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Optical system, optical apparatus, and method of manufacturing optical system

Abstract

An optical system comprises a first lens group having positive refractive power, a second lens group having positive refractive power, and a third lens group having negative refractive power, arranged in order from an object side, wherein, when focusing, the second lens group moves along an optical axis, and the optical system satisfies the conditional expressions $0.100<BFa/f<0.500$ and $-5.000<(-G1R1)/f<500.000$, where BFa is an air equivalent distance on the optical axis between a lens surface on an image side of a lens disposed closest to an image and the image, f is a focal length of the optical system, and G1R1 is a radius of curvature of a lens surface on the object side for a lens component disposed farthest on the object side in the first lens group.

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Background/Summary

TECHNICAL FIELD
(1) The present invention relates to an optical system, an optical apparatus, and a method of manufacturing an optical system.
TECHNICAL BACKGROUND
(2) In the related art, a fixed focal point optical system of the inner focus type that focuses by drawing out a positive lens group disposed on the image side of the diaphragm to the object side has been proposed (for example, see Patent literature 1). In a case where such an optical system is increased in diameter, it is difficult to correct various aberrations favorably.
PRIOR ARTS LIST
Patent Document
(3) Patent literature 1: Japanese Laid-open Patent Publication No. 2012-234169 (A)
SUMMARY OF THE INVENTION
(4) An optical system according to a first mode comprises a first lens group having positive refractive power, a second lens group having positive refractive power, and a third lens group having negative refractive power, arranged in order from the object side, wherein when focusing, the second lens group moves along the optical axis, and the optical system satisfies the following conditional expressions
$0.100<BFa/f<0.500$ and
$-5.000<(-G1R1)/f<500.000$ where BFa is an air equivalent distance on the optical axis from the lens surface on the image side to the image surface for the lens disposed farthest on the image side in the optical system, f is the focal length of the optical system, and G1R1 is the radius of curvature of the lens surface on the object side for the lens component disposed farthest on the object side in the first lens group.
(5) An optical apparatus according to a second mode is provided with the above optical system.
(6) A method of manufacturing an optical system according to a third mode is a method of manufacturing an optical system including a first lens group having positive refractive power, a second lens group having positive refractive power, and a third lens group having negative refractive power, arranged in order from the object side, the method comprising: disposing each lens within a lens barrel such that when focusing, the second lens group moves along the optical axis, and the optical system satisfies the following conditional expressions
$0.100<BFa/f<0.500$ and
$-5.000<(-G1R1)/f<500.000$ where BFa is an air equivalent distance on the optical axis from the lens surface on the image side to the image surface for the lens disposed farthest on the image side in the optical system, f is the focal length of the optical system, and
(7) G1R1 is the radius of curvature of the lens surface on the object side for the lens component disposed farthest on the object side in the first lens group.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. **1** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 1st example;

(2) FIG. **2**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 1st example, while FIG. **2**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 1st example;

(3) FIG. **3** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 2nd example;

(4) FIG. **4**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 2nd example, while FIG. **4**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 2nd example;

(5) FIG. **5** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 3rd example;

(6) FIG. **6**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 3rd example, while FIG. **6**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 3rd example;

(7) FIG. **7** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 4th example;

(8) FIG. **8**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 4th example, while FIG. **8**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 4th example;

(9) FIG. **9** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 5th example;

(10) FIG. **10**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 5th example, while FIG. **10**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 5th example;

(11) FIG. **11** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 6th example;

(12) FIG. **12**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 6th example, while FIG. **12**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 6th example;

(13) FIG. **13** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 7th example;

(14) FIG. **14**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 7th example, while FIG. **14**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 7th example;

(15) FIG. **15** is a lens configuration diagram for the state of focusing on infinity in an optical system according to an 8th example;

(16) FIG. **16**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 8th example, while FIG. **16**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 8th example;

(17) FIG. **17** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 9th example;

(18) FIG. **18**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 9th example, while FIG. **18**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 9th example;

(19) FIG. **19** is a lens configuration diagram for the state of focusing on infinity in an optical

system according to a 10th example;
(20) FIG. **20**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 10th example, while FIG. **20**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 10th example;
(21) FIG. **21** is a lens configuration diagram for the state of focusing on infinity in an optical system according to an 11th example;
(22) FIG. **22**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 11th example, while FIG. **22**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 11th example;
(23) FIG. **23** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 12th example;
(24) FIG. **24**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 12th example, while FIG. **24**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 12th example;
(25) FIG. **25** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 13th example;
(26) FIG. **26**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 13th example, while FIG. **26**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 13th example;
(27) FIG. **27** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 14th example;
(28) FIG. **28**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 14th example, while FIG. **28**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 14th example;
(29) FIG. **29** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 15th example;
(30) FIG. **30**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 15th example, while FIG. **30**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 15th example;
(31) FIG. **31** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 16th example;
(32) FIG. **32**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 16th example, while FIG. **32**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 16th example;
(33) FIG. **33** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 17th example;
(34) FIG. **34**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 17th example, while FIG. **34**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 17th example;
(35) FIG. **35** is a lens configuration diagram for the state of focusing on infinity in an optical system according to an 18th example;
(36) FIG. **36**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 18th example, while FIG. **36**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 18th example;
(37) FIG. **37** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 19th example;
(38) FIG. **38**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 19th example, while FIG. **38**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 19th example;
(39) FIG. **39** is a lens configuration diagram for the state of focusing on infinity in an optical

system according to a 20th

(40) FIG. **40**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 20th example, while FIG. **40**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 20th example;

(41) FIG. **41** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 21st example;

(42) FIG. **42**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 21st example, while FIG. **42**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 21st example;

(43) FIG. **43** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 22nd example;

(44) FIG. **44**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 22nd example, while FIG. **44**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 22nd example;

(45) FIG. **45** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 23rd example;

(46) FIG. **46**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 23rd example, while FIG. **46**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 23rd example;

(47) FIG. **47** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 24th example;

(48) FIG. **48**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 24th example, while FIG. **48**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 24th example;

(49) FIG. **49** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 25th example;

(50) FIG. **50**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 25th example, while FIG. **50**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 25th example;

(51) FIG. **51** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 26th example;

(52) FIG. **52**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 26th example, while FIG. **52**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 26th example;

(53) FIG. **53** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 27th example;

(54) FIG. **54**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 27th example, while FIG. **54**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 27th example;

(55) FIG. **55** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 28th example;

(56) FIG. **56**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 28th example, while FIG. **56**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 28th example;

(57) FIG. **57** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 29th example;

(58) FIG. **58**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 29th example, while FIG. **58**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 29th example;

(59) FIG. **59** is a lens configuration diagram for the state of focusing on infinity in an optical

system according to a 30th
(60) FIG. **60**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 30th example, while FIG. **60**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 30th example;
(61) FIG. **61** is a lens configuration diagram for the state of focusing on infinity in an optical system according to a 31st example;
(62) FIG. **62**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 31st example, while FIG. **62**B illustrates various aberration graphs upon focusing on a short-distance object in the optical system according to the 31st example;
(63) FIG. **63** is a diagram illustrating a configuration of a camera provided with the optical system according to the present embodiment; and
(64) FIG. **64** is a flowchart illustrating a method of manufacturing the optical system according to the present embodiment.

DESCRIPTION OF THE EMBODIMENT

(65) Hereinafter, an optical system and an optical apparatus according to the present embodiment will be described with reference to the drawings. First, a camera (optical apparatus) provided with the optical system according to the present embodiment will be described on the basis of FIG. **63**. As illustrated in FIG. **63**, a camera **1** is a digital camera provided with the optical system according to the present embodiment as a photographic lens **2**. In the camera **1**, light from a physical object not illustrated (the subject) is condensed by the photographic lens **2**, and arrives at an image sensor **3**. With this arrangement, the light from the subject is captured by the image sensor **3** and recorded to memory not illustrated as a subject image. In this way, a photographer is able to capture an image of the subject with the camera **1**. Note that the camera may be a mirrorless camera or a single-lens reflex camera having a quick-return mirror.
(66) As illustrated in FIG. **1**, an optical system LS(**1**) treated as an example of the optical system (photographic lens) LS according to the present embodiment comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing, the second lens group G**2** moves along the optical axis. This arrangement makes it possible to obtain favorable optical performance throughout the focusing range from infinity to short distances, while also restraining changes in image magnification.
(67) The optical system LS according to the present embodiment is not limited to the optical system LS(**1**) illustrated in FIG. **1**, and may also be the optical system LS(**2**) illustrated in FIG. **3**. Similarly, the optical system LS according to the present embodiment may be any of the optical systems LS(**3**) to LS(**31**) illustrated in FIG. **5** and subsequent drawings.
(68) Given the above configuration, the optical system LS according to the present embodiment satisfies the following conditional expressions.
$0.100<BFa/f<0.500$ (1)
$-5.000<(-G1R1)/f<500.000$ (2) where BFa is an air equivalent distance on the optical axis from the lens surface on the image side to the image surface for the lens disposed farthest on the image side in the optical system LS, f is the focal length of the optical system LS, and G1R1 is the radius of curvature of the lens surface on the object side for the lens component disposed farthest on the object side in the first lens group G**1**.
(69) Conditional Expression (1) prescribes the appropriate range of the ratio between the focal length of the whole optical system LS and the back focus. By satisfying Conditional Expression (1), astigmatism can be corrected favorably.
(70) If the corresponding value of Conditional Expression (1) exceeds the upper limit, correcting astigmatism is difficult. By setting the upper limit of Conditional Expression (1) to 0.450, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the upper limit of Conditional Expression (1) preferably is set to 0.420, 0.400,

0.380, 0.350, 0.320, 0.300, 0.290, 0.280, 0.275, 0.270, or 0.265, more preferably to 0.260.
(71) If the corresponding value of Conditional Expression (1) falls below the lower limit, correcting astigmatism is also difficult. By setting the lower limit of Conditional Expression (1) to 0.110, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the lower limit of Conditional Expression (1) preferably is set to 0.120, 0.130, 0.140, 0.150, or 0.160, more preferably to 0.170.
(72) Conditional Expression (2) prescribes the appropriate range of the ratio between the radius of curvature of the lens surface farthest on the object side in the first lens group G**1** and the focal length of the whole optical system LS. By satisfying Conditional Expression (2), favorable optical performance can be secured for the state of focusing on infinity. In the present embodiment, a lens component refers to a single lens or a cemented lens.
(73) If the corresponding value of Conditional Expression (2) exceeds the upper limit, the radius of curvature of the lens surface farthest on the object side in the first lens group G**1** decreases, and therefore an increased amount of various aberrations occur, and variations in coma aberration when focusing become larger. By setting the upper limit of Conditional Expression (2) to 400.000, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the upper limit of Conditional Expression (2) preferably is set to 300.000, 200.000, 100.000, 85.000, 75.000, 60.000, 45.000, or 30.000, more preferably to 20.000.
(74) If the corresponding value of Conditional Expression (2) falls below the lower limit, the radius of curvature of the lens surface farthest on the object side in the first lens group G**1** increases, which makes correcting coma aberration difficult. By setting the lower limit of Conditional Expression (2) to −4.000, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the lower limit of Conditional Expression (2) preferably is set to −3.000, −2.000, −1.000, 0.010, 0.100, 0.200, 0.250, 0.300, 0.350, 0.400, 0.450, 0.500, 0.550, 0.600, or 0.650, more preferably to 0.700.
(75) It is desirable for the optical system LS according to the present embodiment to satisfy Conditional Expression (3) below.
$-5.000<(-G1R1)/f1<50.000$ (3) where f1 is the focal length of the first lens group G**1**.
(76) Conditional Expression (3) prescribes the appropriate range of the ratio between the radius of curvature of the lens surface farthest on the object side in the first lens group G**1** and the focal length of the first lens group G**1**. By satisfying Conditional Expression (3), favorable optical performance can be secured for the state of focusing on infinity.
(77) If the corresponding value of Conditional Expression (3) exceeds the upper limit, the radius of curvature of the lens surface farthest on the object side in the first lens group G**1** decreases, and therefore an increased amount of various aberrations occur, and variations in coma aberration when focusing become larger. By setting the upper limit of Conditional Expression (3) to 40.000, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the upper limit of Conditional Expression (3) preferably is set to 30.000, 20.000, or 10.000, more preferably to 5.000.
(78) If the corresponding value of Conditional Expression (3) falls below the lower limit, the radius of curvature of the lens surface farthest on the object side in the first lens group G**1** increases, which makes correcting coma aberration difficult. By setting the lower limit of Conditional Expression (3) to −4.000, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the lower limit of Conditional Expression (3) preferably is set to −3.000, −2.000, −1.000, 0.010, 0.050, 0.100, 0.150, 0.200, 0.250, 0.300, 0.350, 0.400, or 0.450, more preferably to 0.500.
(79) The optical system LS according to the present embodiment may also satisfy Conditional Expression (3-1) below.
$0.010<(-G1R1)/f1<1.100.$ (3-1) where f1 is the focal length of the first lens group G**1**.
(80) Conditional Expression (3-1) is an expression similar to Conditional Expression (3), and

effects similar to those of Conditional Expression (3) can be obtained. This range is desirable because various aberrations such as coma aberration can be corrected favorably. Particularly, by setting the lower limit of Conditional Expression (3-1) to 0.050, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the lower limit of Conditional Expression (3-1) preferably is set to 0.100, 0.150, 0.200, 0.250, 0.300, 0.350, 0.400, or 0.450, more preferably to 0.500. The optical system LS according to the present
(81) embodiment may also satisfy Conditional Expression (3-2) below.

$1.000<(-G1R1)/f1<50.000$ (3-2) where f1 is the focal length of the first lens group G**1**.

(82) Conditional Expression (3-2) is an expression similar to Conditional Expression (3), and effects similar to those of Conditional Expression (3) can be obtained. This range is desirable because various aberrations such as coma aberration can be corrected favorably. Particularly, by setting the upper limit of Conditional Expression (3-2) to 40.000, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the upper limit of Conditional Expression (3-2) preferably is set to 30.000, 20.000, or 10.000, more preferably to 5.000.

(83) In the optical system LS according to the present embodiment, it is desirable for the first lens group G**1** to comprise a diaphragm. With this arrangement, various aberrations such as coma aberration and astigmatism can be corrected favorably for the state of focusing on a short-distance object.

(84) In the optical system LS according to the present embodiment, it is desirable for the first lens group G**1** to be stationary. With this arrangement, the optical system LS can be made more compact as a whole.

(85) It is desirable for the optical system LS according to the present embodiment to satisfy Conditional Expression (4) below.

$0.010<f/f1<5.000$ (4) where f1 is the focal length of the first lens group G**1**.

(86) Conditional Expression (4) prescribes the appropriate range of the ratio between the focal length of the whole optical system LS and the focal length of the first lens group G**1**. By satisfying Conditional Expression (4), favorable optical performance can be secured for the state of focusing on infinity.

(87) If the corresponding value of Conditional Expression (4) exceeds the upper limit, the focal length of the first lens group G**1** is shortened, and therefore an increased amount of various aberrations occur, and variations in coma aberration when focusing become larger. By setting the upper limit of Conditional Expression (4) to 4.500, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the upper limit of Conditional Expression (4) preferably is set to 4.000, 3.500, 3.000, 2.500, 2.000, 1.500, or 1.200, more preferably to 1.000.

(88) If the corresponding value of Conditional Expression (4) falls below the lower limit, the focal length of the first lens group G**1** is lengthened, which makes correcting coma aberration difficult. By setting the lower limit of Conditional Expression (4) to 0.050, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the lower limit of Conditional Expression (4) preferably is set to 0.100, 0.150, 0.200, 0.250, 0.300, 0.350, 0.400, 0.450, or 0.500, more preferably to 0.550.

(89) It is desirable for the optical system LS according to the present embodiment to satisfy Conditional Expression (5) below.

$0.010<f/£2<5.000$.Math. (5) where f2 is the focal length of the second lens group G**2**.

(90) Conditional Expression (5) prescribes the appropriate range of the ratio between the focal length of the whole optical system LS and the focal length of the second lens group G**2**. By satisfying Conditional Expression (5), favorable optical performance can be secured for the state of focusing on a short-distance object.

(91) If the corresponding value of Conditional Expression (5) exceeds the upper limit, the focal

length of the second lens group G**2** is shortened, and therefore an increased amount of various aberrations occur, and variations in coma aberration when focusing become larger. By setting the upper limit of Conditional Expression (5) to 4.500, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the upper limit of Conditional Expression (5) preferably is set to 4.000, 3.500, 3.000, 2.500, 2.000, 1.800, or 1.500, more preferably to 1.300.

(92) If the corresponding value of Conditional Expression (5) falls below the lower limit, the focal length of the second lens group G**2** is lengthened, and therefore the amount of movement by the second lens group G**2** when focusing increases, and variations in spherical aberration and curvature of field when focusing become larger. By setting the lower limit of Conditional Expression (5) to 0.050, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the lower limit of Conditional Expression (5) preferably is set to 0.100, 0.150, 0.200, 0.250, 0.300, 0.350, 0.400, 0.450, 0.500, 0.550, or 0.600, more preferably to 0.650.

(93) It is desirable for the optical system LS according to the present embodiment to satisfy Conditional Expression (6) below.

$0.010<f1/f2<5.000$ (6) where f1 is the focal length of the first lens group G**1**, and f2 is the focal length of the second lens group G**2**.

(94) Conditional Expression (6) prescribes the appropriate range of the ratio between the focal length of the first lens group G**1** and the focal length of the second lens group G**2**. By satisfying Conditional Expression (6), favorable optical performance can be secured for the state of focusing on infinity and for the state of focusing on a short-distance object.

(95) If the corresponding value of Conditional Expression (6) exceeds the upper limit, the focal length of the second lens group G**2** is shortened, and therefore an increased amount of various aberrations occur, and variations in coma aberration when focusing become larger. By setting the upper limit of Conditional Expression (6) to 4.000, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the upper limit of Conditional Expression (6) preferably is set to 3.500, 3.000, 2.500, or 2.000, more preferably to 1.800.

(96) If the corresponding value of Conditional Expression (6) falls below the lower limit, the focal length of the second lens group G**2** is lengthened, and therefore the amount of movement by the second lens group G**2** when focusing increases, and variations in spherical aberration and curvature of field when focusing become larger. By setting the lower limit of Conditional Expression (6) to 0.100, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the lower limit of Conditional Expression (6) preferably is set to 0.200, 0.250, 0.300, 0.350, 0.400, 0.450, 0.500, 0.600, 0.700, or 0.800, more preferably to 0.900.

(97) It is desirable for the optical system LS according to the present embodiment to satisfy Conditional Expression (7) below.

$0.010<f1/(-f3)<3.000$ (7) where f1 is the focal length of the first lens group G**1**, and f3 is the focal length of the third lens group G**3**.

(98) Conditional Expression (7) prescribes the appropriate range of the ratio between the focal length of the first lens group G**1** and the focal length of the third lens group G**3**. By satisfying Conditional Expression (7), favorable optical performance can be secured for the state of focusing on infinity and for the state of focusing on a short-distance object.

(99) If the corresponding value of Conditional Expression (7) exceeds the upper limit, the focal length of the first lens group G**1** is lengthened, which makes correcting coma aberration difficult. By setting the upper limit of Conditional Expression (7) to 2.500, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the upper limit of Conditional Expression (7) preferably is set to 2.000, 1.800, 1.500, 1.300, 1.200, 1.180, or 1.165, more preferably to 1.160.

(100) If the corresponding value of Conditional Expression (7) falls below the lower limit, the focal

length of the first lens group G**1** is shortened, and therefore an increased amount of various aberrations occur, and variations in coma aberration when focusing become larger. Also, the focal length of the third lens group G**3** is lengthened on the negative side, which makes it difficult to correct various aberrations, and variations in curvature of field when focusing become larger. By setting the lower limit of Conditional Expression (7) to 0.050, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the lower limit of Conditional Expression (7) preferably is set to 0.100, 0.150, 0.200, 0.250, 0.300, 0.350, 0.400, 0.450, 0.500, or 0.520, more preferably to 0.550.
(101) It is desirable for the optical system LS according to the present embodiment to satisfy Conditional Expression (8) below.
$0.10<fF/fR<3.00$ (8) where fF is the composite focal length of the lenses disposed farther on the object side than the diaphragm in the optical system LS, and fR is the composite focal length of the lenses disposed farther on the image side than the diaphragm in the optical system LS.
(102) Conditional Expression (8) prescribes the appropriate range of the ratio between the composite focal length of the lenses disposed farther on the object side than the diaphragm and the composite focal length of the lenses disposed farther on the image side than the diaphragm. Note that each composite focal length is the composite focal length for the state of focusing on infinity. By satisfying Conditional Expression (8), astigmatism and distortion can be corrected favorably.
(103) If the corresponding value of Conditional Expression (8) exceeds the upper limit, correcting astigmatism and distortion is difficult. By setting the upper limit of Conditional Expression (8) to 2.50, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the upper limit of Conditional Expression (8) preferably is set to 2.00, 1.80, 1.50, or 1.20, more preferably to 1.10.
(104) If the corresponding value of Conditional Expression (8) falls below the lower limit, correcting astigmatism and distortion is also difficult. By setting the lower limit of Conditional Expression (8) to 0.20, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the lower limit of Conditional Expression (8) preferably is set to 0.25, 0.27, 0.30, or 0.34, more preferably to 0.35.
(105) It is desirable for the optical system LS according to the present embodiment to satisfy Conditional Expression (9) below.
$-10.0<(G1R2+G1R1)/(G1R2-G1R1)<10.0$ (9) where G1R2 is the radius of curvature of the lens surface on the image side for the lens component disposed farthest on the object side in the first lens group G**1**.
(106) Conditional Expression (9) prescribes the shape factor of the lens component disposed farthest on the object side in the first lens group G**1**. By satisfying Conditional Expression (9), favorable optical performance can be secured for the state of focusing on infinity.
(107) If the corresponding value of Conditional Expression (9) exceeds the upper limit, the curvature of the lens surface on the object side for the lens component disposed farthest on the object side in the first lens group G**1** is tightened, and therefore an increased amount of various aberrations occur, and variations in coma aberration when focusing become larger. By setting the upper limit of Conditional Expression (9) to 8.0, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the upper limit of Conditional Expression (9) preferably is set to 7.0, 6.0, or 5.0, more preferably to 4.0.
(108) If the corresponding value of Conditional Expression (9) falls below the lower limit, the curvature of the lens surface on the object side for the lens component disposed farthest on the object side in the first lens group G**1** is loosened, which makes correcting coma aberration difficult. By setting the lower limit of Conditional Expression (9) to −8.0, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the lower limit of Conditional Expression (9) preferably is set to −7.0, −6.0, −5.0, −4.0, or −3.0, more preferably to −2.0.

(109) It is desirable for the optical system LS according to the present embodiment to satisfy Conditional Expression (10) below.

$0.30<\{1-(\beta 2)^2\}\times(\beta 3)^2<2.00$ (10) where β2 is the lateral magnification of the second lens group G**2** for the state of focusing on infinity, and β3 is the lateral magnification of the third lens group G**3**.

(110) Conditional Expression (10) prescribes the displacement of the focal position with respect to movement by the second lens group G**2**. By satisfying Conditional Expression (10), favorable optical performance can be secured for the state of focusing on a short-distance object both on-axis and off-axis.

(111) If the corresponding value of Conditional Expression (10) exceeds the upper limit, correcting coma aberration and astigmatism for the state of focusing on a short-distance object is difficult. By setting the upper limit of Conditional Expression (10) to 1.80, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the upper limit of Conditional Expression (10) preferably is set to 1.60, 1.40, 1.20, 1.00, 0.95, or 0.91, more preferably to 0.89.

(112) If the corresponding value of Conditional Expression (10) falls below the lower limit, correcting coma aberration and astigmatism for the state of focusing on a short-distance object is also difficult. By setting the lower limit of Conditional Expression (10) to 0.35, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the lower limit of Conditional Expression (10) preferably is set to 0.40, 0.45, or 0.48, more preferably to 0.50.

(113) It is desirable for the optical system LS according to the present embodiment to satisfy Conditional Expression (11) below.

$0.50<FNO\times(f1/f)<5.50$ (11) where FNO is the F-number of the optical system LS, and f1 is the focal length of the first lens group G**1**.

(114) Conditional Expression (11) prescribes a value corresponding to the F-number of the first lens group G**1**. By satisfying Conditional Expression (11), various aberrations such as coma aberration can be corrected favorably.

(115) If the corresponding value of Conditional Expression (11) exceeds the upper limit, correcting coma aberration and astigmatism is difficult. By setting the upper limit of Conditional Expression (11) to 5.00, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the upper limit of Conditional Expression (11) preferably is set to 4.50, 4.00, 3.50, or 3.20, more preferably to 3.00.

(116) If the corresponding value of Conditional Expression

(117) (11) falls below the lower limit, correcting spherical aberration and coma aberration is also difficult. By setting the lower limit of Conditional Expression (11) to 0.80, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the lower limit of Conditional Expression (11) preferably is set to 1.00, 1.40, 1.60, or 1.80, more preferably to 1.95.

(118) It is desirable for the optical system LS according to the present embodiment to satisfy Conditional Expression (12) below.

$15.0°<2\omega<85.0°$ (12) where 2ω is the angle of view of the optical system LS.

(119) Conditional Expression (12) prescribes the angle of view of the optical system LS. By satisfying Conditional Expression (12), various aberrations can be corrected favorably, while maintaining a wide angle of view. By setting the upper limit of Conditional Expression (12) to 80.0°, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the upper limit of Conditional Expression (12) preferably is set to 75.0°, 70.0°, or 68.0°, more preferably to 65.0°. By setting the lower limit of Conditional Expression (12) to 17.0°, the effects of the present embodiment can be further ensured. To further ensure the effects of the present embodiment, the lower limit of Conditional Expression (12) preferably is set to

18.0°, 20.0°, or 22.0°, more preferably to 25.0°.

(120) In the optical system LS according to the present embodiment, the lens disposed farthest on the object side in the first lens group G**1** may also be a negative lens. With this arrangement, coma aberration can be corrected favorably.

(121) In the optical system LS according to the present embodiment, the lens disposed farthest on the object side in the second lens group G**2** may also be a negative lens. With this arrangement, curvature of field can be corrected favorably.

(122) In the optical system LS according to the present embodiment, the second lens group G**2** may comprise at least one positive lens and at least one negative lens. With this arrangement, various aberrations such as chromatic aberration can be corrected favorably.

(123) In the optical system LS according to the present embodiment, the third lens group G**3** may comprise at least one positive lens and at least one negative lens. With this arrangement, various aberrations such as chromatic aberration can be corrected favorably.

(124) Next, a method of manufacturing the optical system LS described above will be summarized with reference to FIG. **64**. First, the first lens group G**1** having positive refractive power, the second lens group G**2** having positive refractive power, and the third lens group G**3** having negative refractive power are arranged in order from the object side (step ST**1**). Thereafter, the second lens group G**2** is configured to move along the optical axis when focusing (step ST**2**). Also, each lens is disposed within a lens barrel to satisfy at least Conditional Expressions (1) and (2) above (step ST**3**). According to such a manufacturing method, it is possible to manufacture an optical system capable of obtaining favorable optical performance throughout the focusing range from infinity to short distances, while also restraining changes in image magnification.

EXAMPLES

(125) Hereinafter, the optical system LS according to examples of the present embodiment will be described on the basis of the drawings. FIG. **1** is a cross section illustrating the configuration and the refractive power distribution of an optical system LS {LS(**1**)} according to a 1st example. Similarly, FIGS. **3**, **5**, **7**, **9**, **11**, **13**, **15**, **17**, **19**, and **21** are cross sections illustrating the configuration and the refractive power distribution of an optical system LS {LS(**2**) to LS(**11**)} according to second to 11th examples. FIGS. **23**, **25**, **27**, **29**, **31**, **33**, **35**, **37**, **39**, and **41** are cross sections illustrating the configuration and the refractive power distribution of an optical system LS {LS(**12**) to LS(**21**)} according to 12th to 21st examples. FIGS. **43**, **45**, **47**, **49**, **51**, **53**, **55**, **57**, **59**, and **61** are cross sections illustrating the configuration and the refractive power distribution of an optical system LS {LS(**22**) to LS(**31**)} according to 22nd to 31st examples. In each cross section, the movement direction when the focusing lens group focuses from infinity to a short-distance object is indicated by the arrow labeled “Focusing”.

(126) In these diagrams, each lens group is denoted by the combination of the sign G and a numeral, while each lens is denoted by the combination of the sign L and a numeral. In this case, to avoid confusion due to a large variety of signs and numerals and their values, the lens groups and the like are referenced using combinations of signs and numerals that are respectively independent in each of the examples. Consequently, even if the same combinations of signs and numerals are used between examples, this does not mean that the examples have the same configuration.

(127) Tables 1 to 31 below indicate data regarding each of the 1st to 31st examples. In each example, the d-line (wavelength A=587.6 nm) is chosen as the target for computing aberration characteristics.

(128) In the [General Data] table, f is the focal length of the entire lens system, FNO is the F-number, ω is the half angle of view (in units of degrees)) (°, and Y is the image height. Also, TL is the distance from the lens forefront surface to the lens last surface on the optical axis upon focusing on infinity plus BF, BF is the distance (back focus) from the lens last surface to the image surface I on the optical axis upon focusing on infinity, and BFa is the air equivalent length of the back focus.

(129) In the [Lens Data] table, the surface number indicates the order of optical surfaces from the

object side in the advancement direction of light rays, R is the radius of curvature of each optical surface (taken to be a positive value for a surface whose center of curvature is positioned on the image side), D is the distance from each optical surface to the next optical surface (or the image surface) on the optical axis, nd is the refractive index with respect to the d-line of the material of an optical member, and vd is the Abbe number with reference to the d-line of the material of an optical member. A radius of curvature of "∞" means a flat surface or an aperture, while "(Aperture Stop S)" means an aperture stop S. The refractive index of air nd=1.00000 is not listed. In a case where an optical surface is an aspherical surface, an asterisk (*) is appended to the surface number, and the paraxial radius of curvature is listed in the radius of curvature R field.
(130) In the [Aspherical Surface Data] table, the shapes of the aspherical surfaces indicated in [Lens Data] are expressed by the subsequent expressions (A). X (y) is the distance (sag amount) in the optical axis direction from the tangential plane at the vertex of the aspherical surface to a position on the aspherical surface at the height y, R is the radius of curvature (paraxial radius of curvature) of a reference spherical surface, κ is the conical coefficient, and Ai is the ith order aspherical coefficient. Also, "E−n" denotes "×10.sup.−n". For example, 1.234E−05=1.234×10.sup.−5. Note that the 2nd order aspherical coefficient A2 is 0, and is not listed.
(131) In the [Variable Distance Data] table, the distance to the next lens surface Di is indicated for the surface number i whose distance to the next lens surface is indicated as "variable" in the [Lens Data] table. For example, in the 1st example, the distances to the next lens surface D11, D17, and D23 are indicated for the surface numbers 11, 17, and 23. These values are indicated for the state of focusing on infinity and the state upon focusing on a short-distance (close-up) object.
(132) In the [Lens Group Data] table, the first surface (the surface farthest on the object side) and the focal length of each lens group are indicated.
(133) In the [Conditional Expression Corresponding Value] table, the value corresponding to each conditional expression is indicated.
(134) In all of the data values hereinafter, the listed values of the focal length f, the radius of curvature R, the distance to the next lens surface D, and other lengths generally are given in "mm" unless otherwise specified, but are not limited thereto, because the same optical performance is obtained even if the optical system is enlarged proportionally or reduced proportionally.
(135) The description of the tables so far is common to all of the examples, and hereinafter a duplicate description will be omitted.
1st Example
(136) The 1st example will be described using FIGS. **1** and **2** and Table 1. FIG. **1** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 1st example of the present embodiment. The optical system LS(**1**) according to the 1st example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place. The sign (+) or (−) appended to each lens group sign indicates the refractive power of each lens group. The same applies to all of the examples hereinafter.
(137) The first lens group G**1** comprises a first negative lens L**11** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**12** having a meniscus shape whose concave surface is pointed toward the object, a second positive lens L**13** that is biconvex, a third positive lens L**14** that is biconvex, a second negative lens L**15** having a meniscus shape whose convex surface is pointed toward the object, and an aperture stop S, arranged in order from the object side. The lens surface on either side of the second positive lens L**13** is an aspherical surface.
(138) The second lens group G**2** comprises a negative lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**22** that is biconvex, and a

second positive lens L**23** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on either side of the first positive lens L**22** is an aspherical surface.

(139) The third lens group G**3** comprises a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object and a negative lens L**32** that is biconcave, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I. A filter such as a neutral color (NC) filter, a color filter, a polarizing filter, a neutral density (ND) filter, or an infrared cut-off (IR) filter is used as the interchangeable optical filter FL, for example. Note that the above also applies to the interchangeable optical filter FL described in the 2nd to 31st examples described later.

(140) Table 1 below lists data values regarding the optical system according to the 1st example.

(141) TABLE-US-00001 TABLE 1 [General Data] f 51.59 FNO 1.85 ω 22.6 Y 21.70 TL 80.800 BF 13.599 BFa 13.054 [Lens Data] Surface Number R D nd vd 1 −37.21999 1.800 1.60342 38.0 2 −301.75553 2.422 3 −50.10561 3.350 1.49782 82.6 4 −32.57310 0.200 5* 45.59156 5.050 1.82080 42.7 6* −214.20431 0.200 7 24.72595 7.194 1.59319 67.9 8 −5040.38050 0.100 9 1752.78680 1.000 1.60342 38.0 10 18.45027 5.608 11 ∞ D11 (Aperture (Variable) Stop S) 12 −23.43011 1.000 1.67270 32.2 13 −582.82234 0.200 14* 127.87476 4.350 1.82080 42.7 15* −43.94757 1.950 16 −157.95993 5.600 1.60300 65.4 17 −28.85150 D17 (Variable) 18 −374.08672 3.200 2.00100 29.1 19 −68.25108 4.109 20 −36.81307 1.500 1.69895 30.1 21 177.00000 11.000 22 ∞ 1.600 1.51680 63.9 23 ∞ D23 (Variable) [Aspherical surface data] Fifth surface k = 1.00000 A4 = −1.10646E−06, A6 = −5.14585E−10, A8 = 0.00000E+00, A10 = 0.00000E+00 Sixth surface k = 1.00000 A4 = 3.82437E−07, A6 = −2.48354E−10, A8 = 0.00000E+00, A10 = 0.00000E+00 Fourteenth surface k = 1.00000 A4 = 2.59966E−06, A6 = 2.78570E−09, A8 = 0.00000E+00, A10 = 0.00000E+00 Fifteenth surface k = 1.00000 A4 = 9.97453E−06, A6 = 1.00933E−08, A8 = 0.00000E+00, A10 = 0.00000E+00 [Variable distance data] Upon Upon focusing focusing on a short- on infinity distance object f = 51.59 β = −0.1508 D0 ∞ 319.20 D11 15.367 5.165 D17 3.000 13.203 D23 0.999 0.999 [lens group data] starting group surface focal length G1 1 68.17 G2 12 56.22 G3 18 −101.37 [Conditional Expression Corresponding Value] Conditional Expression (1) BFa/f = 0.253 Conditional Expression (2) (−G1R1)/f = 0.721 Conditional Expression (3), (−G1R1)/f1 = 0.546 (3-1), (3-2) Conditional Expression (4) f/f1 = 0.757 Conditional Expression (5) f/f2 = 0.918 Conditional Expression (6) f1/f2 = 1.213 Conditional Expression (7) f1/(−f3) = 0.672 Conditional Expression (8) fF/fR = 0.646 Conditional Expression (9) (G1R2 + G1R1)/(G1R2 − G1R1) = 1.281 Conditional Expression (10) {1 − (β2).sup.2} × (β3).sup.2 = 0.613 Conditional Expression (11) FNO × (f1/f) = 2.451 Conditional Expression (12) 2ω = 45.2

(142) FIG. **2**A illustrates various aberration n graphs upon focusing on infinity in the optical system according to the 1st example. In each aberration graph of FIG. **2**A, FNO is the F-number and A is the half angle of view. Note that in the spherical aberration graph, the value of the F-number corresponding to the maximum aperture is illustrated, while in each of the astigmatism graph and the distortion graph, the maximum value of the half angle of view is illustrated, and in the lateral aberration graph, the value of each half angle of view is illustrated. FIG. **2**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 1st example. In each aberration graph of FIG. **2**B, NA is the numerical aperture and H0 is the object height. Note that in the spherical aberration graph, the value of the numerical aperture corresponding to the maximum aperture is illustrated, while in each of the astigmatism graph and the distortion graph, the maximum value of the object height is illustrated, and in the lateral aberration graph, the value of each object height is illustrated. Also, in the astigmatism graphs of FIGS. **2**A and **2**B, the solid line illustrates the sagittal image surface, while the dashed line illustrates the meridional image surface. Note that in the aberration graphs of each example illustrated hereinafter, signs similar to the present example will be used, and a duplicate description

will be omitted.
(143) The various aberration graphs demonstrate that the optical system according to the 1st example has excellent image forming performance in which various aberrations are corrected favorably.
2nd Example
(144) The 2nd example will be described using FIGS. **3** and **4** and Table 2. FIG. **3** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 2nd example of the present embodiment. The optical system LS(**2**) according to the 2nd example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.
(145) The first lens group G**1** comprises a cemented lens consisting of a first negative lens L**11** having a meniscus shape whose concave surface is pointed toward the object and a first positive lens L**12** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**13** having a meniscus shape whose concave surface is pointed toward the object, a third positive lens L**14** that is biconvex, a cemented lens consisting of a fourth positive lens L**15** that is biconvex and a second negative lens L**16** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L**14** is an aspherical surface.
(146) The second lens group G**2** comprises a negative lens L**21** that is biconcave, a first positive lens L**22** that is biconvex, and a second positive lens L**23** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the image surface I side of the first positive lens L**22** is an aspherical surface.
(147) The third lens group G**3** comprises a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object, a first negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, and a second negative lens L**33** having a plano-concave shape whose concave surface is pointed toward the object, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.
(148) Table 2 below lists data values regarding the optical system according to the 2nd example. Note that the 13th surface is a virtual surface.
(149) TABLE-US-00002 TABLE 2 [General Data] f 51.60 FNO 1.85 ω 22.8 Y 21.70 TL 88.456 BF 13.100 BFa 12.555 [Lens Data] Surface Number R D nd vd 1 −39.70605 1.800 1.73800 32.3 2 68.44172 3.469 1.92286 20.9 3 740.55070 0.985 4 −250.61896 4.504 1.59319 67.9 5 −42.16654 0.200 6* 41.73745 0.103 1.56093 36.6 7 40.99975 5.408 1.83481 42.7 8 −316.20679 0.200 9 36.83151 7.628 1.49782 82.6 10 −47.01014 1.500 1.62004 36.4 11 25.38130 4.386 12 ∞ D12 (Aperture (Variable) Stop S) 13 ∞ 3.000 14 −22.68035 1.100 1.64769 33.7 15 219.09880 0.200 16 85.95366 4.848 1.83481 42.7 17 −48.70070 0.100 1.56093 36.6 18* −38.65718 2.196 19 −133.55548 6.300 1.60300 65.4 20 −26.81373 D20 (Variable) 21 −112.24414 2.782 1.90265 35.7 22 −53.62057 5.134 23 −41.69274 2.000 1.53172 48.8 24 −133.37205 2.166 25 −49.50596 2.000 1.60342 38.0 26 ∞ 10.500 27 ∞ 1.600 1.51680 64.1 28 ∞ D28 (Variable) [Aspherical surface data] Sixth surface k = 1.00000 A4 = −8.44128E−07, A6 = 9.38473E−10, A8 = −2.90073E−12, A10 = 6.84753E−15 Eighteenth surface k = 1.00000 A4 = 1.66834E−05, A6 = 1.07396E−08, A8 = 3.36895E−11, A10 = −1.25245E−13 [Variable distance data] Upon Upon focusing focusing on a short- on infinity distance object f = 51.60 β = −0.1562 D0 ∞ 311.54 D12 10.848 2.392 D20 2.500 10.956 D28 1.000 1.000 [lens group data] starting group surface focal length G1 1 78.05 G2 13 49.80 G3 21 −88.77 [Conditional Expression Corresponding Value]

Conditional Expression (1) BFa/f = 0.243 Conditional Expression (2) (−G1R1)/f = 0.769 Conditional Expression (3), (−G1R1)/f1 = 0.509 (3-1), (3-2) Conditional Expression (4) f/f1 = 0.661 Conditional Expression (5) f/f2 = 1.036 Conditional Expression (6) f1/f2 = 1.567 Conditional Expression (7) f1/(−f3) = 0.879 Conditional Expression (8) fF/fR = 0.877 Conditional Expression (9) (G1R2 + G1R1)/ (G1R2 − G1R1) = 0.898 Conditional Expression (10) {1 − (β2).sup.2} × (β3).sup.2 = 0.827 Conditional Expression (11) FNO × (f1/f) = 2.805 Conditional Expression (12) 2ω = 45.6

(150) FIG. **4**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 2nd example. FIG. **4**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 2nd example. The various aberration graphs demonstrate that the optical system according to the 2nd example has excellent image forming performance in which various aberrations are corrected favorably.

3rd Example

(151) The 3rd example will be described using FIGS. **5** and **6** and Table 3. FIG. **5** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 3rd example of the present embodiment . . . . The optical system LS(**3**) according to the 3rd example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

(152) The first lens group G**1** comprises a cemented lens consisting of a first negative lens L**11** that is biconcave and a first positive lens L**12** that is biconvex, a second positive lens L**13** having a meniscus shape whose concave surface is pointed toward the object, a third positive lens L**14** that is biconvex, a cemented lens consisting of a fourth positive lens L**15** that is biconvex and a second negative lens L**16** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L**14** is an aspherical surface.

(153) The second lens group G**2** comprises a negative lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**22** that is biconvex, and a second positive lens L**23** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the image surface I side of the first positive lens L**22** is an aspherical surface.

(154) The third lens group G**3** comprises a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object, a first negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, and a second negative lens L**33** that is biconcave, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

(155) Table 3 below lists data values regarding the optical system according to the 3rd example. Note that the 6th surface and the 14th surface are virtual surfaces.

(156) TABLE-US-00003 TABLE 3 [General Data] f 51.60 FNO 1.86 ω 23.0 Y 21.70 TL 95.000 BF 13.826 BFa 13.291 [Lens Data] Surface Number R D nd vd 1 −43.62202 1.800 1.95375 32.3 2 62.41759 5.000 1.84666 23.8 3 −281.93425 0.654 4 −167.37782 5.500 1.59319 67.9 5 −40.10469 0.476 6 ∞ 0.000 7* 39.95627 0.100 1.56093 36.6 8 41.35117 6.000 1.83481 42.7 9 −308.32218 0.200 10 32.49687 8.500 1.49782 82.6 11 −50.34522 1.500 1.58144 41.0 12 20.84633 5.400 13 ∞ D13 (Aperture (Variable) Stop S) 14 ∞ 3.100 15 −19.87542 1.100 1.67270 32.2 16 −102.49215 0.200 17 349.06334 4.800 1.75500 52.3 18 −33.68733 0.100 1.56093 36.6 19* −30.20400 1.700 20 −294.17915 6.900 1.49782 82.6 21 −26.73936 D21 (Variable) 22 −208.87897 3.500 2.00069 25.5 23 −59.64897 4.172 24 −45.02223 2.000 1.62004 36.4 25 −133.33333 2.419 26 −45.00000 2.000 1.62004 36.4 27 224.57692 11.236 28 ∞ 1.600 1.51680 64.1 29 ∞ D29 (Variable) [Aspherical

surface data] Seventh surface k = 1.00000 A4 = −1.17140E−06, A6 = 4.04242E−10, A8 = 0.00000E+00, A10 = 0.00000E+00 Nineteenth surface k = 1.00000 A4 = 1.13379E−05, A6 = 1.62636E−08, A8 = 0.00000E+00, A10 = 0.00000E+00 [Variable distance data] Upon focusing Upon on a focusing short-distance on infinity object f = 51.60 β = −0.1591 D0 ∞ 305.00 D13 11.043 2.821 D21 3.000 11.223 D29 1.000 1.000 [lens group data] group starting surface focal length G1 1 82.69 G2 14 49.27 G3 22 −80.88 [Conditional Expression Corresponding Value] Conditional Expression (1) BFa/f = 0.258 Conditional Expression (2) (−G1R1)/f = 0.845 Conditional Expression (3), (−G1R1)/f1 = 0.528 (3-1), (3-2) Conditional Expression (4) f/f1 = 0.624 Conditional Expression (5) f/f2 = 1.047 Conditional Expression (6) f1/f2 = 1.678 Conditional Expression (7) f1/(−f3) = 1.022 Conditional Expression (8) fF/fR = 0.923 Conditional Expression (9) (G1R2 + G1R1)/ (G1R2 − G1R1) = 1.366 Conditional Expression (10) {1 − (β2).sup.2} × (β3).sup.2 = 0.881 Conditional Expression (11) FNO × (f1/f) = 2.983 Conditional Expression (12) 2ω = 46.0

(157) FIG. **6**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 3rd example. FIG. **6**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 3rd example. The various aberration graphs demonstrate that the optical system according to the 3rd example has excellent image forming performance in which various aberrations are corrected favorably.

4th Example

(158) The 4th example will be described using FIGS. **7** and **8** and Table 4. FIG. **7** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 4th example of the present embodiment. The optical system LS(**4**) according to the 4th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

(159) The first lens group G**1** comprises a cemented lens consisting of a first negative lens L**11** that is biconcave and a first positive lens L**12** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**13** having a meniscus shape whose concave surface is pointed toward the object, a third positive lens L**14** having a meniscus shape whose convex surface is pointed toward the object, a cemented lens consisting of a fourth positive lens L**15** that is biconvex and a second negative lens L**16** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L**14** is an aspherical surface.

(160) The second lens group G**2** comprises a negative lens L**21** that is biconcave, a first positive lens L**22** that is biconvex, and a second positive lens L**23** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the image surface I side of the first positive lens L**22** is an aspherical surface.

(161) The third lens group G**3** comprises a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object, a first negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, and a second negative lens L**33** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

(162) Table 4 below lists data values regarding the optical system according to the 4th example. Note that the 13th surface is a virtual surface.

(163) TABLE-US-00004 TABLE 4 [General Data] f 51.60 FNO 1.85 ω 23.0 Y 21.70 TL 93.423 BF 13.099 BFa 12.554 [Lens Data] Surface Number R D nd νd 1 −49.34582 1.800 1.64769 33.7 2

46.34338 4.852 1.94595 18.0 3 88.17135 2.830 4 −385.68443 6.805 1.75500 52.3 5 −55.81519 0.100 6* 32.37146 0.300 1.56093 36.6 7 34.78660 6.291 1.75500 52.3 8 3421.80810 0.200 9 34.21341 7.021 1.59319 67.9 10 −76.80721 1.500 1.64769 33.7 11 20.90542 5.045 12 ∞ D12 (Aperture (Variable) Stop S) 13 ∞ 2.700 14 −23.99823 1.100 1.64769 33.7 15 814.45031 0.200 16 93.44777 5.100 1.80400 46.6 17 −40.16052 0.152 1.56093 36.6 18* −34.60672 3.204 19 −128.30142 6.400 1.49782 82.6 20 −26.31276 D20 (Variable) 21 −78.26552 2.798 1.94595 18.0 22 −44.00653 2.232 23 −46.73961 2.000 1.64769 33.7 24 −150.55235 2.958 25 −40.00000 1.900 1.64769 33.7 26 −179.87126 10.500 27 ∞ 1.600 1.51680 64.1 28 ∞ D28 (Variable) [Aspherical surface data] Sixth surface k = 1.00000 A4 = −1.82369E−06, A6 = −1.73726E−09, A8 = 2.00735E−12, A10 = −4.32700E−15 Eighteenth surface k = 1.00000 A4 = 1.61711E−05, A6 = 1.10899E−08, A8 = 3.81964E−11, A10 = −1.19949E−13 [Variable distance data] Upon focusing Upon focusing on a short- on infinity distance object f = 51.60 β = −0.1563 D0 ∞ 306.58 D12 10.336 2.398 D20 2.500 10.438 D28 0.999 0.999 [lens group data] group starting surface focal length G1 1 73.48 G2 13 47.81 G3 21 −81.77 [Conditional Expression Corresponding Value] Conditional Expression (1) BFa/f = 0.243 Conditional Expression (2) (−G1R1)/f = 0.845 Conditional Expression (3), (−G1R1)/f1 = 0.528 (3-1), (3-2) Conditional Expression (4) f/f1 = 0.624 Conditional Expression (5) f/f2 = 1.047 Conditional Expression (6) f1/f2 = 1.678 Conditional Expression (7) f1/(−f3) = 1.022 Conditional Expression (8) fF/fR = 0.923 Conditional Expression (9) (G1R2 + G1R1)/ (G1R2 − G1R1) = 1.366 Conditional Expression (10) {1 − (β2).sup.2} × (β3).sup.2 = 0.881 Conditional Expression (11) FNO × (f1/f) = 2.983 Conditional Expression (12) 2ω = 46.0

(164) FIG. **8**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 4th example. FIG. **8**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 4th example. The various aberration graphs demonstrate that the optical system according to the 4th example has excellent image forming performance in which various aberrations are corrected favorably.

5th Example

(165) The 5th example will be described using FIGS. **9** and **10** and Table 5. FIG. **9** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 5th example of the present embodiment. The optical system LS(**5**) according to the 5th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

(166) The first lens group G**1** comprises a cemented lens consisting of a first negative lens L**11** that is biconcave and a first positive lens L**12** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**13** having a meniscus shape whose concave surface is pointed toward the object, a third positive lens L**14** having a meniscus shape whose convex surface is pointed toward the object, a cemented lens consisting of a fourth positive lens L**15** that is biconvex and a second negative lens L**16** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L**14** is an aspherical surface.

(167) The second lens group G**2** comprises a negative lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**22** that is biconvex, and a second positive lens L**23** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on either side of the first positive lens L**22** is an aspherical surface.

(168) The third lens group G**3** comprises a cemented lens consisting of a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object and a first negative lens L**32**

having a meniscus shape whose concave surface is pointed toward the object, and a second negative lens L**33** having a plano-concave shape whose concave surface is pointed toward the object, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

(169) Table 5 below lists data values regarding the optical system according to the 5th example. Note that the 13th surface is a virtual surface.

(170) TABLE-US-00005 TABLE 5 [General Data] f 51.61 FNO 1.85 ω 22.8 Y 21.70 TL 94.298 BF 13.104 BFa 12.558 [Lens Data] Surface Number R D nd νd 1 −55.81981 2.351 1.67270 32.2 2 40.92718 3.030 1.94595 18.0 3 73.81686 2.866 4 −2179.29960 8.923 1.75500 52.3 5 −55.86755 0.100 6* 31.91227 0.300 1.56093 36.6 7 33.62812 5.941 1.80400 46.6 8 179.47342 0.200 9 31.36834 10 −117.41333 1.500 1.67270 32.2 11 20.83074 5.078 12 ∞ D12 (Aperture (Variable) Stop S) 13 ∞ 2.700 14 −23.88176 1.100 1.64769 33.7 15 −464.00395 0.306 16* 107.59212 4.886 1.77377 47.2 17* −34.57866 3.604 18 −87.29087 6.386 1.49782 82.6 19 −24.79412 D19 (Variable) 20 −168.93770 2.949 1.94595 18.0 21 −62.61109 1.900 1.62004 36.4 22 −408.98106 2.897 23 −49.70122 1.900 1.64769 33.7 24 ∞ 10.500 25 ∞ 1.600 1.51680 64.1 26 ∞ D26 (Variable) [Aspherical surface data] Sixth surface k = 1.00000 A4 = −9.25285E−07, A6 = −2.44172E−10, A8 = −5.83429E−13, A10 = 9.84913E−16 Sixteenth surface k = 1.00000 A4 = 2.83184E−06, A6 = 1.30771E−08, A8 = 3.97727E−11, A10 = 2.50432E−13 Seventeenth surface k = 1.00000 A4 = 1.51803E−05, A6 = 3.07472E−08, A8 = −2.44486E−11, A10 = 5.97193E−13 [Variable distance data] Upon focusing Upon focusing on a short- on infinity distance object f = 51.61 β = −0.1566 D0 ∞ 305.70 D12 10.295 2.359 D19 4.868 12.804 D26 1.004 1.004 [lens group data] group starting surface focal length G1 1 74.25 G2 13 47.70 G3 20 −83.87 [Conditional Expression Corresponding Value] Conditional Expression (1) BFa/f = 0.243 Conditional Expression (2) (−G1R1)/f = 1.082 Conditional Expression (3), (−G1R1)/f1 = 0.752 (3-1), (3-2) Conditional Expression (4) f/f1 = 0.695 Conditional Expression (5) f/f2 = 1.082 Conditional Expression (6) f1/f2 = 1.556 Conditional Expression (7) f1/(−f3) = 0.885 Conditional Expression (8) fF/fR = 0.805 Conditional Expression (9) (G1R2 + G1R1)/ (G1R2 − G1R1) = 0.139 Conditional Expression (10) {1 − (β2).sup.2} × (β3).sup.2 = 0.883 Conditional Expression (11) FNO × (f1/f) = 2.668 Conditional Expression (12) 2ω = 45.6

(171) FIG. **10**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 5th example. FIG. **10**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 5th example. The various aberration graphs demonstrate that the optical system according to the 5th example has excellent image forming performance in which various aberrations are corrected favorably.

6th Example

(172) The 6th example will be described using FIGS. **11** and **12** and Table 6. FIG. **11** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 6th example of the present embodiment. The optical system LS(**6**) according to the 6th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

(173) The first lens group G**1** comprises a cemented lens consisting of a first negative lens L**11** that is biconcave and a first positive lens L**12** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**13** that is biconvex, a third positive lens L**14** having a meniscus shape whose convex surface is pointed toward the object, a cemented lens consisting of a fourth positive lens L**15** that is biconvex and a second negative lens L**16** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the

third positive lens L**14** is an aspherical surface.

(174) The second lens group G**2** comprises a negative lens L**21** that is biconcave, a first positive lens L**22** that is biconvex, and a second positive lens L**23** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on either side of the first positive lens L**22** is an aspherical surface.

(175) The third lens group G**3** comprises a cemented lens consisting of a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object and a first negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, and a second negative lens L**33** having a plano-concave shape whose concave surface is pointed toward the object, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

(176) Table 6 below lists data values regarding the optical system according to the 6th example. Note that the 13th surface is a virtual surface.

(177) TABLE-US-00006 TABLE 6 [General Data] f 51.61 FNO 1.85 ω 22.7 Y 21.70 TL 94.879 BF 13.103 BFa 12.558 [Lens Data] Surface Number R D nd νd 1 −59.41700 3.521 1.67270 32.2 2 39.22460 3.028 1.94595 18.0 3 67.63630 2.963 4 3381.87660 8.656 1.75500 52.3 5 −56.77477 0.200 6* 32.10469 0.100 1.56093 36.6 7 32.39825 5.977 1.77250 49.6 8 150.72327 0.200 9 29.50426 7.110 1.59319 67.9 10 −150.81319 1.500 1.64769 33.7 11 20.38598 5.145 12 ∞ D12 (Aperture (Variable) Stop S) 13 ∞ 2.700 14 −23.88655 1.100 1.64769 33.7 15 11241.53800 0.200 16* 115.09348 4.892 1.77377 47.2 17* −33.45446 3.784 18 −154.31773 6.454 19 −26.83890 D19 (Variable) 20 −99.15080 2.941 1.94595 18.0 21 −50.06903 1.900 1.60342 38.0 22 −157.80139 2.610 23 −45.69693 10.500 24 −615.80945 1.600 1.51680 64.1 25 ∞ 26 ∞ D26 (Variable) [Aspherical surface data] Sixth surface k = 1.00000 A4 = −7.49375E−07, A6 = −1.64453E−10, A8 = −6.23627E−13, A10 = 1.37024E−15 Sixteenth surface k = 1.00000 A4 = 4.71706E−08, A6 = 1.49836E−08, A8 = 4.37655E−13, A10 = 2.84793E−13 Seventeenth surface k = 1.00000 A4 = 1.11172E−05, A6 = 3.11358E−08, A8 = −9.41425E−11, A10 = 7.16057E−13 [Variable distance data] Upon focusing Upon focusing on a short- on infinity distance object f = 51.61 β = −0.1566 D0 ∞ 305.12 D12 10.330 2.348 D19 4.563 12.545 D26 1.003 1.005 [lens group data] group starting surface focal length G1 1 71.11 G2 13 47.97 G3 20 −83.32 [Conditional Expression Corresponding Value] Conditional Expression (1) BFa/f = 0.243 Conditional Expression (2) (−G1R1)/f = 1.151 Conditional Expression (3), (−G1R1)/f1 = 0.836 (3-1), (3-2) Conditional Expression (4) f/f1 = 0.726 Conditional Expression (5) f/f2 = 1.076 Conditional Expression (6) f1/f2 = 1.482 Conditional Expression (7) f1/(−f3) = 0.853 Conditional Expression (8) fF/fR = 0.731 Conditional Expression (9) (G1R2 + G1R1)/ (G1R2 − G1R1) = 0.065 Conditional Expression (10) {1 − (β2).sup.2} × (β3).sup.2 = 0.886 Conditional Expression (11) FNO × (f1/f) = 2.555 Conditional Expression (12) 2ω = 45.4

(178) FIG. **12**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 6th example. FIG. **12**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 6th example. The various aberration graphs demonstrate that the optical system according to the 6th example has excellent image forming performance in which various aberrations are corrected favorably.

7th Example

(179) The 7th example will be described using FIGS. **13** and **14** and Table 7. FIG. **13** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 7th example of the present embodiment. The optical system LS(**7**) according to the 7th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the

optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.
(180) The first lens group G**1** comprises a cemented lens consisting of a first negative lens L**11** that is biconcave and a first positive lens L**12** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**13** having a meniscus shape whose concave surface is pointed toward the object, a third positive lens L**14** having a meniscus shape whose convex surface is pointed toward the object, a cemented lens consisting of a fourth positive lens L**15** that is biconvex and a second negative lens L**16** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L**14** is an aspherical surface.
(181) The second lens group G**2** comprises a negative lens L**21** that is biconcave, a first positive lens L**22** that is biconvex, and a second positive lens L**23** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on either side of the first positive lens L**22** is an aspherical surface.
(182) The third lens group G**3** comprises a cemented lens consisting of a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object and a first negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, and a second negative lens L**33** having a plano-concave shape whose concave surface is pointed toward the object, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.
(183) Table 7 below lists data values regarding the optical system according to the 7th example. Note that the 13th surface is a virtual surface.
(184) TABLE-US-00007 TABLE 7 [General Data] f 51.60 FNO 1.85 ω 23.0 Y 21.70 TL 92.606 BF 13.099 BFa 12.554 [Lens Data] Surface Number R D nd vd 1 −45.97401 3.464 1.67270 32.2 2 49.61070 3.386 1.94595 18.0 3 104.71966 2.977 4 −171.07801 4.990 1.72916 54.6 5 −45.04067 0.200 6* 34.58722 0.100 1.56093 36.6 7 35.08925 6.046 1.80400 46.6 8 271.36284 0.200 9 30.75373 7.301 1.59319 67.9 10 −109.57751 1.500 1.64769 33.7 11 21.09749 5.107 12 ∞ D12 (Aperture (Variable) Stop S) 13 ∞ 2.700 14 −23.42611 1.100 1.64769 33.7 15 1293.83890 0.200 16* 96.25206 5.000 1.77377 47.2 17* −33.63182 2.984 18 −84.68095 6.400 1.49782 82.6 19 −24.24361 D19 (Variable) 20 −198.33414 2.923 1.94595 18.0 21 −66.60448 2.000 1.64769 33.7 22 −1255.72680 2.962 23 −53.07631 2.000 1.64769 33.7 24 ∞ 10.500 25 ∞ 1.600 1.51680 64.1 26 ∞ D26 (Variable) [Aspherical surface data] Sixth surface k = 1.00000 A4 = −9.44039E−07, A6 = −7.11276E−10, A8 = 1.77477E−12, A10 = −1.49090E−15 Sixteenth surface k = 1.00000 A4 = −7.09863E−07, A6 = 1.39281E−08, A8 = −7.11118E−11, A10 = −9.85203E−14 Seventeenth surface k = 1.00000 A4 = 1.29000E−05, A6 = 1.77000E−08, A8 = 4.64016E−11, A10 = −4.30856E−13 [Variable distance data] Upon focusing Upon focusing on a short- on infinity distance object f = 51.60 β = −0.1564 D0 ∞ 307.39 D12 10.322 2.393 D19 5.645 13.574 D26 0.999 0.999 [lens group data] group starting surface focal length G1 1 73.64 G2 13 48.40 G3 20 −83.16 [Conditional Expression Corresponding Value] Conditional Expression (1) BFa/f = 0.243 Conditional Expression (2) (−G1R1)/f = 0.891 Conditional Expression (3), (−G1R1)/f1 = 0.624 (3-1), (3-2) Conditional Expression (4) f/f1 = 0.701 Conditional Expression (5) f/f2 = 1.066 Conditional Expression (6) f1/f2 = 1.522 Conditional Expression (7) f1/(−f3) = 0.886 Conditional Expression (8) fF/fR = 0.769 Conditional Expression (9) (G1R2 + G1R1)/ (G1R2 − G1R1) = 0.390 Conditional Expression (10) {1 − (β2).sup.2} × (β3).sup.2 = 0.883 Conditional Expression (11) FNO × (f1/f) = 2.646 Conditional Expression (12) 2ω = 46.0
(185) FIG. **14**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 7th example. FIG. **14**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 7th example. The various aberration graphs demonstrate that the optical system according to the 7th example has excellent image forming performance in which various aberrations are corrected favorably.

8th Example

(186) The 8th example will be described using FIGS. **15** and **16** and Table 8. FIG. **15** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 8th example of the present embodiment. The optical system LS(**8**) according to the 8th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

(187) The first lens group G**1** comprises a cemented lens consisting of a first negative lens L**11** that is biconcave and a first positive lens L**12** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**13** having a meniscus shape whose concave surface is pointed toward the object, a third positive lens L**14** having a meniscus shape whose convex surface is pointed toward the object, a cemented lens consisting of a fourth positive lens L**15** that is biconvex and a second negative lens L**16** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L**14** is an aspherical surface.

(188) The second lens group G**2** comprises a negative lens L**21** that is biconcave, a first positive lens L**22** that is biconvex, and a second positive lens L**23** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on either side of the first positive lens L**22** is an aspherical surface.

(189) The third lens group G**3** comprises a cemented lens consisting of a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object and a first negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, and a second negative lens L**33** having a plano-concave shape whose concave surface is pointed toward the object, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

(190) Table 8 below lists data values regarding the optical system according to the 8th example. Note that the 13th surface is a virtual surface.

(191) TABLE-US-00008 TABLE 8 [General Data] f 51.60 FNO 1.85 ω 22.9 Y 21.70 TL 93.035 BF 13.101 BFa 12.556 [Lens Data] Surface Number R D nd νd 1 −49.74101 2 51.83840 3.342 1.94595 18.0 3 105.00000 2.890 4 −198.79923 5.698 1.72916 54.6 5 −48.74109 0.216 6* 39.85460 0.100 1.56093 36.6 7 39.94369 5.459 1.80400 46.6 8 306.55979 0.200 9 27.39919 7.979 1.59319 67.9 10 −244.36823 1.500 1.64769 33.7 11 21.09582 5.098 12 ∞ D12 (Aperture (Variable) Stop S) 13 ∞ 2.700 14 −23.37434 1.100 1.64769 33.7 15 630.74141 0.200 16* 88.88240 5.000 1.77377 47.2 17* −34.54296 2.466 18 −91.09112 6.400 1.49782 82.6 19 −24.26835 D19 (Variable) 20 −173.73017 2.915 1.94595 18.0 21 −63.36086 2.000 1.64769 33.7 22 −410.38800 2.872 23 −49.55593 1.900 1.64769 33.7 24 ∞ 10.500 25 ∞ 1.600 1.51680 64.1 26 ∞ D26 (Variable) [Aspherical surface data] Sixth surface k = 1.00000 A4 = −1.98971E−07, A6 = −9.88462E−10, A8 = 4.89667E−12, A10 = −4.46361E−15 Sixteenth surface k = 1.00000 A4 = −1.30154E−06, A6 = 1.97109E−08, A8 = −1.12019E−10, A10 = −2.74309E−14 Seventeenth surface k = 1.00000 A4 = 1.29000E−05, A6 = 1.77000E−08, A8 = 4.40194E−11, A10 = −4.63161E−13 [Variable distance data] Upon focusing Upon focusing on a short- on infinity distance object f = 51.60 β = −0.1566 D0 ∞ 306.96 D12 10.321 2.394 D19 6.070 13.997 D26 1.000 1.000 [lens group data] group starting surface focal length G1 1 73.37 G2 13 48.59 G3 20 −81.56 [Conditional Expression Corresponding Value] Conditional Expression (1) BFa/f = 0.243 Conditional Expression (2) (−G1R1)/f = 0.964 Conditional Expression (3), (−G1R1)/f1 = 0.678 (3-1), (3-2) Conditional Expression (4) f/f1 = 0.703 Conditional Expression (5) f/f2 = 1.062 Conditional Expression (6) f1/f2 = 1.510 Conditional Expression (7) f1/(−f3) = 0.900 Conditional Expression (8) fF/fR = 0.747

Conditional Expression (9) (G1R2 + G1R1)/ (G1R2 − G1R1) = 0.357 Conditional Expression (10) {1 − (β2).sup.2} × (β3).sup.2 = 0.885 Conditional Expression (11) FNO × (f1/f) = 2.636 Conditional Expression (12) 2ω = 45.8

(192) FIG. **16**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 8th example. FIG. **16**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 8th example. The various aberration graphs demonstrate that the optical system according to the 8th example has excellent image forming performance in which various aberrations are corrected favorably.

9th Example

(193) The 9th example will be described using FIGS. **17** and **18** and Table 9. FIG. **17** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 9th example of the present embodiment. The optical system LS(**9**) according to the 9th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

(194) The first lens group G**1** comprises a cemented lens consisting of a first negative lens L**11** that is biconcave and a first positive lens L**12** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**13** having a meniscus shape whose concave surface is pointed toward the object, a third positive lens L**14** having a meniscus shape whose convex surface is pointed toward the object, a cemented lens consisting of a fourth positive lens L**15** that is biconvex and a second negative lens L**16** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L**14** is an aspherical surface.

(195) The second lens group G**2** comprises a negative lens L**21** that is biconcave, a first positive lens L**22** that is biconvex, and a second positive lens L**23** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on either side of the first positive lens L**22** is an aspherical surface.

(196) The third lens group G**3** comprises a cemented lens consisting of a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object and a first negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, and a second negative lens L**33** having a plano-concave shape whose concave surface is pointed toward the object, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

(197) Table 9 below lists data values regarding the optical system according to the 9th example. Note that the 13th surface is a virtual surface.

(198) TABLE-US-00009 TABLE 9 [General Data] f 51.60 FNO 1.85 ω 22.9 Y 21.70 TL 92.330 BF 13.100 BFa 12.554 [Lens Data] Surface Number R D nd vd 1 −48.06457 2.000 1.67270 32.2 2 50.03333 2.861 1.94595 18.0 3 105.00000 2.805 4 −226.31231 6.827 1.72916 54.6 5 −47.98013 0.644 6* 36.64910 0.100 1.56093 36.6 7 36.85687 5.622 1.80400 46.6 8 217.92780 0.200 9 28.49361 7.332 1.59319 67.9 10 −161.37986 1.500 1.64769 33.7 11 20.99038 5.164 12 ∞ D12 (Variable) (Aperture Stop S) 13 ∞ 2.700 14 −23.41799 1.100 1.64769 33.7 15 998.77224 0.200 16* 85.12299 5.000 1.77377 47.2 17* −35.29338 2.485 18 −73.80381 6.400 1.49782 82.6 19 −23.23519 D19 (Variable) 20 −177.75440 2.927 1.94595 18.0 21 −63.69645 1.900 1.64769 33.7 22 −482.01125 2.887 23 −50.20764 1.900 1.64769 33.7 24 ∞ 10.500 25 ∞ 1.600 1.51680 64.1 26 ∞ D26 (Variable) [Aspherical surface data] Sixth surface κ = 1.00000 A4 = −4.74106E−07, A6 = −3.40824E−10, A8 = 2.15394E−12, A10 = −1.54492E−15 Sixteenth surface κ = 1.00000 A4 = −1.95205E−07, A6 = 1.94342E−08, A8 = −8.61846E−11, A10 = −2.07763E−13

Seventeenth surface κ = 1.00000 A4 = 1.47643E−05, A6 = 2.08671E−08, A8 = 8.44852E−11, A10 = −6.93210E−13 [Variable distance data] Upon focusing Upon focusing on a short- on infinity distance object f = 51.60 β = −0.1565 D0 ∞ 307.67 D12 10.320 2.409 D19 6.356 14.267 D26 1.000 1.000 [lens group data] group starting surface focal length G1 1 73.63 G2 13 48.76 G3 20 −81.76 [Conditional Expression Corresponding Value] Conditional Expression (1) BFa/f = 0.243 Conditional Expression (2) (−G1R1)/f = 0.964 Conditional Expression (3), (3-1), (3-2) (−G1R1)/f1 = 0.676 Conditional Expression (4) f/f1 = 0.701 Conditional Expression (5) f/f2 = 1.058 Conditional Expression (6) f1/f2 = 1.510 Conditional Expression (7) f1/(−f3) = 0.900 Conditional Expression (8) fF/fR = 0.748 Conditional Expression (9) (G1R2 + G1R1)/(G1R2 − G1R1) = 0.357 Conditional Expression (10) {1 − (β2).sup.2} × (β3).sup.2 = 0.888 Conditional Expression (11) FNO × (f1/f) = 2.645 Conditional Expression (12) 2ω = 45.8

(199) FIG. **18**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 9th example. FIG. **18**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 9th example. The various aberration graphs demonstrate that the optical system according to the 9th example has excellent image forming performance in which various aberrations are corrected favorably.

10th Example

(200) The 10th example will be described using FIGS. **19** and **20** and Table 10. FIG. **19** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 10th example of the present embodiment. The optical system LS(**10**) according to the 10th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

(201) The first lens group G**1** comprises a cemented lens consisting of a first negative lens L**11** that is biconcave and a first positive lens L**12** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**13** having a meniscus shape whose concave surface is pointed toward the object, a third positive lens L**14** having a meniscus shape whose convex surface is pointed toward the object, a cemented lens consisting of a fourth positive lens L**15** that is biconvex and a second negative lens L**16** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L**14** is an aspherical surface.

(202) The second lens group G**2** comprises a negative lens L**21** that is biconcave, a first positive lens L**22** that is biconvex, and a second positive lens L**23** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on either side of the first positive lens L**22** is an aspherical surface.

(203) The third lens group G**3** comprises a cemented lens consisting of a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object and a first negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, and a second negative lens L**33** having a plano-concave shape whose concave surface is pointed toward the object, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

(204) Table 10 below lists data values regarding the optical system according to the 10th example. Note that the 13th surface is a virtual surface.

(205) TABLE-US-00010 TABLE 10 [General Data] f 51.61 FNO 1.85 ω 23.0 Y 21.70 TL 92.630 BF 13.111 BFa 12.566 [Lens Data] Surface Number R D nd vd 1 −47.48420 2.000 1.67270 32.2 2 49.34200 2.900 1.94595 18.0 3 105.06869 2.850 4 −214.61709 6.650 1.72916 54.6 5 −47.45376 0.640 6* 36.92032 0.100 1.56093 36.6 7 37.08029 5.650 1.80400 46.6 8

227.67817 0.250 9 28.81243 7.400 1.59319 67.9 10 −141.32000 1.500 1.64769 33.7 11 21.19231 5.130 12 ∞ D12 (Variable) (Aperture Stop S) 13 ∞ 2.700 14 −23.47056 1.100 1.64769 33.7 15 682.91466 0.200 16* 83.29512 5.000 1.77377 47.2 17* −35.02672 2.570 18 −71.96528 6.400 1.49782 82.6 19 −23.20263 D19 (Variable) 20 −192.79576 2.950 1.94595 18.0 21 −65.62300 2.000 1.64769 33.7 22 −664.53730 2.909 23 −51.20031 1.900 1.64769 33.7 24 ∞ 10.500 25 ∞ 1.600 1.51680 64.1 26 ∞ D26 (Variable) [Aspherical surface data] Sixth surface κ = 1.00000 A4 = −4.82693E−07, A6 = −2.32147E−10, A8 = 1.82978E−12, A10 = −1.19713E−15 Sixteenth surface κ = 1.00000 A4 = −2.77465E−07, A6 = 1.84476E−08, A8 = −7.60811E−11, A10 = −2.05509E−13 Seventeenth surface κ = 1.00000 A4 = 1.46947E−05, A6 = 2.13572E−08, A8 = 8.25934E−11, A10 = −6.58549E−13 [Variable distance data] Upon focusing Upon focusing on a short- on infinity distance object f = 51.61 β = −0.1568 D0 ∞ 307.37 D12 10.320 2.403 D19 6.400 14.317 D26 1.011 1.011 [lens group data] group starting surface focal length G1 1 74.30 G2 13 48.80 G3 20 −82.85 [Conditional Expression Corresponding Value] Conditional Expression (1) BFa/f = 0.243 Conditional Expression (2) (−G1R1)/f = 0.920 Conditional Expression (3), (−G1R1)/f1 = 0.639 (3-1), (3-2) Conditional Expression (4) f/f1 = 0.695 Conditional Expression (5) f/f2 = 1.058 Conditional Expression (6) f1/f2 = 1.523 Conditional Expression (7) f1/(−f3) = 0.897 Conditional Expression (8) fF/fR = 0.768 Conditional Expression (9) (G1R2 + G1R1)/(G1R2 − G1R1) = 0.377 Conditional Expression (10) {1 − (β2).sup.2} × (β3).sup.2 = 0.890 Conditional Expression (11) FNO × (f1/f) = 2.670 Conditional Expression (12) 2ω = 46.0

(206) FIG. **20**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 10th example. FIG. **20**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 10th example. The various aberration graphs demonstrate that the optical system according to the 10th example has excellent image forming performance in which various aberrations are corrected favorably.

11th Example

(207) The 11th example will be described using FIGS. **21** and **22** and Table 11. FIG. **21** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 11th example of the present embodiment. The optical system LS(**11**) according to the 11th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

(208) The first lens group G**1** comprises a first negative lens L**11** that is biconcave, a cemented lens consisting of a second negative lens L**12** that is biconcave and a first positive lens L**13** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**14** that is biconvex, a third positive lens L**15** that is biconvex, a cemented lens consisting of a fourth positive lens L**16** that is biconvex and a third negative lens L**17** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L**15** is an aspherical surface.

(209) The second lens group G**2** comprises a negative lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**22** that is biconvex, and a second positive lens L**23** that is biconvex, arranged in order from the object side. The lens surface on either side of the first positive lens L**22** is an aspherical surface.

(210) The third lens group G**3** comprises a positive lens L**31** having a meniscus shape whose convex surface is pointed toward the object and a negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the object side of the negative lens L**32** is an aspherical surface. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

(211) Table 11 below lists data values regarding the optical system according to the 11th example. Note that the 14th surface is a virtual surface.
(212) TABLE-US-00011 TABLE 11 [General Data] f 37.63 FNO 1.85 ω 30.0 Y 21.70 TL 110.000 BF 9.600 BFa 9.055 [Lens Data] Surface Number R D nd vd 1 −662.83160 3.000 1.80920 33.6 2 33.87219 9.404 3 −109.33916 3.000 1.48749 70.4 4 89.77072 4.000 1.94595 18.0 5 317.57072 1.945 6 44.26915 8.500 1.48749 70.4 7 −112.47821 3.972 8* 41.20576 6.500 1.80400 46.6 9 −255.27183 0.200 10 26.75656 9.000 1.59319 67.9 11 −57.15784 1.500 1.67270 32.2 12 17.14008 5.399 13 ∞ D13 (Variable) (Aperture Stop S) 14 ∞ 3.000 15 −21.57444 1.000 1.67270 32.2 16 −1291.14570 0.200 17* 157.44017 4.500 1.77377 47.2 18* −44.84339 0.200 19 155.77289 9.000 1.59319 67.9 20 −25.32306 D20 (Variable) 21 71.98835 3.000 1.94595 18.0 22 81.46254 6.736 23* −41.56282 1.500 1.64769 33.7 24 −168.89768 7.000 25 ∞ 1.600 1.51680 64.1 26 ∞ D26 (Variable) [Aspherical surface data] Eighth surface κ = 1.00000 A4 = −1.90145E−06, A6 = −9.52591E−10, A8 = −1.08708E−12, A10 = −6.77034E−16 Seventeenth surface κ = 1.00000 A4 = 6.23513E−06, A6 = −1.23942E−08, A8 = 3.34827E−11, A10 = −3.01713E−13 Eighteenth surface κ = 1.00000 A4 = 1.88293E−05, A6 = 1.24857E−08, A8 = 2.84962E−11, A10 = −3.23051E−13 Twenty-third surface κ = 1.00000 A4 = 5.43854E−06, A6 = −1.52554E−08, A8 = 0.00000E+00, A10 = 0.00000E+00 [Variable distance data] Upon focusing Upon focusing on a short- on infinity distance object f = 37.63 β = −0.2078 D0 ∞ 151.72 D13 11.387 2.404 D20 3.456 12.439 D26 1.000 1.000 [lens group data] group starting surface focal length G1 1 58.79 G2 14 43.00 G3 21 −104.59 [Conditional Expression Corresponding Value] Conditional Expression (1) BFa/f = 0.241 Conditional Expression (2) (−G1R1)/f = 17.613 Conditional Expression (3), (3-1), (3-2) (−G1R1)/f1 = 11.275 Conditional Expression (4) f/f1 = 0.640 Conditional Expression (5) f/f2 = 0.875 Conditional Expression (6) f1/f2 = 1.367 Conditional Expression (7) f1/(−f3) = 0.562 Conditional Expression (8) fF/fR = 0.945 Conditional Expression (9) (G1R2 + G1R1)/(G1R2 − G1R1) = −0.903 Conditional Expression (10) {1 − (β2).sup.2} × (β3).sup.2 = 0. 728 Conditional Expression (11) FNO × (f1/f) = 2.893 Conditional Expression (12) 2ω = 60.0
(213) FIG. **22**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 11th example. FIG. **22**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 11th example. The various aberration graphs demonstrate that the optical system according to the 11th example has excellent image forming performance in which various aberrations are corrected favorably.
12th Example
(214) The 12th example will be described using FIGS. **23** and **24** and Table 12. FIG. **23** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 12th example of the present embodiment. The optical system LS(**12**) according to the 12th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.
(215) The first lens group G**1** comprises a first negative lens L**11** that is biconcave, a cemented lens consisting of a second negative lens L**12** that is biconcave and a first positive lens L**13** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**14** that is biconvex, a third positive lens L**15** that is biconvex, a cemented lens consisting of a fourth positive lens L**16** that is biconvex and a third negative lens L**17** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L**15** is an aspherical surface.
(216) The second lens group G**2** comprises a negative lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**22** having a meniscus shape whose concave surface is pointed toward the object, a second positive lens L**23** that is biconvex,

and a third positive lens L**24** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on either side of the first positive lens L**22** is an aspherical surface.

(217) The third lens group G**3** comprises a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object and a negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the object side of the negative lens L**32** is an aspherical surface. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

(218) Table 12 below lists data values regarding the optical system according to the 12th example. Note that the 14th surface is a virtual surface.

(219) TABLE-US-00012 TABLE 12 [General Data] f 37.70 FNO 1.88 ω 30.0 Y 21.70 TL 110.000 BF 9.600 BFa 9.055 [Lens Data] Surface Number R D nd vd 1 −3112.32120 3.000 1.73282 32.6 2 32.68764 8.690 3 −440.00413 3.000 1.48749 70.4 4 57.93171 4.000 1.94595 18.0 5 108.74454 3.168 6 42.60783 8.500 1.50267 62.2 7 −141.78756 3.866 8* 45.06258 6.500 1.80400 46.6 9 −210.82291 0.200 10 36.02017 9.000 1.59319 67.9 11 −45.79266 1.500 1.67270 32.2 12 22.46589 5.399 13 ∞ D13 (Variable) (Aperture Stop S) 14 ∞ 3.000 15 −22.15003 1.000 1.67270 32.2 16 −98.33346 0.318 17* −130.89892 2.500 1.77377 47.2 18* −43.35291 1.224 19 101.79100 5.500 1.59319 67.9 20 −53.62571 0.100 21 −81.82793 6.000 1.59319 67.9 22 −25.48031 D22 (Variable) 23 −75.16977 3.000 1.94595 18.0 24 −63.16701 8.776 25* −25.51533 1.500 1.64769 33.7 26 −99.50792 7.000 27 ∞ 1.600 1.51680 64.1 28 ∞ D28 (Variable) [Aspherical surface data] Eighth surface κ = 1.00000 A6 = −1.62936E−06, A6 = −1.61898E−09, A8 = 3.72851E−12, A10 = −6.56781E−15 Seventeenth surface κ = 1.00000 A4 = 3.15178E−05, A6 = 1.77790E−07, A8 = −3.27517E−10, A10 = −1.26227E−12 Eighteenth surface κ = 1.00000 A4 = 4.17433E−05, A6 = 1.91618E−07, A8 = 1.40927E−10, A10 = −2.86119E−12 Twenty-fifth surface κ = 1.00000 A4 = 1.10584E−05, A6 = −1.56481E−10, A8 = 0.00000E+00, A10 = 0.00000E+00 [Variable distance data] Upon focusing Upon focusing on a short- on infinity distance object f = 37.70 β = −0.1179 D0 ∞ 290.00 D13 6.605 2.441 D22 4.053 8.217 D28 1.000 1.000 [lens group data] group starting surface focal length G1 1 63.38 G2 14 39.22 G3 23 −62.57 [Conditional Expression Corresponding Value] Conditional Expression (1) BFa/f = 0.240 Conditional Expression (2) (−G1R1)/f = 82.547 Conditional Expression (3), (3-1), (3-2) (−G1R1)/f1 = 49.101 Conditional Expression (4) f/f1 = 0.595 Conditional Expression (5) f/f2 = 0.961 Conditional Expression (6) f1/f2 = 1.616 Conditional Expression (7) f1/(−f3) = 1.013 Conditional Expression (8) fF/fR = 0.873 Conditional Expression (9) (G1R2 + G1R1)/(G1R2 − G1R1) = −0.979 Conditional Expression (10) {1 − (β2).sup.2} × (β3).sup.2 = 0. 994 Conditional Expression (11) FNO × (f1/f) = 3.160 Conditional Expression (12) 2ω = 60.0

(220) FIG. **24**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 12th example. FIG. **24**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 12th example. The various aberration graphs demonstrate that the optical system according to the 12th example has excellent image forming performance in which various aberrations are corrected favorably.

13th Example

(221) The 13th example will be described using FIGS. **25** and **26** and Table 13. FIG. **25** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 13th example of the present embodiment. The optical system LS(**13**) according to the 13th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

(222) The first lens group G**1** comprises a first negative lens L**11** that is biconcave, a cemented lens consisting of a second negative lens L**12** that is biconcave and a first positive lens L**13** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**14** that is biconvex, a third positive lens L**15** that is biconvex, a cemented lens consisting of a fourth positive lens L**16** that is biconvex and a third negative lens L**17** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L**15** is an aspherical surface.
(223) The second lens group G**2** comprises a negative lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**22** having a meniscus shape whose concave surface is pointed toward the object, a second positive lens L**23** that is biconvex, and a third positive lens L**24** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the object side of the first positive lens L**22** is an aspherical surface.
(224) The third lens group G**3** comprises a positive lens L**31** having a meniscus shape whose convex surface is pointed toward the object and a negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the object side of the negative lens L**32** is an aspherical surface. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.
(225) Table 13 below lists data values regarding the optical system according to the 13th example. Note that the 14th surface is a virtual surface.
(226) TABLE-US-00013 TABLE 13 [General Data] f 36.52 FNO 1.85 ω 30.6 Y 21.70 TL 100.000 BF 9.600 BFa 9.055 [Lens Data] Surface Number R D nd νd 1 −344.23276 3.000 1.71736 29.6 2 31.47663 8.864 3 −5197.94500 3.000 1.48749 70.3 4 59.50193 4.000 1.94595 18.0 5 141.00357 0.152 6 49.20783 7.500 1.60300 65.4 7 −563.87665 4.981 8* 39.11480 6.000 1.77250 49.6 9 −139.68211 0.427 10 28.58681 8.000 1.59319 67.9 11 −50.06370 1.500 1.67270 32.2 12 19.18437 5.399 13 ∞ D13 (Variable) (Aperture Stop S) 14 ∞ 3.000 15 −22.50724 1.000 1.67270 32.2 16 −81.31951 0.549 17* −74.31824 3.000 1.77377 47.2 18 −35.67165 0.203 19 180.93759 5.000 1.59319 67.9 20 −43.85092 0.500 21 −132.62507 6.000 1.59319 67.9 22 −29.07561 D22 (Variable) 23 317.64282 3.000 1.94595 18.0 24 314.90339 6.932 25* −26.84153 1.500 1.64769 33.7 26 −77.55848 7.000 27 ∞ 1.600 1.51680 64.1 28 ∞ D28 (Variable) [Aspherical surface data] Eighth surface κ = 1.00000 A4 = −1.59558E−06, A6 = −1.61180E−09, A8 = 2.67206E−12, A10 = −4.02129E−15 Seventeenth surface κ = 1.00000 A4 = −1.62012E−05, A6 = −2.42502E−08, A8 = 1.25145E−10, A10 = −1.02694E−12 Twenty-fifth surface κ = 1.00000 A4 = 7.25982E−06, A6 = 1.79235E−08, A8 = −4.70327E−11, A10 = 2.68072E−14 [Variable distance data] Upon focusing Upon focusing on a short- on infinity distance object f = 36.52 β = −0.1131 D0 ∞ 290.00 D13 6.346 1.987 D22 0.549 4.907 D28 1.000 1.000 [lens group data] group starting surface focal length G1 1 52.27 G2 14 37.19 G3 23 −64.36 [Conditional Expression Corresponding Value] Conditional Expression (1) BFa/f = 0.248 Conditional Expression (2) (−G1R1)/f = 9.427 Conditional Expression (3), (3-1), (3-2) (−G1R1)/f1 = 6.586 Conditional Expression (4) f/f1 = 0.699 Conditional Expression (5) f/f2 = 0.982 Conditional Expression (6) f1/f2 = 1.406 Conditional Expression (7) f1/(−f3) = 0.812 Conditional Expression (8) fF/fR = 0.724 Conditional Expression (9) (G1R2 + G1R1)/(G1R2 − G1R1) = −0.832 Conditional Expression (10) {1 − (β2).sup.2} × (β3).sup.2 = 0.853 Conditional Expression (11) FNO × (f1/f) = 2.645 Conditional Expression (12) 2ω = 61.2
(227) FIG. **26**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 13th example. FIG. **26**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 13th example. The various aberration graphs demonstrate that the optical system according to the 13th example has excellent image forming performance in which various aberrations are corrected favorably.

14th Example

(228) The 14th example will be described using FIGS. **27** and **28** and Table 14. FIG. **27** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 14th example of the present embodiment. The optical system LS(**14**) according to the 14th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

(229) The first lens group G**1** comprises a first negative lens L**11** that is biconcave, a cemented lens consisting of a second negative lens L**12** having a meniscus shape whose convex surface is pointed toward the object and a first positive lens L**13** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**14** having a meniscus shape whose convex surface is pointed toward the object, a third positive lens L**15** that is biconvex, a cemented lens consisting of a fourth positive lens L**16** that is biconvex and a third negative lens L**17** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L**15** is an aspherical surface.

(230) The second lens group G**2** comprises a negative lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**22** having a meniscus shape whose concave surface is pointed toward the object, a second positive lens L**23** that is biconvex, and a third positive lens L**24** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on either side of the first positive lens L**22** is an aspherical surface.

(231) The third lens group G**3** comprises a positive lens L**31** having a meniscus shape whose convex surface is pointed toward the object and a negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the object side of the negative lens L**32** is an aspherical surface. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

(232) Table 14 below lists data values regarding the optical system according to the 14th example. Note that the 14th surface is a virtual surface.

(233) TABLE-US-00014 TABLE 14 [General Data] f 36.50 FNO 1.85 ω 30.7 Y 21.70 TL 100.000 BF 9.600 BFa 9.055 [Lens Data] Surface Number R D nd vd 1 −328.51209 3.000 1.71736 29.6 2 30.62735 8.724 3 862.45645 3.000 1.48749 70.3 4 57.42336 4.000 1.94595 18.0 5 141.63170 0.100 6 44.98135 7.500 1.60300 65.4 7 5539.31740 5.241 8* 41.34810 6.000 1.77250 49.6 9 −119.73719 0.200 10 28.47480 8.000 1.59319 67.9 11 −45.24565 1.500 1.67270 32.2 12 19.20206 5.399 13 ∞ D13 (Variable) (Aperture Stop S) 14 ∞ 3.000 15 −23.51305 1.000 1.67270 32.2 16 −129.15388 0.457 17* −103.44705 3.000 1.77377 47.2 18* −39.20704 0.417 19 131.40567 5.000 1.59319 67.9 20 −48.12075 0.500 21 −100.00000 6.000 1.59319 67.9 22 −26.83541 D22 (Variable) 23 102.68371 3.000 1.94595 18.0 24 106.30512 6.996 25* −28.73049 1.500 1.64769 33.7 26 −98.04242 7.000 27 ∞ 1.600 1.51680 64.1 28 ∞ D28 (Variable) [Aspherical surface data] Eighth surface κ = 1.00000 A4 = −1.74572E−06, A6 = −1.86902E−09, A8 = 3.70243E−12, A10 = −5.65794E−15 Seventeenth surface κ = 1.00000 A4 = −4.49752E−06, A6 = −4.35264E−08, A8 = 1.70129E−10, A10 = −7.71012E−13 Eighteenth surface κ = 1.00000 A4 = 1.06552E−05, A6 = 0.00000E+00, A8 = 0.00000E+00, A10 = 0.00000E+00 Twenty-fifth surface κ = 1.00000 A4 = 6.97711E−06, A6 = 8.30426E−09, A8 = −3.04728E−11, A10 = −2.65514E−15 [Variable distance data] Upon focusing Upon focusing on a short- on infinity distance object f = 36.50 β = −0.1131 D0 ∞ 290.00 D13 6.366 1.830 D22 0.500 5.036 D28 1.000 1.000 [lens group data] group starting surface focal length G1 1 52.56 G2 14 38.05 G3 23 −66.26 [Conditional Expression Corresponding Value] Conditional Expression (1) BFa/f = 0.248 Conditional Expression (2) (−G1R1)/f = 9.000

Conditional Expression (3), (3-1), (3-2) (−G1R1)/f1 = 6.250 Conditional Expression (4) f/f1 = 0.694 Conditional Expression (5) f/f2 = 0.959 Conditional Expression (6) f1/f2 = 1.381 Conditional Expression (7) f1/(−f3) = 0.793 Conditional Expression (8) fF/fR = 0.729 Conditional Expression (9) (G1R2 + G1R1)/(G1R2 − G1R1) Conditional Expression (10) {1 − (β2).sup.2} × (β3).sup.2 = −0.829 Conditional Expression (11) FNO × (f1/f) = 2.664 Conditional Expression (12) 2ω = 61.4

(234) FIG. **28**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 14th example. FIG. **28**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 14th example. The various aberration graphs demonstrate that the optical system according to the 14th example has excellent image forming performance in which various aberrations are corrected favorably.

15th Example

(235) The 15th example will be described using FIGS. **29** and **30** and Table 15. FIG. **29** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 15th example of the present embodiment. The optical system LS(**15**) according to the 15th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

(236) The first lens group G**1** comprises a first negative lens L**11** that is biconcave, a cemented lens consisting of a second negative lens L**12** having a meniscus shape whose convex surface is pointed toward the object and a first positive lens L**13** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**14** that is biconvex, a third positive lens L**15** that is biconvex, a cemented lens consisting of a fourth positive lens L**16** that is biconvex and a third negative lens L**17** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L**15** is an aspherical surface.

(237) The second lens group G**2** comprises a negative lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**22** having a meniscus shape whose concave surface is pointed toward the object, a second positive lens L**23** that is biconvex, and a third positive lens L**24** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on either side of the first positive lens L**22** is an aspherical surface.

(238) The third lens group G**3** comprises a negative lens L**31** having a meniscus shape whose concave surface is pointed toward the object. The lens surface on the object side of the negative lens L**31** is an aspherical surface. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

(239) Table 15 below lists data values regarding the optical system according to the 15th example. Note that the 14th surface is a virtual surface.

(240) TABLE-US-00015 TABLE 15 [General Data] f 36.50 FNO 1.87 ω 30.7 Y 21.70 TL 100.000 BF 9.600 BFa 9.054 [Lens Data] Surface Number R D nd vd 1 −188.20085 3.000 1.71736 29.6 2 30.66496 8.404 3 547.03690 3.000 1.48749 70.3 4 62.69373 4.000 1.94595 18.0 5 190.11798 0.100 6 45.62385 7.500 1.60300 65.4 7 −115579.46000 5.673 8* 44.63892 6.000 1.77250 49.6 9 −102.19551 0.200 10 28.17341 8.000 1.59319 67.9 11 −42.44281 1.500 1.67270 32.2 12 19.02911 5.399 13 ∞ D13 (Variable) (Aperture 14 ∞ 3.000 Stop S) 15 −23.61092 1.000 1.67270 32.2 16 −109.82047 0.899 17* −60.75679 3.000 1.77377 47.2 18* −33.74626 0.200 19 105.85192 5.000 1.59319 67.9 20 −52.67684 0.500 21 −100.00000 6.000 1.59319 67.9 22 −26.83541 D22 (Variable) 23* −35.17199 1.500 1.64769 33.7 24 −148.75840 7.000 25 ∞ 1.600 1.51680 64.1 26 ∞ D26 (Variable) [Aspherical surface data] Eighth surface κ = 1.00000 A4 = −1.59317E−06, A6 = −1.58329E−09, A8 = 3.51477E−12, A10 = −5.52433E−15 Seventeenth

surface κ = 1.00000 A4 = −1.23191E−05, A6 = −4.63629E−08, A8 = 2.30352E−10, A10 = −1.55636E−12 Eighteenth surface κ = 1.00000 A4 = 3.43104E−06, A6 = 0.00000E+00, A8 = 0.00000E+00, A10 = 0.00000E+00 Twenty-third surface κ = 1.00000 A4 = 2.07644E−06, A6 = 2.61568E−09, A8 = −1.43218E−11, A10 = −5.83085E−14 [Variable distance data] Upon focusing Upon focusing on a short- on infinity distance object f = 36.50 β = −0.1132 D0 8 290.00 D13 6.253 1.764 D22 10.273 14.761 D28 1.000 1.000 [lens group data] group starting surface focal length G1 1 52.70 G2 14 38.26 G3 23 −71.49 [Conditional Expression Corresponding Value] Conditional Expression (1) BFa/f = 0.248 Conditional Expression (2) (−G1R1)/f = 5.156 Conditional Expression (3), (3-1), (3-2) (−G1R1)/f1 = 3.571 Conditional Expression (4) f/f1 = 0.693 Conditional Expression (5) f/f2 = 0.954 Conditional Expression (6) f1/f2 = 1.377 Conditional Expression (7) f1/(−f3) = 0.737 Conditional Expression (8) fF/fR = 0.758 Conditional Expression (9) (G1R2 + G1R1)/(G1R2 − G1R1) = −0.720 Conditional Expression (10) {1 − (β2).sup.2} × (β3).sup.2 = 0.828 Conditional Expression (11) FNO × (f1/f) = 2.696 Conditional Expression (12) 2ω = 61.4

(241) FIG. **30**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 15th example. FIG. **30**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 15th example. The various aberration graphs demonstrate that the optical system according to the 15th example has excellent image forming performance in which various aberrations are corrected favorably.

16th Example

(242) The 16th example will be described using FIGS. **31** and **32** and Table 16. FIG. **31** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 16th example of the present embodiment. The optical system LS(**16**) according to the 16th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

(243) The first lens group G**1** comprises a first negative lens L**11** that is biconcave, a cemented lens consisting of a second negative lens L**12** having a meniscus shape whose convex surface is pointed toward the object and a first positive lens L**13** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**14** that is biconvex, a third positive lens L**15** that is biconvex, a cemented lens consisting of a fourth positive lens L**16** that is biconvex and a third negative lens L**17** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L**15** is an aspherical surface.

(244) The second lens group G**2** comprises a negative lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**22** that is biconvex, a second positive lens L**23** having a meniscus shape whose concave surface is pointed toward the object, and a third positive lens L**24** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on either side of the first positive lens L**22** is an aspherical surface.

(245) The third lens group G**3** comprises a positive lens L**31** having a meniscus shape whose convex surface is pointed toward the object and a negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the object side of the negative lens L**32** is an aspherical surface. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

(246) Table 16 below lists data values regarding the optical system according to the 16th example. Note that the 14th surface is a virtual surface.

(247) TABLE-US-00016 TABLE 16 [General Data] f 36.50 FNO 1.86 ω 30.8 Y 21.70 TL 100.000

BF 9.600 BFa 9.055 [Lens Data] Surface Number R D nd vd 1 −133.60683 2.000 1.71736 29.6 2 32.54620 8.076 3 388.71645 2.500 1.48749 70.3 4 65.47753 4.000 1.94595 18.0 5 219.57835 0.100 6 57.60424 7.000 1.60300 65.4 7 −387.08519 6.523 8* 44.24367 6.000 1.77250 49.6 9 −104.52830 0.200 10 31.09490 9.000 1.59319 67.9 11 −42.99037 1.500 1.67270 32.2 12 20.68411 5.399 13 ∞ D13 (Aperture (Variable) Stop S) 14 ∞ 3.000 15 −23.39527 1.000 1.67270 32.2 16 −374.05277 0.224 17* 89.21164 4.000 1.77377 47.2 18* −62.00927 1.388 19 −586.47623 4.500 1.59319 67.9 20 −38.88857 0.500 21 −100.00000 5.500 1.59319 67.9 22 −29.94109 D22 (Variable) 23 59.66877 3.000 1.94595 18.0 24 59.44379 6.722 25* −32.82899 1.500 1.64769 33.7 26 −177.92654 7.000 27 ∞ 1.600 1.51680 63.9 28 ∞ D28 (Variable) [Aspherical surface data] Eighth surface k = 1.00000 A4 = −1.04917E−06, A6 = −1.42831E−09, A8 = 4.66129E−12, A10 = −6.33796E−15 Seventeenth surface k = 1.00000 A4 = 1.65960E−05, A6 = 5.96989E−08, A6 = −6.57382E−11, A10 = 1.19611E−13 Eighteenth surface k = 1.00000 A4 = 2.95825E−05, A6 = 7.91633E−08, A8 = 0.00000E+00, A10 = 0.00000E+00 Twenty−fifth surface k = 1.00000 A4 = 4.39415E−06, A6 = −1.10198E−08, A8 = 5.26933E−11, A10 = −1.66739E−13 [Variable distance data] Upon focusing Upon focusing on a short- on infinity distance object f = 36.50 β = −0.1137 D0 ∞ 290.00 D13 6.258 1.649 D22 0.509 5.118 D28 1.000 1.000 [lens group data] group starting surface focal length G1 1 53.58 G2 14 39.30 G3 23 −65.49 [Conditional Expression Corresponding Value] Conditional Expression (1) BFa/f = 0.248 Conditional Expression (2) (−G1R1)/f = 3.660 Conditional Expression (3), (−G1R1)/f1 = 2.494 (3-1), (3-2) Conditional Expression (4) f/f1 = 0.681 Conditional Expression (5) f/f2 = 0.929 Conditional Expression (6) f1/f2 = 1.363 Conditional Expression (7) f1/(−f3) = 0.818 Conditional Expression (8) fF/fR = 0.714 Conditional Expression (9) (G1R2 + G1R1)/ (G1R2 − G1R1) = −0.608 Conditional Expression (10) {1 − (β2).sup.2} × (β3).sup.2 = 0.810 Conditional Expression (11) FNO × (f1/f) = 2.734 Conditional Expression (12) 2ω = 61.6

(248) FIG. **32**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 16th example. FIG. **32**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 16th example. The various aberration graphs demonstrate that the optical system according to the 16th example has excellent image forming performance in which various aberrations are corrected favorably.

17th Example

(249) The 17th example will be described using FIGS. **33** and **34** and Table 17. FIG. **33** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 17th example of the present embodiment. The optical system LS(**17**) according to the 17th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

(250) The first lens group G**1** comprises a first negative lens L**11** that is biconcave, a first positive lens L**12** having a meniscus shape whose convex surface is pointed toward the object, a second negative lens L**13** having a meniscus shape whose concave surface is pointed toward the object, a second positive lens L**14** that is biconvex, a cemented lens consisting of a third positive lens L**15** that is biconvex and a third negative lens L**16** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the image surface I side of the second negative lens L**13** is an aspherical surface. The lens surface on the object side of the second positive lens L**14** is an aspherical surface.

(251) The second lens group G**2** comprises a negative lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**22** that is biconvex, and a second positive lens L**23** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on either side of the first positive

lens L**22** is an aspherical surface.
(252) The third lens group G**3** comprises a cemented lens consisting of a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object and a first negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, and a second negative lens L**33** having a plano-concave shape whose concave surface is pointed toward the object, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.
(253) Table 17 below lists data values regarding the optical system according to the 17th example. Note that the 13th surface is a virtual surface.
(254) TABLE-US-00017 TABLE 17 [General Data] f 36.05 FNO 1.85 ω 31.6 Y 21.70 TL 99.592 BF 13.100 BFa 12.555 [Lens Data] Surface Number R D nd νd 1 −500.00000 2.000 1.59270 35.3 2 27.30135 8.716 3 60.46320 3.840 1.94594 18.0 4 220.11217 9.742 5 −29.41908 1.659 1.77377 47.2 6* −33.35969 1.884 7* 47.17368 10.592 1.76801 49.2 8 −60.97010 0.200 9 27.06671 6.869 1.59319 67.9 10 −38.40610 1.500 1.69895 30.1 11 22.53254 3.899 12 ∞ D12 (Aperture (Variable) Stop S) 13 ∞ 2.700 14 −20.48042 1.100 1.64769 33.7 15 −452.00052 0.648 16* 80.79578 4.788 1.77377 47.2 17* −31.41145 0.568 18 −137.97943 6.400 1.49782 82.6 19 −21.82018 D19 (Variable) 20 −72.37319 4.704 1.94594 18.0 21 −25.72015 1.900 1.80518 25.4 22 −96.08935 2.660 23 −34.82473 1.900 1.64769 33.7 24 ∞ 10.500 25 ∞ 1.600 1.51680 64.1 26 ∞ D26 (Variable) [Aspherical surface data] Sixth surface k = 1.00000 A4 = −1.02986E−07, A6 = 4.20882E−09, A8 = −1.01963E−11, A10 = 2.17897E−14 Seventh surface k = 1.00000 A4 = −2.57635E−07, A6 = 3.44388E−09, A8 = −9.56027E−12, A10 = 7.45193E−15 Sixteenth surface k = 1.00000 A4 = −2.53184E−06, A6 = 4.68537E−08, A8 = −1.77268E−11, A10 = −7.02284E−13 Seventeenth surface k = 1.00000 A4 = 2.23902E−05, A6 = 1.94868E−08, A8 = 4.29642E−10, A10 = −1.80787E−12 [Variable distance data] Upon focusing Upon focusing on a short- on infinity distance object f = 36.05 β = −0.1049 D0 ∞ 314.50 D12 5.722 2.550 D19 2.500 5.667 D26 1.000 1.000 [lens group data] group starting surface focal length G1 1 49.49 G2 13 36.41 G3 20 −55.61 [Conditional Expression Corresponding Value] Conditional Expression (1) BFa/f = 0.348 Conditional Expression (2) (−G1R1)/f = 13.870 Conditional Expression (3), (−G1R1)/f1 = 10.103 (3-1), (3-2) Conditional Expression (4) f/f1 = 0.728 Conditional Expression (5) f/f2 = 0.990 Conditional Expression (6) f1/f2 = 1.359 Conditional Expression (7) f1/(−f3) = 0.890 Conditional Expression (8) fF/fR = 0.554 Conditional Expression (9) (G1R2 + G1R1)/ (G1R2 − G1R1) = −0.896 Conditional Expression (10) {1 − (β2).sup.2} × (β3).sup.2 = 1.114 Conditional Expression (11) FNO × (f1/f) = 2.534 Conditional Expression (12) 2ω = 63.2
(255) FIG. **34**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 17th example. FIG. **34**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 17th example. The various aberration graphs demonstrate that the optical system according to the 17th example has excellent image forming performance in which various aberrations are corrected favorably.
18th Example
(256) The 18th example will be described using FIGS. **35** and **36** and Table 18. FIG. **35** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 18th example of the present embodiment. The optical system LS(**18**) according to the 18th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.
(257) The first lens group G**1** comprises a first negative lens L**11** that is biconcave, a first positive lens L**12** that is biconvex, a second negative lens L**13** having a meniscus shape whose concave

surface is pointed toward the object, a second positive lens L**14** that is biconvex, a cemented lens consisting of a third positive lens L**15** that is biconvex and a third negative lens L**16** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the image surface I side of the second negative lens L**13** is an aspherical surface. The lens surface on the object side of the second positive lens L**14** is an aspherical surface.

(258) The second lens group G**2** comprises a first positive lens L**21** that is biconvex, a negative lens L**22** having a meniscus shape whose concave surface is pointed toward the object, a second positive lens L**23** that is biconvex, and a third positive lens L**24** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on either side of the second positive lens L**23** is an aspherical surface.

(259) The third lens group G**3** comprises a cemented lens consisting of a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object and a first negative lens L**32** that is biconcave, and a second negative lens L**33** having a plano-concave shape whose concave surface is pointed toward the object, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

(260) Table 18 below lists data values regarding the optical system according to the 18th example.

(261) TABLE-US-00018 TABLE 18 [General Data] f 36.05 FNO 1.86 ω 31.6 Y 21.70 TL 99.539 BF 13.100 BFa 12.555 [Lens Data] Surface Number R D nd νd 1 −500.00000 2.000 1.59270 35.3 2 31.30252 8.752 3 77.05411 4.224 1.94594 18.0 4 −4995.87340 12.332 5 −34.14226 3.140 1.77377 47.2 6* −47.59110 0.100 7* 41.62130 5.898 1.76801 49.2 8 −65.35489 0.294 9 31.07689 6.046 1.59319 67.9 10 −44.14843 1.500 1.69895 30.1 11 22.96400 3.883 12 ∞ D12 (Aperture (Variable) Stop S) 13 95.03984 2.062 1.49782 82.6 14 −345.94097 2.289 15 −19.00516 1.100 1.64769 33.7 16* −992.59484 1.622 17* 123.45937 4.722 1.77377 47.2 18 −28.92599 0.200 19 −129.08817 6.400 1.49782 82.6 20 −21.31763 D20 (Variable) 21 −134.41671 5.154 1.94594 18.0 22 −26.15911 1.900 1.80518 25.4 23 1225.10730 3.764 24 −34.85007 1.900 1.64769 33.7 25 ∞ 10.500 26 ∞ 1.600 1.51680 64.1 27 ∞ D27 (Variable) [Aspherical surface data] Sixth surface k = 1.00000 A4 = 9.02554E−07, A6 = 3.14643E−09, A8 = −1.89905E−12, A10 = 1.77634E−14 Seventh surface k = 1.00000 A4 = −1.81054E−07, A6 = 2.54149E−09, A8 = −7.43973E−12, A10 = 8.48515E−15 Seventeenth surface k = 1.00000 A4 = 3.23226E−06, A6 = 4.85057E−08, A8 = 1.37810E−11, A10 = −1.32577E−13 Eighteenth surface k = 1.00000 A4 = 2.32157E−05, A6 = 3.57378E−08, A8 = 3.07145E−10, A10 = −6.42283E−13 [Variable distance data] Upon focusing Upon focusing on a short- on infinity distance object f = 36.05 β = −0.1053 D0 ∞ 314.50 D12 4.656 2.000 D20 2.500 5.150 D27 1.000 1.000 [lens group data] group starting surface focal length G1 1 58.73 G2 13 33.00 G3 20 −46.85 [Conditional Expression Corresponding Value] Conditional Expression (1) BFa/f = 0.348 Conditional Expression (2) (−G1R1)/f = 13.870 Conditional Expression (3), (−G1R1)/f1 = 8.514 (3-1), (3-2) Conditional Expression (4) f/f1 = 0.614 Conditional Expression (5) f/f2 = 1.092 Conditional Expression (6) f1/f2 = 1.780 Conditional Expression (7) f1/(−f3) = 1.253 Conditional Expression (8) fF/fR = 0.765 Conditional Expression (9) (G1R2 + G1R1)/ (G1R2 − G1R1) = −0.882 Conditional Expression (10) {1 − (β2).sup.2} × (β3).sup.2 = 1.369 Conditional Expression (11) FNO × (f1/f) = 3.025 Conditional Expression (12) 2ω = 63.2

(262) FIG. **36**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 18th example. FIG. **36**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 18th example. The various aberration graphs demonstrate that the optical system according to the 18th example has excellent image forming performance in which various aberrations are corrected favorably.

19th Example

(263) The 19th example will be described using FIGS. **37** and **38** and Table 19. FIG. **37** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system

according to the 19th example of the present embodiment. The optical system LS(**19**) according to the 19th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.
(264) The first lens group G**1** comprises a first negative lens L**11** that is biconcave, a first positive lens L**12** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**13** that is biconvex, a cemented lens consisting of a third positive lens L**14** that is biconvex and a second negative lens L**15** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on either side of the second positive lens L**13** is an aspherical surface.
(265) The second lens group G**2** comprises a first positive lens L**21** having a plano-convex shape whose convex surface is pointed toward the image surface I, a negative lens L**22** having a meniscus shape whose concave surface is pointed toward the object, a second positive lens L**23** that is biconvex, and a third positive lens L**24** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on either side of the second positive lens L**23** is an aspherical surface.
(266) The third lens group G**3** comprises a cemented lens consisting of a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object and a first negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, and a second negative lens L**33** having a plano-concave shape whose concave surface is pointed toward the object, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.
(267) Table 19 below lists data values regarding the optical system according to the 19th example. Note that the 5th surface and the 6th surface are virtual surfaces.
(268) TABLE-US-00019 TABLE 19 [General Data] f 36.05 FNO 1.87 ω 31.2 Y 21.70 TL 99.566 BF 13.100 BFa 12.555 [Lens Data] Surface Number R D nd νd 1 −500.00000 2.000 1.59270 35.3 2 26.44740 11.431 3 54.58955 3.977 1.94594 18.0 4 151.93034 2.197 5 ∞ 0.000 6 ∞ 10.067 7* 40.90811 5.557 1.76801 49.2 8* −104.02802 0.200 9 29.51647 6.609 1.59319 67.9 10 −42.76988 1.500 1.69895 30.1 11 23.53316 6.210 12 ∞ D12 (Aperture (Variable) Stop S) 13 ∞ 2.090 1.49782 82.6 14 −74.67300 2.012 15 −18.81061 1.100 1.64769 33.7 16 −248.50402 1.512 17* 118.78898 4.866 1.77377 47.2 18* −28.64501 0.200 19 −125.10532 6.400 1.49782 82.6 20 −22.16547 D20 1.94594 18.0 (Variable) 21 −66.18341 4.709 1.94594 18.0 22 −24.96921 1.900 1.80518 25.4 23 −199.98195 2.935 24 −38.28094 1.900 1.64769 33.7 25 ∞ 10.500 26 ∞ 1.600 1.51680 64.1 27 ∞ D27 (Variable) [Aspherical surface data] Seventh surface k = 1.00000 A4 = 3.16584E−07, A6 = 2.60390E−09, A8 = −1.78975E−11, A10 = 5.41316E−14 Eighth surface k = 1.00000 A4 = 4.34400E−08, A6 = −4.51994E−10, A8 = −7.80080E−12, A10 = 3.78367E−14 Seventeenth surface k = 1.00000 A4 = −3.61366E−06, A6 = 5.25325E−08, A8 = −5.32628E−12, A10 = 1.17020E−14 Eighteenth surface k = 1.00000 A4 = 2.00858E−05, A6 = 3.18374E−08, A8 = 2.71615E−10, A10 = −4.03272E−13 [Variable distance data] Upon focusing Upon focusing on a short- on infinity distance object f = 36.05 β = −0.1049 D0 ∞ 314.50 D12 4.594 2.000 D19 2.500 5.088 D26 1.000 1.000 [lens group data] group starting surface focal length G1 1 53.15 G2 13 32.25 G3 20 −45.20 [Conditional Expression Corresponding Value] Conditional Expression (1) BFa/f = 0.348 Conditional Expression (2) (−G1R1)/f = 13.870 Conditional Expression (3), (−G1R1)/f1 = 9.407 (3-1), (3-2) Conditional Expression (4) f/f1 = 0.678 Conditional Expression (5) f/f2 = 1.118 Conditional Expression (6) f1/f2 = 1.648 Conditional Expression (7) f1/(−f3) = 1.176 Conditional Expression (8) fF/fR = 0.626 Conditional Expression (9) (G1R2 + G1R1)/(G1R2 − G1R1) = −0.900 Conditional Expression (10) {1 − (β2).sup.2} × (β3).sup.2 = 1.388

Conditional Expression (11) FNO × (f1/f) = 2.751 Conditional Expression (12) 2ω = 62.4

(269) FIG. **38**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 19th example. FIG. **38**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 19th example. The various aberration graphs demonstrate that the optical system according to the 19th example has excellent image forming performance in which various aberrations are corrected favorably.

20th Example

(270) The 20th example will be described using FIGS. **39** and **40** and Table 20. FIG. **39** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 20th example of the present embodiment. The optical system LS(**20**) according to the 20th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

(271) The first lens group G**1** comprises a first negative lens L**11** having a meniscus shape whose convex surface is pointed toward the object, a cemented lens consisting of a second negative lens L**12** having a meniscus shape whose convex surface is pointed toward the object and a first positive lens L**13** having a meniscus shape whose convex surface is pointed toward the object, a third negative lens L**14** having a meniscus shape whose concave surface is pointed toward the object, a second positive lens L**15** that is biconvex, a cemented lens consisting of a third positive lens L**16** that is biconvex and a fourth negative lens L**17** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the second positive lens L**15** is an aspherical surface.

(272) The second lens group G**2** comprises a negative lens L**21** that is biconcave, a first positive lens L**22** having a meniscus shape whose concave surface is pointed toward the object, a second positive lens L**23** that is biconvex, and a third positive lens L**24** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the object side of the first positive lens L**22** is an aspherical surface.

(273) The third lens group G**3** comprises a first negative lens L**31** having a meniscus shape whose convex surface is pointed toward the object and a second negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the object side of the second negative lens L**32** is an aspherical surface. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

(274) Table 20 below lists data values regarding the optical system according to the 20th example.

(275) TABLE-US-00020 TABLE 20 [General Data] f 36.41 FNO 1.45 ω 30.7 Y 21.70 TL 120.000 BF 9.600 BFa 9.055 [Lens Data] Surface Number R D nd vd 1 117.52540 2.000 1.71736 29.6 2 26.99520 8.652 3 42.97983 2.500 1.48749 70.3 4 34.72137 5.000 1.94595 18.0 5 45.17490 9.389 6 −52.71945 6.000 1.60300 65.4 7 −131.66451 0.200 8* 55.12835 9.000 1.77250 49.6 9 −66.63993 0.200 10 57.67591 13.000 1.59319 67.9 11 −28.99052 1.500 1.67270 32.2 12 230.60272 5.399 13 ∞ D13 (Aperture (Variable) Stop S) 14 −30.96994 1.000 1.67270 32.2 15 1151.90580 2.000 16* −406.76312 4.000 1.77377 47.2 17 −45.06075 0.881 18 140.10078 6.000 1.59319 67.9 19 −58.07296 0.500 20 −100.00000 7.000 1.59319 67.9 21 −30.10496 D21 (Variable) 22 74.17179 3.000 1.94595 18.0 23 67.04188 7.824 24* −26.97932 1.500 1.64769 33.7 25 −290.34268 7.000 26 ∞ 1.600 1.51680 63.9 27 ∞ D27 (Variable) [Aspherical surface data] Eighth surface k = 1.00000 A4 = −6.93107E−07, A6 = −4.54051E−10, A8 = 1.72053E−12, A10 = −1.39325E−15 Sixteenth surface k = 1.00000 A4 = −1.46752E−05, A6 = −1.19814E−08, A8 = 3.20679E−11, A10 = −2.43972E−13 Twenty-fourth surface k = 1.00000 A4 = 1.09875E−05, A6 = 2.56103E−09, A8 = −8.64670E−12, A10 = −3.14024E−14 [Variable distance data] Upon focusing

Upon focusing on a short- on infinity distance object f = 36.41 β = −0.1095 D0 ∞ 290.00 D13 13.354 9.399 D21 0.500 4.455 D27 1.000 1.000 [lens group data] group starting surface focal length G1 1 48.51 G2 14 38.61 G3 22 −44.33 [Conditional Expression Corresponding Value] Conditional Expression (1) BFa/f = 0.249 Conditional Expression (2) (−G1R1)/f = −3.228 Conditional Expression (3), (−G1R1)/f1 = −2.423 (3-1), (3-2) Conditional Expression (4) f/f1 = 0.751 Conditional Expression (5) f/f2 = 0.943 Conditional Expression (6) f1/f2 = 1.256 Conditional Expression (7) f1/(−f3) = 1.094 Conditional Expression (8) fF/fR = 0.358 Conditional Expression (9) (G1R2 + G1R1)/ (G1R2 − G1R1) = −1.596 Conditional Expression (10) {1 − (β2).sup.2} × (β3).sup.2 = 0.914 Conditional Expression (11) FNO × (f1/f) = 1.936 Conditional Expression (12) 2ω = 61.4

(276) FIG. **40**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 20th example. FIG. **40**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 20th example. The various aberration graphs demonstrate that the optical system according to the 20th example has excellent image forming performance in which various aberrations are corrected favorably.

21st Example

(277) The 21st example will be described using FIGS. **41** and **42** and Table 21. FIG. **41** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 21st example of the present embodiment. The optical system LS(**21**) according to the 21st example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

(278) The first lens group G**1** comprises a first negative lens L**11** that is biconcave, a cemented lens consisting of a second negative lens L**12** having a meniscus shape whose convex surface is pointed toward the object and a first positive lens L**13** having a meniscus shape whose convex surface is pointed toward the object, a third negative lens L**14** that is biconcave, a second positive lens L**15** that is biconvex, a third positive lens L**16** having a meniscus shape whose convex surface is pointed toward the object, a cemented lens consisting of a fourth negative lens L**17** having a meniscus shape whose convex surface is pointed toward the object and a fourth positive lens L**18** having a meniscus shape whose convex shape is pointed toward the object, and an aperture stop S, arranged in order from the object side. The lens surface on either side of the second positive lens L**15** is an aspherical surface.

(279) The second lens group G**2** comprises a negative lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**22** having a meniscus shape whose concave surface is pointed toward the object, a second positive lens L**23** that is biconvex, and a third positive lens L**24** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the object side of the first positive lens L**22** is an aspherical surface.

(280) The third lens group G**3** comprises a first negative lens L**31** having a meniscus shape whose convex surface is pointed toward the object and a second negative lens L**32** having a plano-concave shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the object side of the second negative lens L**32** is an aspherical surface. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

(281) Table 21 below lists data values regarding the optical system according to the 21st example.

(282) TABLE-US-00021 TABLE 21 [General Data] f 36.00 FNO 1.42 ω 31.2 Y 21.70 TL 125.000 BF 9.600 BFa 9.055 [Lens Data] Surface Number R D nd νd 1 −2103.91320 2.000 1.67884 31.5 2 35.70457 7.893 3 323.10172 2.500 1.49086 69.1 4 67.22138 5.500 1.94595 18.0 5 787.71792

7.911 6 39.04627 2.00 1.69166 30.1 7 213.89102 0.100 8* 137.58827 12.000 1.85135 40.1 9* −47.56574 0.200 10 39.72534 7.000 1.83481 42.7 11 181.94050 2.130 12 117.83429 1.500 1.75520 27.6 13 23.80746 9.000 1.59319 67.9 14 183.46004 3.500 15 ∞ D15 (Aperture (Variable) Stop S) 16 −34.21404 1.000 1.67270 32.2 17 −122.91319 2.000 18* −86.16442 3.500 1.77377 47.2 19 −48.56224 2.416 20 1800.15400 5.500 1.59319 67.9 21 −42.45537 0.500 22 −100.00000 6.500 1.59319 67.9 23 −30.05033 D23 (Variable) 24 39.40559 3.000 1.94595 18.0 25 34.37457 9.136 26* −44.57372 1.500 1.64769 33.7 27 ∞ 7.000 28 ∞ 1.600 1.51680 63.9 29 ∞ D29 (Variable) [Aspherical surface data] Eighth surface k = 1.00000 A4 = 3.90875E−07, A6 = 5.99792E−10, A8 = −1.78965E−12, A10 = 1.89102E−15 Ninth surface k = 1.00000 A4 = 5.52339E−07, A6 = 1.13820E−09, A8 = −1.99242E−12, A10 = 2.23323E−15 Eighteenth surface k = 1.00000 A4 = −1.62045E−05, A6 = −1.75085E−08, A8 = 3.19334E−11, A10 = −3.05989E−13 Twenty-sixth surface k = 1.00000 A4 = −1.48857E−06, A6 = −3.93600E−09, A8 = 2.22864E−12, A10 = −4.82017E−14 [Variable distance data] Upon focusing Upon focusing on a short- on infinity distance object f = 36.00 β = −0.1086 D0 ∞ 290.00 D13 16.614 12.490 D21 0.500 4.624 D27 1.000 1.000 [lens group data] group starting surface focal length G1 1 52.88 G2 16 39.96 G3 24 −59.46 [Conditional Expression Corresponding Value] Conditional Expression (1) BFa/f = 0.252 Conditional Expression (2) (−G1R1)/f = 58.442 Conditional Expression (3), (−G1R1)/f1 = 39.787 (3-1), (3-2) Conditional Expression (4) f/f1 = 0.681 Conditional Expression (5) f/f2 = 0.901 Conditional Expression (6) f1/f2 = 1.323 Conditional Expression (7) f1/(−f3) = 0.889 Conditional Expression (8) fF/fR = 0.622 Conditional Expression (9) (G1R2 + G1R1)/ (G1R2 − G1R1) = −0.967 Conditional Expression (10) {1 − (β2).sup.2} × (β3).sup.2 = 0.867 Conditional Expression (11) FNO × (f1/f) = 2.080 Conditional Expression (12) 2ω = 62.4

(283) FIG. **42**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 21st example. FIG. **42**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 21st example. The various aberration graphs demonstrate that the optical system according to the 21st example has excellent image forming performance in which various aberrations are corrected favorably.

22nd Example

(284) The 22nd example will be described using FIGS. **43** and **44** and Table 22. FIG. **43** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 22nd example of the present embodiment. The optical system LS(**22**) according to the 22nd example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

(285) The first lens group G**1** comprises a cemented lens consisting of a first negative lens L**11** that is biconcave and a first positive lens L**12** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**13** having a meniscus shape whose concave surface is pointed toward the object, a third positive lens L**14** that is biconvex, a cemented lens consisting of a fourth positive lens L**15** that is biconvex and a second negative lens L**16** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L**14** is an aspherical surface.

(286) The second lens group G**2** comprises a negative lens L**21** having a meniscus shape whose concave surface is pointed toward the object and a positive lens L**22** that is biconvex, arranged in order from the object side. The lens surface on either side of the positive lens L**22** is an aspherical surface.

(287) The third lens group G**3** comprises a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object and a negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. An

image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.
(288) Table 22 below lists data values regarding the optical system according to the 22nd example. Note that the 12th surface is a virtual surface.
(289) TABLE-US-00022 TABLE 22 [General Data] f 36.00 FNO 1.42 ω 31.2 Y 21.70 TL 125.000 BF 9.600 BFa 9.055 [Lens Data] Surface Number R D nd νd 1 −47.35217 2.500 1.67270 32.2 2 94.47970 3.500 1.94595 18.0 3 340.13397 3.236 4 −287.21979 5.000 1.72916 54.6 5 −56.34930 0.100 6* 35.86692 6.000 1.80400 46.6 7 −2318.43510 0.200 8 45.67330 7.000 1.59319 67.9 9 −80.81919 1.500 1.64769 33.7 10 23.62983 4.933 11 ∞ D11 (Aperture (Variable) Stop S) 12 ∞ 3.000 13 −19.53832 1.100 1.75520 27.6 14 −43.18210 1.500 15* 190.26772 7.000 1.75501 51.2 16* −24.77289 D16 (Variable) 17 −104.87147 2.500 1.94595 18.0 18 −78.84438 14.090 19 −38.56539 1.900 1.64769 33.7 20 −200.67448 7.000 21 ∞ 1.600 1.51680 64.1 22 ∞ D22 (Variable) [Aspherical surface data] Sixth surface k = 1.00000 A4 = −1.5861E−06, A6 = −8.54477E−10, A8 = −4.09102E−13, A10 = 5.85218E−16 Fifteenth surface k = 1.00000 A4 = 4.66858E−07, A6 = −2.10629E−08, A8 = 1.67228E−10, A10 = −2.90665E−13 Sixteenth surface k = 1.00000 A4 = 8.47233E−06, A6 = 2.18602E−10, A8 = 2.67616E−11, A10 = 1.23427E−13 [Variable distance data] Upon focusing Upon focusing on a short- on infinity distance object f = 51.50 β = −0.1588 D0 ∞ 305.05 D11 12.719 2.695 D16 2.111 12.136 D22 1.000 1.000 [lens group data] group starting surface focal length G1 1 75.53 G2 12 56.74 G3 17 −100.37 [Conditional Expression Corresponding Value] Conditional Expression (1) BFa/f = 0.176 Conditional Expression (2) (−G1R1)/f = 0.919 Conditional Expression (3), (−G1R1)/f1 = 0.627 (3-1), (3-2) Conditional Expression (4) f/f1 = 0.682 Conditional Expression (5) f/f2 = 0.908 Conditional Expression (6) f1/f2 = 1.331 Conditional Expression (7) f1/(−f3) = 0.753 Conditional Expression (8) fF/fR = 0.762 Conditional Expression (9) (G1R2 + G1R1)/ (G1R2 − G1R1) = 0.756 Conditional Expression (10) {1 − (β2).sup.2} × (β3).sup.2 = 0.687 Conditional Expression (11) FNO × (f1/f) = 2.716 Conditional Expression (12) 2ω = 45.8
(290) FIG. **44**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 22nd example. FIG. **44**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 22nd example. The various aberration graphs demonstrate that the optical system according to the 22nd example has excellent image forming performance in which various aberrations are corrected favorably.
23rd Example
(291) The 23rd example will be described using FIGS. **45** and **46** and Table 23. FIG. **45** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 23rd example of the present embodiment. The optical system LS(**23**) according to the 23rd example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.
(292) The first lens group G**1** comprises a cemented lens consisting of a first negative lens L**11** that is biconcave and a first positive lens L**12** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**13** having a meniscus shape whose concave surface is pointed toward the object, a third positive lens L**14** that is biconvex, a cemented lens consisting of a fourth positive lens L**15** having a meniscus shape whose convex surface is pointed toward the object and a second negative lens L**16** having a meniscus shape whose convex surface is pointed toward the object, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L**14** is an aspherical surface.
(293) The second lens group G**2** comprises a first positive lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a negative lens L**22** having a meniscus shape whose

concave surface is pointed toward the object, and a second positive lens L**23** that is biconvex, arranged in order from the object side. The lens surface on either side of the second positive lens L**23** is an aspherical surface.

(294) The third lens group G**3** comprises a first negative lens L**31** having a meniscus shape whose concave surface is pointed toward the object and a second negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

(295) Table 23 below lists data values regarding the optical system according to the 23rd example. Note that the 20th surface is a virtual surface.

(296) TABLE-US-00023 TABLE 23 [General Data] f 51.08 FNO 1.86 ω 23.0 Y 21.70 TL 90.000 BF 9.600 BFa 9.055 [Lens Data] Surface Number R D nd νd 1 −52.31571 2.500 1.67270 32.2 2 167.47695 3.500 1.94595 18.0 3 223.17328 4.121 4 −82.07390 4.000 1.72916 54.6 5 −45.42951 0.100 6* 38.12626 6.000 1.80400 46.6 7 −3600.28350 1.699 8 27.04928 5.000 1.59319 67.9 9 41.33566 1.500 1.64769 33.7 10 20.68760 5.718 11 ∞ D11 (Aperture (Variable) Stop S) 12 −22.93194 2.500 1.49700 81.6 13 −17.98615 0.500 14 −17.23374 1.100 1.67270 32.2 15 −49.04852 1.500 16* 279.75740 6.000 1.75501 51.2 17* −26.00590 D17 (Variable) 18 −221.46549 2.500 1.94595 18.0 19 −230.39803 0.000 20 ∞ 10.724 21 −38.50025 1.900 1.64769 33.7 22 −110.45885 7.000 23 ∞ 1.600 1.51680 63.9 24 ∞ D24 (Variable) [Aspherical surface data] Sixth surface k = 1.00000 A4 = −1.19548E−06, A6 = −9.73538E−10, A8 = 3.03150E−12, A10 = −5.31839E−15 Sixteenth surface k = 1.00000 A4 = −1.22099E−06, A6 = −9.91302E−09, A8 = 8.68866E−11, A10 = −1.19726E−13 Seventeenth surface k = 1.00000 A4 = 5.66916E−06, A6 = 2.72450E−09, A8 = −8.54602E−12, A10 = 1.63651E−13 [Variable distance data] Upon focusing Upon focusing on a short- on infinity distance object f = 51.08 β = −0.1171 D0 ∞ 413.36 D11 12.216 4.956 D17 7.322 14.582 D24 1.000 1.000 [lens group data] group starting surface focal length G1 1 68.94 G2 12 58.61 G3 18 −90.38 [Conditional Expression Corresponding Value] Conditional Expression (1) BFa/f = 0.177 Conditional Expression (2) (−G1R1)/f = 1.024 Conditional Expression (3), (−G1R1)/f1 = 0.759 (3-1), (3-2) Conditional Expression (4) f/f1 = 0.741 Conditional Expression (5) f/f2 = 0.872 Conditional Expression (6) f1/f2 = 1.176 Conditional Expression (7) f1/(−f3) = 0.763 Conditional Expression (8) fF/fR = 0.542 Conditional Expression (9) (G1R2 + G1R1)/ (G1R2 − G1R1) = 0.620 Conditional Expression (10) {1 − (β2).sup.2} × (β3).sup.2 = 0.721 Conditional Expression (11) FNO × (f1/f) = 2.508 Conditional Expression (12) 2ω = 46.0

(297) FIG. **46**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 23rd example. FIG. **46**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 23rd example. The various aberration graphs demonstrate that the optical system according to the 23rd example has excellent image forming performance in which various aberrations are corrected favorably.

24th Example

(298) The 24th example will be described using FIGS. **47** and **48** and Table 24. FIG. **47** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 24th example of the present embodiment. The optical system LS(**24**) according to the 24th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

(299) The first lens group G**1** comprises a first negative lens L**11** that is biconcave, a first positive lens L**12** having a meniscus shape whose concave surface is pointed toward the object, a second positive lens L**13** having a meniscus shape whose convex surface is pointed toward the object, a

cemented lens consisting of a third positive lens L**14** having a meniscus shape whose convex surface is pointed toward the object and a second negative lens L**15** having a meniscus shape whose convex surface is pointed toward the object, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the second positive lens L**13** is an aspherical surface.

(300) The second lens group G**2** comprises a first positive lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a negative lens L**22** having a meniscus shape whose concave surface is pointed toward the object, and a second positive lens L**23** that is biconvex, arranged in order from the object side. The lens surface on either side of the second positive lens L**23** is an aspherical surface.

(301) The third lens group G**3** comprises a positive lens L**31** having a meniscus shape whose convex surface is pointed toward the object and a negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

(302) Table 24 below lists data values regarding the optical system according to the 24th example.

(303) TABLE-US-00024 TABLE 24 [General Data] f 51.50 FNO 1.85 ω 22.9 Y 21.70 TL 82.941 BF 9.600 BFa 9.055 [Lens Data] Surface Number R D nd νd 1 −47.29734 2.000 1.67270 32.2 2 2331.06620 3.670 3 −71.21945 4.000 1.72916 54.6 4 −42.49265 0.100 5* 34.70954 6.000 1.80400 46.6 6 6260.90290 0.947 7 27.53256 5.000 1.59319 67.9 8 40.45186 1.500 1.64769 33.7 9 19.48030 5.755 10 ∞ D10 (Aperture (Variable) Stop S) 11 −21.95759 2.500 1.49700 81.6 12 −17.97990 0.500 13 −17.33726 1.100 1.67270 32.2 14 −65.42718 0.387 15* 210.98797 6.000 1.75501 51.2 16* −24.41048 D16 (Variable) 17 79.42309 2.500 1.94595 18.0 18 102.63179 8.767 19 −46.77211 1.900 1.84666 23.8 20 −182.21442 7.000 21 ∞ 1.600 1.51680 63.9 22 ∞ D22 (Variable) [Aspherical surface data] Fifth surface k = 1.00000 A4 = −1.79931E−06, A6 = −1.35228E−09, A8 = 1.30531E−12, A10 = −3.27717E−15 Fifteenth surface k = 1.00000 A4 = −1.14256E−06, A6 = −1.30370E−08, A8 = 1.13854E−10, A10 = −1.79669E−13 Sixteenth surface k = 1.00000 A4 = 6.47116E−06, A6 = 6.32503E−09, A8 = −2.44521E−11, A10 = 2.46075E−13 [Variable distance data] Upon focusing Upon focusing on a short- on infinity distance object f = 51.50 β = 0.1181 D0 ∞ 413.36 D10 14.069 5.072 D16 6.646 15.643 D22 1.000 1.000 [lens group data] group starting surface focal length G1 1 68.06 G2 11 64.03 G3 17 −99.89 [Conditional Expression Corresponding Value] Conditional Expression (1) BFa/f = 0.176 Conditional Expression (2) (−G1R1)/f = 0.918 Conditional Expression (3), (−G1R1)/f1 = 0.695 (3-1), (3-2) Conditional Expression (4) f/f1 = 0.757 Conditional Expression (5) f/f2 = 0.804 Conditional Expression (6) f1/f2 = 1.063 Conditional Expression (7) f1/(−f3) = 0.681 Conditional Expression (8) fF/fR = 0.514 Conditional Expression (9) (G1R2 + G1R1)/ (G1R2 − G1R1) = 0.960 Conditional Expression (10) {1 − (β2).sup.2} × (β3).sup.2 = 0.563 Conditional Expression (11) FNO × (f1/f) = 2.445 Conditional Expression (12) 2ω = 45.8

(304) FIG. **48**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 24th example. FIG. **48**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 24th example. The various aberration graphs demonstrate that the optical system according to the 24th example has excellent image forming performance in which various aberrations are corrected favorably.

25th Example

(305) The 25th example will be described using FIGS. **49** and **50** and Table 25. FIG. **49** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 25th example of the present embodiment. The optical system LS(**25**) according to the 25th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a

short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.
(306) The first lens group G**1** comprises a first negative lens L**11** that is biconcave, a first positive lens L**12** having a meniscus shape whose concave surface is pointed toward the object, a second positive lens L**13** having a meniscus shape whose convex surface is pointed toward the object, a second negative lens L**14** having a meniscus shape whose convex surface is pointed toward the object, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the second positive lens L**13** is an aspherical surface.
(307) The second lens group G**2** comprises a first positive lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a negative lens L**22** having a meniscus shape whose concave surface is pointed toward the object, and a second positive lens L**23** that is biconvex, arranged in order from the object side. The lens surface on either side of the second positive lens L**23** is an aspherical surface.
(308) The third lens group G**3** comprises a positive lens L**31** having a meniscus shape whose convex surface is pointed toward the object and a negative lens L**32** having a plano-concave shape whose concave surface is pointed toward the object, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.
(309) Table 25 below lists data values regarding the optical system according to the 25th example.
(310) TABLE-US-00025 TABLE 25 [General Data] f 50.81 FNO 1.85 ω 23.1 Y 21.70 TL 80.000 BF 9.600 BFa 9.055 [Lens Data] Surface Number R D nd νd 1 −48.70279 2.000 1.67270 32.2 2 958.65257 2.567 3 −87.18050 3.500 1.72916 54.6 4 −45.33683 0.100 5* 28.25675 6.500 1.77250 49.6 6 735.50092 0.365 7 28.50942 2.465 1.67270 32.2 8 19.47871 6.238 9 ∞ D9 (Aperture (Variable) Stop S) 10 −21.86257 2.000 1.49700 81.6 11 −18.15776 0.500 12 −17.46272 1.100 1.67270 32.2 13 −78.54612 0.200 14* 259.64263 6.500 1.75501 51.2 15* −23.47358 D15 (Variable) 16 45.54867 2.500 1.94595 18.0 17 56.06952 6.419 18 −49.21248 1.900 1.84666 23.8 19 ∞ 7.000 20 ∞ 1.600 1.51680 63.9 21 ∞ D21 (Variable) [Aspherical surface data] Fifth surface k = 1.00000 A4 = −3.06009E−06, A6 = −3.83923E−09, A8 = 3.08021E−12, A10 = −1.31813E−14 Fourteenth surface k = 1.00000 A4 = −2.38445E−06, A6 = −7.07397E−10, A8 = 4.93804E−11, A10 = −6.99716E−14 Fifteenth surface k = 1.00000 A4 = 6.07250E−06, A6 = 1.41158E−08, A8 = −5.03385E−11, A10 = 2.68237E−13 [Variable distance data] Upon focusing Upon focusing on a short− on infinity distance object f = 50.81 β = −0.1180 D0 ∞ 413.36 D9 14.286 5.350 D15 11.261 20.197 D21 1.000 1.000 [lens group data] group starting surface focal length G1 1 67.37 G2 10 68.93 G3 16 −83.91 [Conditional Expression Corresponding Value] Conditional Expression (1) BFa/f = 0.178 Conditional Expression (2) (−G1R1)/f = 0.958 Conditional Expression (3), (−G1R1)/f1 = 0.695 (3-1), (3-2) Conditional Expression (4) f/f1 = 0.754 Conditional Expression (5) f/f2 = 0.737 Conditional Expression (6) f1/f2 = 0.977 Conditional Expression (7) f1/(−f3) = 0.803 Conditional Expression (8) fF/fR = 0.349 Conditional Expression (9) (G1R2 + G1R1)/(G1R2 − G1R1) = 0.903 Conditional Expression (10) {1 − (β2).sup.2} × (β3).sup.2 = 0.567 Conditional Expression (11) FNO × (f1/f) = 2.456 Conditional Expression (12) 2ω = 46.2
(311) FIG. **50**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 25th example. FIG. **50**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 25th example. The various aberration graphs demonstrate that the optical system according to the 25th example has excellent image forming performance in which various aberrations are corrected favorably.

26th Example

(312) The 26th example will be described using FIGS. **51** and **52** and Table 26. FIG. **51** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 26th example of the present embodiment. The optical system LS(**26**) according to the 26th example comprises a first lens group G**1** having positive refractive power, a second lens

group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. Additionally, the second lens group G**2** includes a first subgroup G2A having negative refractive power and a second subgroup G2B having positive refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the first subgroup G2A and the second subgroup G2B of the second lens group G**2** move toward the object by different amounts along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.
(313) The first lens group G**1** comprises a cemented lens consisting of a first negative lens L**11** that is biconcave and a first positive lens L**12** having a meniscus shape whose convex surface is pointed toward the object, a second negative lens L**13** that is biconcave, a second positive lens L**14** that is biconvex, a third positive lens L**15** that is biconvex, a cemented lens consisting of a fourth positive lens L**16** that is biconvex and a third negative lens L**17** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on either side of the third positive lens L**15** is an aspherical surface.
(314) The first subgroup G2A of the second lens group G**2** comprises a negative lens L**21** having a meniscus shape whose concave surface is pointed toward the object. The second subgroup G2B of the second lens group G**2** comprises a first positive lens L**22** that is biconvex and a second positive lens L**23** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on either side of the first positive lens L**22** is an aspherical surface.
(315) The third lens group G**3** comprises a cemented lens consisting of a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object and a first negative lens L**32** that is biconcave, and a second negative lens L**33** having a plano-concave shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the object side of the second negative lens L**33** is an aspherical surface. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.
(316) Table 26 below lists data values regarding the optical system according to the 26th example.
(317) TABLE-US-00026 TABLE 26 [General Data] f 51.60 FNO 1.44 ω 22.7 Y 21.70 TL 113.685 BF 13.100 BFa 12.555 [Lens Data] Surface Number R D nd νd 1 −171.72474 2.000 1.62588 35.7 2 35.44631 5.392 1.94594 18.0 3 74.33039 6.970 4 −53.50931 3.610 1.75520 27.6 5 91.70821 0.200 6 74.06522 7.512 1.90265 35.7 7 −104.97613 0.100 8* 56.97323 7.742 1.85135 40.1 9* −173.82221 0.200 10 38.89486 12.894 1.59319 67.9 11 −34.37837 1.500 1.74077 27.7 12 37.65571 4.597 13 ∞ D13 (Aperture (Variable) Stop S) 14 −22.59808 1.100 1.64769 33.7 15 −145.29857 D15 (Variable) 16* 85.83165 6.797 1.77377 47.2 17* −32.92442 1.000 18 −62.36306 6.400 1.49782 82.6 19 −26.53221 D19 (Variable) 20 −15532.87600 5.451 1.94594 18.0 21 −42.26207 4.169 1.75520 27.6 22 1509.21760 3.688 23* −47.39475 1.900 1.88202 37.2 24 ∞ 10.500 25 ∞ 1.600 1.51680 64.1 26 ∞ D26 (Variable) [Aspherical surface data] Eighth surface k = 1.00000 A4 = 1.10048E−06, A6 = 1.15261E−10, A8 = 4.34134E−12, A10 = −9.02791E−16 Ninth surface k = 1.00000 A4 = 2.53480E−06, A6 = −1.36378E−09, A8 = 6.90741E−12, A10 = −6.44423E−15 Sixteenth surface k = 1.00000 A4 = −2.74525E−06, A6 = 1.71160E−08, A8 = −1.40699E−11, A10 = 1.45752E−14 Seventeenth surface k = 1.00000 A4 = 1.20601E−05, A6 = 1.19411E−08, A8 = 3.74420E−11, A10 = −3.48136E−14 Twenty-third surface k = 1.00000 A4 = 1.37602E−06, A6 = −3.97295E−09, A8 = 7.39073E−12, A10 = −9.76367E−15 [Variable distance data] Upon focusing Upon focusing on a short- on infinity distance object f = 51.60 β = −0.1471 D0 ∞ 314.50 D13 13.416 6.329 D15 1.447 1.481 D19 2.500 9.547 D26 1.000 1.000 [lens group data] group starting surface focal length G1 1 81.01 G2 14 42.29 (G2A 14 −41.46) (G2B 16 25.11) G4 20 −70.49 [Conditional Expression Corresponding Value] Conditional Expression (1) BFa/f = 0.243 Conditional Expression (2) (−G1R1)/f = 0.922 Conditional Expression (3), (−G1R1)/f1 = 0.588 (3-1), (3-2) Conditional Expression (4) f/f1 = 0.637 Conditional Expression (5) f/f2 = 1.192

Conditional Expression (6) f1/f2 = 1.871 Conditional Expression (7) f1/(−f3) = 1.149 Conditional Expression (8) fF/fR = 0.976 Conditional Expression (9) (G1R2 + G1R1)/ (G1R2 − G1R1) = 0.219 Conditional Expression (10) {1 − (β2).sup.2} × (β3).sup.2 = 0.957 Conditional Expression (11) FNO × (f1/f) = 2.263 Conditional Expression (12) 2ω = 45.4

(318) FIG. **52**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 26th example. FIG. **52**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 26th example. The various aberration graphs demonstrate that the optical system according to the 26th example has excellent image forming performance in which various aberrations are corrected favorably.

27th Example

(319) The 27th example will be described using FIGS. **53** and **54** and Table 27. FIG. **53** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 27th example of the present embodiment. The optical system LS(**27**) according to the 27th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

(320) The first lens group G**1** comprises a first negative lens L**11** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**12** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**13** that is biconvex, a third positive lens L**14** having a meniscus shape whose convex surface is pointed toward the object, a cemented lens consisting of a fourth positive lens L**15** that is biconvex and a second negative lens L**16** that is biconcave, and an aperture stop S, arranged in order from the object side.

(321) The second lens group G**2** comprises a negative lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**22** that is biconvex, and a second positive lens L**23** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the image surface I side of the first positive lens L**22** is an aspherical surface.

(322) The third lens group G**3** comprises a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object and a negative lens L**32** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

(323) Table 27 below lists data values regarding the optical system according to the 27th example.

(324) TABLE-US-00027 TABLE 27 [General Data] f 85.00 FNO 1.86 ω 14.2 Y 21.70 TL 115.209 BF 21.685 BFa 21.004 [Lens Data] Surface Number R D nd vd 1 −64.83088 2 −188.98518 0.300 3 153.82997 4.500 1.94595 18.0 4 508.32386 0.300 5 420.81318 6.000 1.72916 54.6 6 −110.04917 0.100 7 48.16622 7.000 1.72916 54.6 8 79.79724 0.200 9 40.00000 10.958 1.59282 68.7 10 −125.87904 2.500 1.67270 32.2 11 25.51317 7.152 12 ∞ D12 (Aperture (Variable) Stop S) 13 −30.69513 1.500 1.64769 33.7 14 −1583.64670 1.500 15 84.28063 5.000 1.77377 47.2 16* −60.30181 1.500 17 −115.77812 4.500 1.49700 81.6 18 −35.95414 D18 (Variable) 19 −79.69114 4.000 1.94595 18.0 20 −48.89207 6.639 21 −37.38750 2.000 1.64769 33.7 22 −237.55752 18.685 23 ∞ 2.000 1.51680 64.1 24 ∞ D24 (Variable) [Aspherical surface data] Sixteenth surface k = 1.00000 A4 = 4.07807E−06, A6 = 3.17226E−09, A8 = −8.77566E−12, A10 = 1.60757E−14 [Variable distance data] Upon focusing Upon focusing on a short- on infinity distance object f = 85.00 β = −0.1471 D0 ∞ 661.16 D12 17.304 5.692 D18 8.071 19.684 D24 1.000 1.000 [lens group data] group starting surface focal length G1 1 129.04 G2 13 75.91 G3 19 −161.19 [Conditional Expression Corresponding Value] Conditional Expression (1) BFa/f = 0.247 Conditional Expression (2) (−G1R1)/f = 0.763 Conditional Expression (3), (−G1R1)/f1 = 0.502 (3-

1), (3-2) Conditional Expression (4) f/f1 = 0.659 Conditional Expression (5) f/f2 = 1.120 Conditional Expression (6) f1/f2 = 1.700 Conditional Expression (7) f1/(−f3) = 0.801 Conditional Expression (8) fF/fR = 1.054 Conditional Expression (9) (G1R2 + G1R1)/ (G1R2 − G1R1) = 2.044 Conditional Expression (10) {1 − (β2).sup.2} × (β3).sup.2 = 0.804 Conditional Expression (11) FNO × (f1/f) = 2.825 Conditional Expression (12) 2ω = 28.4

(325) FIG. **54**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 27th example. FIG. **54**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 27th example. The various aberration graphs demonstrate that the optical system according to the 27th example has excellent image forming performance in which various aberrations are corrected favorably.

28th Example

(326) The 28th example will be described using FIGS. **55** and **56** and Table 28. FIG. **55** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 28th example of the present embodiment. The optical system LS(**28**) according to the 28th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

(327) The first lens group G**1** comprises a first negative lens L**11** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**12** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**13** that is biconvex, a third positive lens L**14** having a meniscus shape whose convex surface is pointed toward the object, a cemented lens consisting of a fourth positive lens L**15** that is biconvex and a second negative lens L**16** that is biconcave, and an aperture stop S, arranged in order from the object side.

(328) The second lens group G**2** comprises a negative lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**22** that is biconvex, and a second positive lens L**23** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the image surface I side of the first positive lens L**22** is an aspherical surface.

(329) The third lens group G**3** comprises a positive lens L**31** that is biconvex and a negative lens L**32** that is biconcave, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

(330) Table 28 below lists data values regarding the optical system according to the 28th example.

(331) TABLE-US-00028 TABLE 28 [General Data] f 85.00 FNO 1.83 ω 14.2 Y 21.70 TL 115.187 BF 19.721 BFa 19.039 [Lens Data] Surface Number R D nd vd   1 −72.98373 2.500 1.67270 32.2   2 −170.26652 0.300   3 117.64422 4.500 1.94595 18.0   4 186.71439 0.436   5 189.13820 6.000 1.72916 54.6   6 −151.29429 0.100   7 50.47764 7.000 1.72916 54.6   8 72.74698 0.200   9 40.25986 11.919 1.59282 68.7 10 −195.06452 2.500 1.67270 32.2 11 26.55143 6.702 12 ∞ D12 (Aperture (Variable) Stop S) 13 −29.45199 1.500 1.64769 33.7 14 −432.91007 1.500 15 95.51607 5.000 1.77377 47.2 16* −57.35798 1.500 17 −90.11025 4.500 1.49700 81.6 18 −33.31937 D18 (Variable) 19 17922.25800 4.000 1.94595 18.0 20 −128.51263 6.878 21 −63.86657 2.000 1.64769 33.7 22 153.63984 16.721 23 ∞ 2.000 1.51680 64.1 24 ∞ D24 (Variable) [Aspherical surface data] Sixteenth surface k = 1.00000 A4 = 4.53083E−06, A6 = 3.16311E−09, A8 = −8.83761E−12, A10 = 1.81194E−14 [Variable distance data] Upon focusing Upon focusing on a short- on infinity distance object f = 85.00 β = −0.1247 D0 ∞ 661.16 D12 18.306 5.696 D18 8.127 20.736 D24 1.000 1.000 [lens group data] group starting surface focal length G1 1 131.54 G2 13 77.05 G3 19 −160.72 [Conditional Expression Corresponding Value] Conditional Expression (1) BFa/f = 0.224 Conditional Expression (2) (−G1R1)/f = 0.859 Conditional Expression (3), (−G1R1)/f1 = 0.555 (3-

1), (3-2) Conditional Expression (4) f/f1 = 0.646 Conditional Expression (5) f/f2 = 1.103 Conditional Expression (6) f1/f2 = 1.707 Conditional Expression (7) f1/(−f3) = 0.818 Conditional Expression (8) fF/fR = 1.101 Conditional Expression (9) (G1R2 + G1R1)/ (G1R2 − G1R1) = 2.500 Conditional Expression (10) {1 − (β2).sup.2} × (β3).sup.2 = 0.727 Conditional Expression (11) FNO × (f1/f) = 2.839 Conditional Expression (12) 2ω = 28.4

(332) FIG. **56**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 28th example. FIG. **56**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 28th example. The various aberration graphs demonstrate that the optical system according to the 28th example has excellent image forming performance in which various aberrations are corrected favorably.

29th Example

(333) The 29th example will be described using FIGS. **57** and **58** and Table 29. FIG. **57** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 29th example of the present embodiment. The optical system LS(**29**) according to the 29th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

(334) The first lens group G**1** comprises a first negative lens L**11** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**12** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**13** that is biconvex, a third positive lens L**14** having a meniscus shape whose convex surface is pointed toward the object, a cemented lens consisting of a fourth positive lens L**15** that is biconvex and a second negative lens L**16** that is biconcave, and an aperture stop S, arranged in order from the object side.

(335) The second lens group G**2** comprises a negative lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**22** that is biconvex, and a second positive lens L**23** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the image surface I side of the first positive lens L**22** is an aspherical surface.

(336) The third lens group G**3** comprises a positive lens L**31** that is biconvex and a negative lens L**32** that is biconcave, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

(337) Table 29 below lists data values regarding the optical system according to the 29th example.

(338) TABLE-US-00029 TABLE 29 [General Data] f 85.00 FNO 1.85 ω 14.2 Y 21.70 TL 115.297 BF 15.435 BFa 14.754 [Lens Data] Surface Number R D nd vd 1 −75.54007 2.500 1.67270 32.2 2 −147.54550 0.300 3 88.89576 4.500 1.94595 18.0 4 118.01688 0.648 5 127.59306 6.000 1.80400 46.6 6 −246.54425 0.100 7 47.61283 6.000 1.59282 68.6 8 67.76235 0.200 9 40.00000 10.476 1.59282 68.7 10 −185.31557 2.500 1.67270 32.2 11 26.38137 6.867 12 ∞ D12 (Aperture (Variable) Stop S) 13 −28.70718 1.500 1.64769 33.7 14 −336.87946 1.500 15 97.83173 5.000 1.77377 47.2 16* −54.59764 1.500 17 −87.32308 4.500 1.49700 81.6 18 −32.94421 D18 (Variable) 19 3326.05740 4.000 1.94595 18.0 20 −105.25167 4.274 21 −57.51449 2.000 1.64769 33.7 22 111.93382 12.435 23 ∞ 2.000 1.51680 64.1 24 ∞ D24 (Variable) [Aspherical surface data] Sixteenth surface k = 1.00000 A4 = 4.61985E−06, A6 = 4.41333E−09, A8 = −1.50995E−11, A10 = 2.98769E−14 [Variable distance data] Upon focusing Upon focusing on a short- on infinity distance object f = 85.00 β = −0.1232 D0 ∞ 661.16 D12 21.713 9.146 D18 13.783 26.349 D24 1.000 1.000 [lens group data] group starting surface focal length G1 1 131.08 G2 13 74.60 G3 19 −140.71 [Conditional Expression Corresponding Value] Conditional Expression (1) BFa/f = 0.174 Conditional Expression (2) (−G1R1)/f = 0.889 Conditional Expression (3), (−G1R1)/f1 = 0.576 (3-

1), (3-2) Conditional Expression (4) f/f1 = 0.648 Conditional Expression (5) f/f2 = 1.139 Conditional Expression (6) f1/f2 = 1.757 Conditional Expression (7) f1/(−f3) = 0.932 Conditional Expression (8) fF/fR = 1.081 Conditional Expression (9) (G1R2 + G1R1)/ (G1R2 − G1R1) = 3.098 Conditional Expression (10) {1 − (β2).sup.2} × (β3).sup.2 = 0.717 Conditional Expression (11) FNO × (f1/f) = 2.850 Conditional Expression (12) 2ω = 28.4

(339) FIG. **58**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 29th example. FIG. **58**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 29th example. The various aberration graphs demonstrate that the optical system according to the 29th example has excellent image forming performance in which various aberrations are corrected favorably.

30th Example

(340) The 30th example will be described using FIGS. **59** and **60** and Table 30. FIG. **59** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 30th example of the present embodiment. The optical system LS(**30**) according to the 30th example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

(341) The first lens group G**1** comprises a first negative lens L**11** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**12** having a meniscus shape whose convex surface is pointed toward the object, a second positive lens L**13** that is biconvex, a third positive lens L**14** having a meniscus shape whose convex surface is pointed toward the object, a cemented lens consisting of a fourth positive lens L**15** that is biconvex and a second negative lens L**16** that is biconcave, and an aperture stop S, arranged in order from the object side.

(342) The second lens group G**2** comprises a negative lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**22** that is biconvex, and a second positive lens L**23** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the image surface I side of the first positive lens L**22** is an aspherical surface.

(343) The third lens group G**3** comprises a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object and a negative lens L**32** that is biconcave, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

(344) Table 30 below lists data values regarding the optical system according to the 30th example.

(345) TABLE-US-00030 TABLE 30 [General Data] f 85.00 FNO 1.85 ω 14.2 Y 21.70 TL 115.242 BF 14.943 BFa 14.261 [Lens Data] Surface Number R D nd vd 1 −74.95148 2.500 1.67270 32.2 2 −131.91024 0.300 3 85.64889 4.000 1.94595 18.0 4 120.40884 0.300 5 115.73186 7.000 1.59282 68.6 6 −191.64403 0.100 7 48.88487 5.000 1.80400 46.6 8 63.21824 0.200 9 40.00000 10.246 1.59282 68.7 10 −287.51510 2.500 1.67270 32.2 11 26.35774 7.011 12 ∞ D12 (Aperture (Variable) Stop S) 13 −28.44113 1.500 1.64769 33.7 14 −287.07114 1.500 15 102.04030 5.000 1.77377 47.2 16* −53.66013 1.500 17 −88.84311 4.500 1.49700 81.6 18 −33.17367 D18 (Variable) 19 −397.22387 4.000 1.94595 18.0 20 −86.37143 4.578 21 −52.43868 2.000 1.64769 33.7 22 143.09995 11.943 23 ∞ 2.000 1.51680 64.1 24 ∞ D24 (Variable) [Aspherical surface data] Sixteenth surface k = 1.00000 A4 = 4.49957E−06, A6 = 4.10925E−09, A8 = −1.26128E−11, A10 = 2.42467E−14 [Variable distance data] Upon focusing Upon focusing on a short- on infinity distance object f = 85.00 β = −0.1242 D0 ∞ 661.16 D12 20.672 8.633 D18 15.892 27.931 D24 1.000 1.000 [lens group data] group starting surface focal length G1 1 134.72 G2 13 74.30 G3 19 −130.08 [Conditional Expression Corresponding Value] Conditional Expression (1) BFa/f = 0.168

Conditional Expression (2) (−G1R1)/f = 0.882 Conditional Expression (3), (−G1R1)/f1 = 0.556 (3-1), (3-2) Conditional Expression (4) f/f1 = 0.631 Conditional Expression (5) f/f2 = 1.144 Conditional Expression (6) f1/f2 = 1.813 Conditional Expression (7) f1/(−f3) = 1.036 Conditional Expression (8) fF/fR = 1.075 Conditional Expression (9) (G1R2 + G1R1)/ (G1R2 − G1R1) = 3.632 Conditional Expression (10) {1 − (β2).sup.2} × (β3).sup.2 = 0.766 Conditional Expression (11) FNO × (f1/f) = 2.929 Conditional Expression (12) 2ω = 28.4

(346) FIG. **60**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 30th example. FIG. **60**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 30th example. The various aberration graphs demonstrate that the optical system according to the 30th example has excellent image forming performance in which various aberrations are corrected favorably.

31st Example

(347) The 31st example will be described using FIGS. **61** and **62** and Table 31. FIG. **61** is a diagram illustrating the lens configuration for the state of focusing on infinity in the optical system according to the 31st example of the present embodiment. The optical system LS(**31**) according to the 31st example comprises a first lens group G**1** having positive refractive power, a second lens group G**2** having positive refractive power, and a third lens group G**3** having negative refractive power, arranged in order from the object side. When focusing from an infinitely distant object to a short-distance (finite distance) object, the second lens group G**2** moves toward the object along the optical axis, while the first lens group G**1** and the third lens group G**3** remain fixed in place.

(348) The first lens group G**1** comprises a first negative lens L**11** that is biconcave, a first positive lens L**12** that is biconvex, a second positive lens L**13** that is biconvex, a third positive lens L**14** having a meniscus shape whose convex surface is pointed toward the object, a fourth positive lens L**15** having a meniscus shape whose convex surface is pointed toward the object, a cemented lens consisting of a fifth positive lens L**16** that is biconvex and a second negative lens L**17** that is biconcave, and an aperture stop S, arranged in order from the object side. The lens surface on the object side of the third positive lens L**14** is an aspherical surface.

(349) The second lens group G**2** comprises a negative lens L**21** having a meniscus shape whose concave surface is pointed toward the object, a first positive lens L**22** that is biconvex, and a second positive lens L**23** having a meniscus shape whose concave surface is pointed toward the object, arranged in order from the object side. The lens surface on the image surface I side of the first positive lens L**22** is an aspherical surface.

(350) The third lens group G**3** comprises a positive lens L**31** having a meniscus shape whose concave surface is pointed toward the object and a negative lens L**32** that is biconcave, arranged in order from the object side. An image surface I is disposed on the image side of the third lens group G**3**. An interchangeable optical filter FL is arranged between the third lens group G**3** and the image surface I.

(351) Table 31 below lists data values regarding the optical system according to the 31st example.

(352) TABLE-US-00031 TABLE 31 [General Data] f 85.00 FNO 1.42 ω 14.2 Y 21.70 TL 145.265 BF 14.071 BFa 13.389 [Lens Data] Surface Number R D nd νd 1 −79.06766 3.000 1.67270 32.2 2 104.61579 5.110 3 243.58488 6.500 1.94595 18.0 4 −628.66078 0.300 5 109.12437 16.500 1.59282 68.6 6 −110.85187 0.100 7* 63.25612 11.500 1.77250 49.6 8 360.60495 0.200 9 52.11101 8.500 1.59282 68.7 10 88.79834 0.200 11 71.03249 8.500 1.59282 68.6 12 −790.77200 2.500 1.85025 30.0 13 30.29304 9.299 14 ∞ D14 (Aperture (Variable) Stop S) 15 −35.50553 1.500 1.67270 32.2 16 −19114.07500 1.500 17 96.59624 6.000 1.77377 47.2 18* −65.15132 1.500 19 −154.43166 6.000 1.49700 81.6 20 −40.92465 D20 (Variable) 21 −793.09360 4.000 1.94595 18.0 22 −123.62638 9.551 23 −59.68219 2.000 1.64769 33.7 24 388.46258 11.071 25 ∞ 2.000 1.51680 63.9 26 ∞ D26 (Variable) [Aspherical surface data] Seventh surface A4 = −1.31502E−07, A6 = −4.69010E−11, A8 = 1.13722E−14, A10 = −8.34540E−18 Eighteenth surface k = 1.00000 A4 = 2.96560E−06, A6 = 2.23513E−09, A8 = −5.41262E−12, A10 = 7.26232E−15 [Variable distance

data] Upon focusing Upon focusing on a short- on infinity distance object f = 85.00 β = −0.1177 D0 ∞ 661.16 D14 23.433 7.955 D20 3.500 18.978 D26 1.000 1.000 [lens group data] group starting surface focal length G1 1 117.63 G2 15 83.50 G3 21 −188.48 [Conditional Expression Corresponding Value] Conditional Expression (1) BFa/f = 0.158 Conditional Expression (2) (−G1R1)/f = 0.930 Conditional Expression (3), (−G1R1)/f1 = 0.672 (3-1), (3-2) Conditional Expression (4) f/f1 = 0.723 Conditional Expression (5) f/f2 = 1.018 Conditional Expression (6) f1/f2 = 1.409 Conditional Expression (7) f1/(−f3) = 1.624 Conditional Expression (8) fF/fR = 1.943 Conditional Expression (9) (G1R2 + G1R1)/ (G1R2 − G1R1) = 0.139 Conditional Expression (10) {1 − (β2).sup.2} × (β3).sup.2 = 0.510 Conditional Expression (11) FNO × (f1/f) = 1.968 Conditional Expression (12) 2ω = 28.4

(353) FIG. **62**A illustrates various aberration graphs upon focusing on infinity in the optical system according to the 31st example. FIG. **62**B illustrates various aberration graphs upon focusing on a short-distance (close-up) object in the optical system according to the 31st example. The various aberration graphs demonstrate that the optical system according to the 31st example has excellent image forming performance in which various aberrations are corrected favorably.

(354) According to the above examples, an optical system capable of obtaining favorable optical performance throughout the focusing range from infinity to short distances, while also restraining changes in image magnification can be achieved.

(355) The foregoing examples illustrate concrete instances of the present disclosure, but the present disclosure is not limited to these examples.

(356) Note that it is possible to adopt the following content appropriately within a range that does not hinder the optical performance of the optical system according to the present embodiment.

(357) The focusing lens group refers to a portion having at least one lens separated by a distance that changes when focusing (for example, the second lens group of the present embodiment). In other words, a single lens group, a plurality of lens groups, or a partial lens group may also be treated as the focusing lens group that is moved in the optical axis direction to focus from an infinite distant object to a short-distance object. The focusing lens group can also be applied to autofocus, and is also suited to autofocus motor driving (using an ultrasonic motor or the like).

(358) The examples of the optical system according to the present embodiment illustrate a configuration that lacks an anti-vibration function, but the present disclosure is not limited thereto and may also be configured to have an anti-vibration function.

(359) Each lens surface may be formed as a spherical surface, a planar surface, or an aspherical surface. It is preferable for the lens surface to be spherical or planar because lens processing and assembly adjustment are easy, degraded optical performance due to errors in processing and assembly adjustment can be prevented, and also because depiction performance suffers little degradation even in a case where the image surface is displaced.

(360) In a case where the lens surface is aspherical, the aspherical surface may be any of an aspherical surface obtained by grinding, a molded glass aspherical surface obtained by forming glass into an aspherical shape using a mold, or a composite type aspherical surface obtained by formed a resin into an aspherical shape on the surface of glass. Additionally, the lens surface may also be a diffractive surface, and the lens may also be a gradient index lens (GRIN lens) or a plastic lens.

(361) To achieve high-contrast optical performance with reduced flaring and ghosting, an anti-reflective coating having high transmittance over a wide wavelength range may also be applied to each lens surface. With this arrangement, high-contrast high optical performance with reduced flaring and ghosting can be achieved.

EXPLANATION OF NUMERALS AND CHARACTERS

(362) G**1** first lens group G**2** second lens group G**3** third lens group I image surface S aperture stop

Claims

1. An optical system comprising: a first lens group having positive refractive power, a second lens group having positive refractive power, and a third lens group having negative refractive power, arranged in order from an object side, wherein when focusing, the second lens group moves along an optical axis, the first lens group is stationary when focusing, and the optical system satisfies the following conditional expressions:
$0.100<BFa/f<0.350$
$0.25<fF/fR<3.00$
$0.50<FNO\times(f1/f)<3.20$ and
$1.000<(-G1R1)/f1<50.000$ where BFa is an air equivalent distance on the optical axis between a lens surface on an image side of a lens disposed closest to an image and the image, f is a focal length of the optical system, fF is a composite focal length of lenses disposed farther on the object side than a diaphragm in the optical system, fR is a composite focal length of lenses disposed farther on the image side than the diaphragm in the optical system at a state of focusing on infinity, FNO is an F-number of the optical system, f1 is a focal length of the first lens group, and G1R1 is a radius of curvature of a lens surface on the object side of a lens component disposed closest to the object in the first lens group.
2. The optical system according to claim 1, wherein the optical system satisfies the following conditional expression
$1.000<(-G1R1)/f1<5.000$.
3. The optical system according to claim 1, wherein the first lens group comprises a diaphragm.
4. The optical system according to claim 1, wherein the optical system satisfies the following conditional expression
$0.010<f/f1<5.000$.
5. The optical system according to claim 1, wherein the optical system satisfies the following conditional expression
$0.010<f/f2<5.000$ where f2 is a focal length of the second lens group.
6. The optical system according to claim 1, wherein the optical system satisfies the following conditional expression
$0.010<f1/f2<5.000$ where f2 is a focal length of the second lens group.
7. The optical system according to claim 1, wherein the optical system satisfies the following conditional expression
$0.010<f1/(-f3)<3.000$ where f3 is a focal length of the third lens group.
8. The optical system according to claim 1, wherein the optical system satisfies the following conditional expression
$-10.0<(G1R2+G1R1)/(G1R2-G1R1)<10.0$ where G1R2 is a radius of curvature of a lens surface on the image side for a lens component disposed farthest on the object side in the first lens group.
9. The optical system according to claim 1, wherein the optical system satisfies the following conditional expression
$0.30<\{1-(\beta 2)^{2}\}\times(\beta 3)^{2}<2.00$ where β2 is a lateral magnification of the second lens group for a state of focusing on infinity, and β3 is a lateral magnification of the third lens group.
10. The optical system according to claim 1, wherein the optical system satisfies the following conditional expression
$15.0°<2\omega<85.00$ where 2ω is an angle of view of the optical system.
11. An optical apparatus comprising a lens barrel including the optical system according to claim 1.
12. A method of manufacturing an optical system including a first lens group having positive refractive power, a second lens group having positive refractive power, and a third lens group having negative refractive power, arranged in order from an object side, the method comprising:

disposing each lens within a lens barrel such that when focusing, the second lens group moves along an optical axis, the first lens group is stationary when focusing, and the optical system satisfies set A or set B of conditional expressions, wherein set A comprises:
$0.100<BFa/f<0.350$
$0.25<fF/fR<3.00$
$0.50<FNO\times(f1/f)<3.20$ and
$1.000<(-G1R1)/f1<50.000$ where BFa is an air equivalent distance on the optical axis between a lens surface on an image side of a lens disposed closest to an image and the image, f is a focal length of the optical system, fF is a composite focal length of lenses disposed farther on the object side than a diaphragm in the optical system, fR is a composite focal length of lenses disposed farther on the image side than the diaphragm in the optical system at a state of focusing on infinity, FNO is an F-number of the optical system, f1 is a focal length of the first lens group, and G1R1 is a radius of curvature of a lens surface on the object side of a lens component disposed closest to the object in the first lens group, and wherein set B comprises:
$0.100<BFa/f\leq 0.249$
$0.50<FNO\times(f1/f)<3.00$ and
$20.0°<2\omega<85.0°$ where 2ω is an angle of view of the optical system.
13. An optical system comprising: a first lens group having positive refractive power, a second lens group having positive refractive power, and a third lens group having negative refractive power, arranged in order from an object side, wherein when focusing, the second lens group moves along an optical axis, the first lens group is stationary when focusing, and the optical system satisfies the following conditional expressions:
$0.100<BFa/f\leq 0.249$ and
$0.50<FNO\times(f1/f)<3.00$ and
$20.0°<2\omega<85.0°$ where BFa is an air equivalent distance on the optical axis between a lens surface on an image side of a lens disposed closest to an image and the image, f is a focal length of the optical system, FNO is an F-number of the optical system, f1 is a focal length of the first lens group, and 2ω is an angle of view of the optical system.