 7.29823E-01 |
| 598 | 7.17252E-01 |
| 599 | 7.04582E-01 |
| 600 | 6.91855E-01 |
| 601 | 6.79101E-01 |
| 602 | 6.66285E-01 |
| 603 | 6.53359E-01 |
| 604 | 6.40281E-01 |
| 605 | 6.27007E-01 |
| 606 | 6.13515E-01 |
| 607 | 5.99849E-01 |
| 608 | 5.86068E-01 |
| 609 | 5.72226E-01 |
| 610 | 5.58375E-01 |
| 611 | 5.44554E-01 |
| 612 | 5.30767E-01 |
| 613 | 5.17013E-01 |
| 614 | 5.03289E-01 |
| 615 | 4.89595E-01 |
| 616 | 4.75944E-01 |
| 617 | 4.62396E-01 |
| 618 | 4.49015E-01 |
| 619 | 4.35862E-01 |
| 620 | 4.22990E-01 |
| 621 | 4.10415E-01 |
| 622 | 3.98036E-01 |
| 623 | 3.85730E-01 |
| 624 | 3.73391E-01 |
| 625 | 3.60924E-01 |
| 626 | 3.48286E-01 |

| λ nm | V |
|---|---|
| 627 | 3.35570E-01 |
| 628 | 3.22896E-01 |
| 629 | 3.10370E-01 |
| 630 | 2.98086E-01 |
| 631 | 2.86116E-01 |
| 632 | 2.74482E-01 |
| 633 | 2.63195E-01 |
| 634 | 2.52263E-01 |
| 635 | 2.41690E-01 |
| 636 | 2.31481E-01 |
| 637 | 2.21638E-01 |
| 638 | 2.12162E-01 |
| 639 | 2.03054E-01 |
| 640 | 1.94312E-01 |
| 641 | 1.85923E-01 |
| 642 | 1.77827E-01 |
| 643 | 1.69965E-01 |
| 644 | 1.62284E-01 |
| 645 | 1.54740E-01 |
| 646 | 1.47308E-01 |
| 647 | 1.40017E-01 |
| 648 | 1.32901E-01 |
| 649 | 1.25991E-01 |
| 650 | 1.19312E-01 |
| 651 | 1.12882E-01 |
| 652 | 1.06711E-01 |
| 653 | 1.00805E-01 |
| 654 | 9.51665E-02 |
| 655 | 8.97959E-02 |
| 656 | 8.46904E-02 |
| 657 | 7.98401E-02 |
| 658 | 7.52337E-02 |
| 659 | 7.08606E-02 |
| 660 | 6.67104E-02 |
| 661 | 6.27736E-02 |
| 662 | 5.90418E-02 |

| λ nm | V |
|---|---|
| 663 | 5.55070E-02 |
| 664 | 5.21614E-02 |
| 665 | 4.89970E-02 |
| 666 | 4.60058E-02 |
| 667 | 4.31788E-02 |
| 668 | 4.05075E-02 |
| 669 | 3.79838E-02 |
| 670 | 3.55998E-02 |
| 671 | 3.33486E-02 |
| 672 | 3.12233E-02 |
| 673 | 2.92178E-02 |
| 674 | 2.73260E-02 |
| 675 | 2.55422E-02 |
| 676 | 2.38612E-02 |
| 677 | 2.22786E-02 |
| 678 | 2.07902E-02 |
| 679 | 1.93919E-02 |
| 680 | 1.80794E-02 |
| 681 | 1.68482E-02 |
| 682 | 1.56919E-02 |
| 683 | 1.46045E-02 |
| 684 | 1.35806E-02 |
| 685 | 1.26157E-02 |
| 686 | 1.17070E-02 |
| 687 | 1.08561E-02 |
| 688 | 1.00648E-02 |
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| 690 | 8.66128E-03 |
| 691 | 8.04605E-03 |
| 692 | 7.48113E-03 |
| 693 | 6.95999E-03 |
| 694 | 6.47707E-03 |
| 695 | 6.02768E-03 |
| 696 | 5.60817E-03 |
| 697 | 5.21669E-03 |
| 698 | 4.85179E-03 |

| λ nm | V |
|---|---|
| 699 | 4.51201E-03 |
| 700 | 4.19594E-03 |
| 701 | 3.90206E-03 |
| 702 | 3.62837E-03 |
| 703 | 3.37301E-03 |
| 704 | 3.13432E-03 |
| 705 | 2.91086E-03 |
| 706 | 2.70153E-03 |
| 707 | 2.50580E-03 |
| 708 | 2.32323E-03 |
| 709 | 2.15333E-03 |
| 710 | 1.99556E-03 |
| 711 | 1.84932E-03 |
| 712 | 1.71398E-03 |
| 713 | 1.58890E-03 |
| 714 | 1.47345E-03 |
| 715 | 1.36702E-03 |
| 716 | 1.26895E-03 |
| 717 | 1.17842E-03 |
| 718 | 1.09464E-03 |
| 719 | 1.01694E-03 |
| 720 | 9.44727E-04 |
| 721 | 8.77517E-04 |
| 722 | 8.15044E-04 |
| 723 | 7.57076E-04 |
| 724 | 7.03376E-04 |
| 725 | 6.53705E-04 |
| 726 | 6.07805E-04 |
| 727 | 5.65344E-04 |
| 728 | 5.26005E-04 |
| 729 | 4.89506E-04 |
| 730 | 4.55597E-04 |
| 731 | 4.24055E-04 |
| 732 | 3.94686E-04 |
| 733 | 3.67318E-04 |
| 734 | 3.41794E-04 |

| λ nm | V |
|---|---|
| 735 | 3.17974E-04 |
| 736 | 2.95744E-04 |
| 737 | 2.75056E-04 |
| 738 | 2.55864E-04 |
| 739 | 2.38114E-04 |
| 740 | 2.21745E-04 |
| 741 | 2.06671E-04 |
| 742 | 1.92747E-04 |
| 743 | 1.79831E-04 |
| 744 | 1.67802E-04 |
| 745 | 1.56557E-04 |
| 746 | 1.46017E-04 |
| 747 | 1.36153E-04 |
| 748 | 1.26945E-04 |
| 749 | 1.18367E-04 |
| 750 | 1.10393E-04 |
| 751 | 1.02991E-04 |
| 752 | 9.61184E-05 |
| 753 | 8.97332E-05 |
| 754 | 8.37969E-05 |
| 755 | 7.82744E-05 |
| 756 | 7.31331E-05 |
| 757 | 6.83414E-05 |
| 758 | 6.38704E-05 |
| 759 | 5.96939E-05 |
| 760 | 5.57886E-05 |
| 761 | 5.21351E-05 |
| 762 | 4.87218E-05 |
| 763 | 4.55385E-05 |
| 764 | 4.25744E-05 |
| 765 | 3.98188E-05 |
| 766 | 3.72588E-05 |
| 767 | 3.48747E-05 |
| 768 | 3.26477E-05 |
| 769 | 3.05614E-05 |
| 770 | 2.86018E-05 |

| λ nm | V |
|---|---|
| 771 | 2.67584E-05 |
| 772 | 2.50294E-05 |
| 773 | 2.34137E-05 |
| 774 | 2.19091E-05 |
| 775 | 2.05126E-05 |
| 776 | 1.92190E-05 |
| 777 | 1.80180E-05 |
| 778 | 1.68990E-05 |
| 779 | 1.58531E-05 |
| 780 | 1.48724E-05 |
| 781 | 1.39509E-05 |
| 782 | 1.30853E-05 |
| 783 | 1.22733E-05 |
| 784 | 1.15123E-05 |
| 785 | 1.08000E-05 |
| 786 | 1.01336E-05 |
| 787 | 9.50992E-06 |
| 788 | 8.92563E-06 |
| 789 | 8.37785E-06 |
| 790 | 7.86392E-06 |
| 791 | 7.38154E-06 |
| 792 | 6.92910E-06 |
| 793 | 6.50514E-06 |
| 794 | 6.10822E-06 |
| 795 | 5.73694E-06 |
| 796 | 5.38983E-06 |
| 797 | 5.06527E-06 |
| 798 | 4.76167E-06 |
| 799 | 4.47756E-06 |
| 800 | 4.21160E-06 |
| 801 | 3.96246E-06 |
| 802 | 3.72867E-06 |
| 803 | 3.50888E-06 |
| 804 | 3.30187E-06 |
| 805 | 3.10656E-06 |
| 806 | 2.92212E-06 |

| λ nm | V |
|---|---|
| 807 | 2.74821E-06 |
| 808 | 2.58456E-06 |
| 809 | 2.43087E-06 |
| 810 | 2.28679E-06 |
| 811 | 2.15191E-06 |
| 812 | 2.02566E-06 |
| 813 | 1.90746E-06 |
| 814 | 1.79679E-06 |

| λ nm | V |
|---|---|
| 815 | 1.69315E-06 |
| 816 | 1.59603E-06 |
| 817 | 1.50490E-06 |
| 818 | 1.41925E-06 |
| 819 | 1.33860E-06 |
| 820 | 1.26256E-06 |
| 821 | 1.19077E-06 |
| 822 | 1.12303E-06 |

| λ nm | V |
|---|---|
| 823 | 1.05915E-06 |
| 824 | 9.98951E-07 |
| 825 | 9.42251E-07 |
| 826 | 8.88880E-07 |
| 827 | 8.38669E-07 |
| 828 | 7.91454E-07 |
| 829 | 7.47077E-07 |
| 830 | 7.05386E-07 |

The V(λ) values in this table are from the 'CIE "physiologically-relevant" luminous efficiency functions consistent with the Stockman & Sharpe cone fundamentals' listing available at http://www.cvrl.org/, the website of the Colour & Vision Research Laboratory of the Institute of Ophthalmology, which is part of University College London. The values were downloaded as a file entitled linCIE2008v2e_1.csv on 9 January 2013.

**3.2 Reporting V(λ)**
Measurements made with the luminous efficiency function specified in this Standard shall be identified as being "per ANSI E1.48 V(λ)."