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Zoom optical system, optical apparatus and method for manufacturing the zoom optical system

Abstract

A variable-power optical system (ZL) comprises a first lens group (G1) having a negative refractive power and a succeeding lens group (GR), which are disposed on an optical axis in that order from the object side. When varying magnification from wide angle to telephoto, the space between the adjacent lens groups changes. The succeeding lens group (GR) comprises: a first focusing lens group (G3) having a positive refractive power; and a second focusing lens group (G5) having a positive refractive power. When focusing from infinity to a proximate distance, the first focusing lens group (G3) moves toward the object side, and the second focusing lens group (G5) moves toward the image side.

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USPC: 359/676-695

References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
2017/0068079	12/2016	Kawamura et al.	N/A	N/A
2018/0210179	12/2017	Kawamura et al.	N/A	N/A

FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
2015-028530	12/2014	JP	N/A
2017-122745	12/2016	JP	N/A
2018005165	12/2017	JP	N/A

OTHER PUBLICATIONS

JP2015028530—English translation (Year: 2015). cited by examiner
English translation of JP2018005165 (Year: 2018). cited by examiner
International Preliminary Report on Patentability for International Patent Application No. PCT/JP2020/031787, Mar. 10, 2022. cited by applicant
Office Action issued Oct. 18, 2022, in Japanese Patent Application No. 2021-542875. cited by applicant
Office Action issued May 22, 2023, in Chinese Patent Application No. 202080060124.2. cited by applicant
International Search Report from International Patent Application No. PCT/JP2020/031787, Nov. 10, 2020. cited by applicant

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Background/Summary

TECHNICAL FIELD
(1) The present invention relates to a zoom optical system, an optical apparatus using the zoom optical system and a method for manufacturing the zoom optical system.
TECHNICAL BACKGROUND
(2) Conventionally, zoom optical systems suitable for photographic cameras, electronic still cameras, video cameras and the like have been proposed (e.g., see PATENT DOCUMENT 1). However, weight reduction of focusing lens groups of the conventional zoom optical systems is insufficient and it has been difficult to suppress fluctuations in various aberrations including spherical aberrations upon focusing on an object from infinity to a short distance.
PRIOR ARTS LIST
Patent Document
(3) PATENT DOCUMENT 1: Japanese Laid-Open Patent Publication No. 2015-28530(A)
SUMMARY OF THE INVENTION
(4) A zoom optical system according to the present invention comprises a first lens group having a negative refractive power and a succeeding lens group, which are disposed on an optical axis in order from an object side, wherein a distance between the adjacent lens groups changes upon zooming from a wide angle end to a telephoto end, the succeeding lens group comprises a first focusing lens group having a positive refractive power and a second focusing lens group having a positive refractive power, the first focusing lens group moves toward the object side and the second focusing lens group moves toward an image side upon focusing from infinity to a short distance.
(5) An optical apparatus according to the present invention is constructed by including the above-described zoom optical system.
(6) A method for manufacturing a zoom optical system according to the present invention is a method for manufacturing a zoom optical system comprising a first lens group having a negative refractive power and a succeeding lens group, which are disposed on an optical axis in order from an object side, wherein the succeeding lens group comprises a first focusing lens group having a positive refractive power and a second focusing lens group having a positive refractive power. The method is configured to dispose each lens inside a lens barrel so that; a distance between the adjacent lens groups changes upon zooming from a wide angle end to a telephoto end, and the first focusing lens group moves toward an object side and the second focusing lens group moves toward an image side upon focusing from infinity to a short distance.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) FIG. **1** is a diagram illustrating a lens configuration of a zoom optical system according to a first example;
(2) FIG. **2**A, FIG. **2**B, and FIG. **2**C are various aberration diagrams upon focusing on infinity in a wide angle end state, an intermediate focal length state and a telephoto end state respectively of the zoom optical system according to the first example;
(3) FIG. **3**A, FIG. **3**B, and FIG. **3**C are various aberration diagrams upon focusing on a short-distance object in a wide angle end state, an intermediate focal length state and a telephoto end state respectively of the zoom optical system according to the first example;
(4) FIG. **4** is a diagram illustrating a lens configuration of a zoom optical system according to a second example;
(5) FIG. **5**A, FIG. **5**B, and FIG. **5**C are various aberration diagrams upon focusing on infinity in a

wide angle end state, an intermediate focal length state and a telephoto end state respectively of the zoom optical system according to the second example;

(6) FIG. **6**A, FIG. **6**B, and FIG. **6**C are various aberration diagrams upon focusing on a short-distance object in a wide angle end state, an intermediate focal length state and a telephoto end state respectively of the zoom optical system according to the second example;

(7) FIG. **7** is a diagram illustrating a lens configuration of a zoom optical system according to a third example;

(8) FIG. **8**A, FIG. **8**B, and FIG. **8**C are various aberration diagrams upon focusing on infinity in a wide angle end state, an intermediate focal length state and a telephoto end state respectively of the zoom optical system according to the third example;

(9) FIG. **9**A, FIG. **9**B, and FIG. **9**C are various aberration diagrams upon focusing on a short-distance object in a wide angle end state, an intermediate focal length state and a telephoto end state respectively of the zoom optical system according to the third example;

(10) FIG. **10** is a diagram illustrating a lens configuration of a zoom optical system according to a fourth example;

(11) FIG. **11**A, FIG. **11**B, and FIG. **11**C are various aberration diagrams upon focusing on infinity in a wide angle end state, an intermediate focal length state and a telephoto end state respectively of the zoom optical system according to the fourth example;

(12) FIG. **12**A, FIG. **12**B, and FIG. **12**C are various aberration diagrams upon focusing on a short-distance object in a wide angle end state, an intermediate focal length state and a telephoto end state respectively of the zoom optical system according to the fourth example;

(13) FIG. **13** is a diagram illustrating a lens configuration of a zoom optical system according to a fifth example;

(14) FIG. **14**A, FIG. **14**B, and FIG. **14**C are various aberration diagrams upon focusing on infinity in a wide angle end state, an intermediate focal length state and a telephoto end state respectively of the zoom optical system according to the fifth example;

(15) FIG. **15**A, FIG. **15**B, and FIG. **15**C are various aberration diagrams upon focusing on a short-distance object in a wide angle end state, an intermediate focal length state and a telephoto end state respectively of the zoom optical system according to the fifth example;

(16) FIG. **16** is a diagram illustrating a camera configuration provided with a zoom optical system according to the present embodiment; and

(17) FIG. **17** is a flowchart illustrating a method for manufacturing a zoom optical system according to the present embodiment.

DESCRIPTION OF THE EMBODIMENTS

(18) Hereinafter, preferable embodiments according to the present invention will be described. First, a camera (optical apparatus) provided with a zoom optical system according to the present embodiment will be described based on FIG. **16**. As shown in FIG. **16**, a camera **1** is constructed of a body **2** and a photographing lens **3** mounted on the body **2**. The body **2** is provided with an image pickup device **4**, a body control part (not shown) that controls operation of the digital camera and a liquid crystal operation screen **5**. The photographing lens **3** comprises an optical system ZL consisting of a plurality of lens groups and a lens position control mechanism (not shown) that controls a position of each lens group. The lens position control mechanism is constructed of a sensor that detects the position of each lens group, a motor that moves the lens group back and forth along an optical axis and a control circuit or the like that drives the motor.

(19) Light from an object is collected by the optical system ZL of the photographing lens **3** and reaches an image surface I of the image pickup device **4**. The light reaching the image surface I from the object is photoelectrically converted by the image pickup device **4** and recorded in a memory (not shown) as digital image data. The digital image data recorded in the memory can be displayed on the liquid crystal screen **5** according to a user's operation. Note that the camera may be a mirrorless camera or a single-lens reflex type camera having a quick return mirror.

(20) Next, the zoom optical system (photographing lens) according to the present embodiment will be described. A zoom optical system ZL (1) as an example of the zoom optical system (zoom lens) ZL according to the present embodiment comprises a first lens group G**1** having a negative refractive power and a succeeding lens group GR, which are disposed on an optical axis in order from an object side as shown in FIG. **1** and the succeeding lens group GR comprises a first focusing lens group having a positive refractive power (e.g., constructed of a third lens group G**3**) and a second focusing lens group having a positive refractive power (e.g., constructed of a fifth lens group G**5**). A distance between the adjacent lens groups changes upon zooming from a wide angle end to a telephoto end. Upon focusing from infinity to a short distance, the first focusing lens group moves toward an object side and the second focusing lens group moves toward an image side as shown by arrows together with characters "focusing" in FIG. **1**.

(21) In this way, upon focusing from infinity to a short distance, configuring the zoom optical system so that the first focusing lens group moves toward the object side and the second focusing lens group moves toward the image side, it is possible to satisfactorily correct a curvature of field generated upon focusing from infinity to a short distance without increasing the size of the focusing lens groups.

(22) The zoom optical system preferably satisfies the following conditional expression (1):

$0.01 < (-MVF1)/MVF2 < 30.0$ (1) where MVF1: an amount of movement of the first focusing lens group upon focusing on an object from infinity to a short distance MVF2: an amount of movement of the second focusing lens group upon focusing on an object from infinity to a short distance. where the movement to the image side is set as positive.

(23) Although the above-described conditional expression (1) defines a ratio of moving distances of the two focusing lens groups upon focusing, satisfying the conditional expression (1) makes it possible to satisfactorily correct a curvature of field generated upon focusing from infinity to a short distance while securing a predetermined photographing distance. In order to ensure the effects of the present embodiment, an upper limit value of the conditional expression (1) is preferably set to, for example, 28.00, 25.00, 23.00, 20.00, 18.00, 15.00, 13.00, 10.00, 8.00, 5.00, 3.00, 2.00, 1.80, 1.50, 1.20, and further 1.00. Moreover, a lower limit value of the conditional expression (1) is preferably set to, for example, 0.05, 0.10, 0.15, 0.18, 0.20, 0.25, 0.28, 0.30, 0.33, 0.35, and further 0.38.

(24) Furthermore, the above-described zoom optical system preferably satisfies the following conditional expression (2):

$0.20 < ff1/ff2 < 1.70$ (2) where ff1: focal length of first focusing lens group ff2: focal length of second focusing lens group

(25) The above-described conditional expression (2) defines the ratio of focal lengths of the two focusing lens groups, and satisfying the conditional expression (2) makes it possible to satisfactorily correct a curvature of field generated upon focusing from infinity to a short distance. In order to ensure the effects of the present embodiment, an upper limit value of the conditional expression (2) is preferably set to, for example, 1.65, 1.60, 1.55, 1.50, 1.40, 1.30, 1.20, 1.15, 1.10, 1.05, 1.00, and further 0.97. A lower limit value of the conditional expression (2) is preferably set to, for example, 0.23, 0.25, 0.28, 0.30, 0.33, 0.35, 0.38, 0.40, 0.42, and further 0.44.

(26) The above-described zoom optical system preferably satisfies the following conditional expression (3):

$0.15 < (-f1)/ff1 < 1.30$ (3) where f1: focal length of first lens group

(27) The above-described conditional expression (3) defines a ratio of focal lengths of the first lens group G**1** and the first focusing lens group, and satisfying the conditional expression (3) makes it possible to satisfactorily correct a curvature of field generated upon focusing from infinity to a short distance while securing a predetermined photographing distance. In order to ensure the effects of the present embodiment, an upper limit value of the conditional expression (3) is preferably set to, for example, 1.25, 1.20, 1.15, 1.10, 1.05, 1.00, 0.95, 0.90, 0.85, 0.80, 0.75, 0.70, 0.68, 0.65, and

further 0.63. Moreover, a lower limit value of the conditional expression (3) is preferably set to, for example, 0.18, 0.20, 0.23, 0.25, 0.28, 0.30, 0.33, 0.35, and further 0.38.

(28) The above-described zoom optical system preferably satisfies the following conditional expression (4):

$$0.10<(-f1)/ff2<0.95 \quad (4)$$

(29) The above-described conditional expression (4) defines the ratio of focal lengths of the first lens group G**1** and the second focusing lens group, and satisfying the conditional expression (4) makes it possible to satisfactorily correct a curvature of field generated upon focusing from infinity to a short distance while securing a predetermined photographing distance. To ensure the effects of the present embodiment, an upper limit value of the conditional expression (4) is preferably set to, for example, 0.90, 0.80, 0.75, 0.70, 0.65, 0.60, 0.58, 0.55, 0.53, and further 0.50. A lower limit value of the conditional expression (4) is preferably set to, for example, 0.13, 0.15, 0.18, 0.20, 0.21, and further 0.23.

(30) In the above-described zoom optical system, the second focusing lens group preferably consists of one convex lens. Configuring the zoom optical system in this way makes it possible to satisfactorily correct a curvature of field generated upon focusing from infinity to a short distance without increasing the size of the focusing lens groups.

(31) In the above-described zoom optical system, the first focusing lens group preferably consists of a cemented lens consisting of a convex lens and a concave lens. Adopting such a configuration makes it possible to satisfactorily correct chromatic aberration of magnification generated upon focusing from infinity to a short distance without increasing the size of the focusing lens groups.

(32) In the above-described zoom optical system, the succeeding lens group comprises a second lens group and a third lens group having a positive refractive power disposed in order from an object side and preferably satisfies the following conditional expression (5)

$$0.10<(-f1)/f2<1.20 \quad (5)$$

(33) The above-described conditional expression (5) defines a configuration of the succeeding lens group and defines a ratio of focal lengths of the first lens group G**1** and the second lens group G**2**, and satisfying the conditional expression (5) makes it possible to satisfactorily correct various aberrations including a spherical aberration upon zooming from a wide angle end to a telephoto end. To ensure the effects of the present embodiment, an upper limit value of the conditional expression (5) is preferably set to, for example, 1.15, 1.10, 1.05, 1.00, 0.95, 0.90, 0.85, 0.80, 0.75, 0.73, and further 0.70. Furthermore, a lower limit value of the conditional expression (5) is preferably set to, for example, 0.15, 0.20, 0.23, 0.27, 0.30, 0.32, and further 0.35.

(34) In the above-described zoom optical system, the first lens group preferably comprises three negative lenses disposed in order from the object side. Such a configuration makes it possible to satisfactorily correct a coma aberration or curvature of field in a wide angle end state.

(35) The above-described zoom optical system preferably satisfies the following conditional expression (6):

$$-0.80<\beta WF1<0.80 \quad (6)$$ where, βWF1: lateral magnification of the first focusing lens group upon focusing on an infinity object in a wide angle end state.

(36) The conditional expression (6) defines a range of lateral magnification of the first focusing lens group upon focusing on an infinity object in a wide angle end state. Satisfying the conditional expression (6) makes it possible to suppress fluctuations in various aberrations including a spherical aberration upon focusing on an object from infinity to a short distance.

(37) When the corresponding value of the conditional expression (6) is out of the defined range, declination of an axial light beam increases and it is more difficult to correct a spherical aberration. Moreover, when symmetry is poor with respect to a principal light beam, it is more difficult to correct a distortion or a coma aberration.

(38) To ensure the effects of the present embodiment, an upper limit value of the conditional expression (6) is set to, for example, 0.78, 0.75, 0.73, 0.70, 0.68, 0.65, 0.63, 0.60, 0.58, and further

0.55, and it is thereby possible to further ensure the effects of the present embodiment. On the other hand, a lower limit value of the conditional expression (6) is set to, for example, −0.75, −0.70, −0.65, −0.60, −0.55, −0.50, −0.45, −0.40, −0.38, −0.35, −0.33, −0.31, −0.25, −0.20, and further −0.10, it is thereby possible to further ensure the effects of the present embodiment.

(39) The above-described zoom optical system preferably satisfies the following conditional expression (7):

$$-0.80 < \beta WF2 < 0.80 \qquad (7)$$ where, $\beta WF2$: lateral magnification of the second focusing lens group upon focusing on an infinity object in a wide angle end state.

(40) The conditional expression (7) defines a range of lateral magnification of the second focusing lens group upon focusing on an infinity object in a wide angle end state. When lateral magnification of the second focusing lens group satisfies the conditional expression (7), it is possible to suppress fluctuations in various aberrations including a spherical aberration upon focusing on an object from infinity to a short distance.

(41) When the corresponding value of the conditional expression (7) is out of the defined range, declination of an axial light beam increases and it is more difficult to correct a spherical aberration. Moreover, when symmetry is poor with respect to a principal light beam, it is more difficult to correct a distortion or a coma aberration.

(42) To ensure the effects of the present embodiment, an upper limit value of the conditional expression (7) is set to, for example, 0.78, 0.75, 0.73, 0.70, 0.68, 0.65, 0.63, 0.60, 0.58, 0.55, 0.53, and further 0.50, and it is thereby possible to further ensure the effects of the present embodiment. On the other hand, a lower limit value of the conditional expression (7) is set to, for example, −0.78, −0.75, −0.73, −0.70, −0.50, −0.40, −0.30, −0.20, and further −0.10, and it is thereby possible to further ensure the effects of the present embodiment.

(43) The above-described zoom optical system preferably satisfies the following conditional expression (8):

$$(\beta WF1 + (1/\beta WF1)).\text{sup.}-2 < 0.25 \qquad (8)$$ where, $\beta WF1$: lateral magnification of the first focusing lens group upon focusing on an infinity object in a wide angle end state.

(44) The conditional expression (8) defines a range of lateral magnification of the first focusing lens group upon focusing on an infinity object in a wide angle end state in a form different from the conditional expression (6). When lateral magnification of the first focusing lens group satisfies the conditional expression (8), it is possible to suppress fluctuations in various aberrations including a spherical aberration upon focusing on an object from infinity to a short distance.

(45) When the corresponding value of the conditional expression (8) is out of the defined range, declination of an axial light beam increases and it is more difficult to correct a spherical aberration. Moreover, when symmetry is poor with respect to a principal light beam, it is more difficult to correct a distortion or a coma aberration.

(46) To ensure the effects of the present embodiment, an upper limit value of the conditional expression (8) is set to, for example, 0.24, 0.23, 0.22, 0.20, 0.18, and further 0.16, and it is thereby possible to further ensure the effects of the present embodiment.

(47) The above-described zoom optical system preferably satisfies the following conditional expression (9):

$$(\beta WF2 + (1/\beta WF2)).\text{sup.}-2 < 0.25 \qquad (9)$$ where, $\beta WF2$: lateral magnification of the second focusing lens group upon focusing on an infinity object in a wide angle end state.

(48) The conditional expression (9) defines a range of lateral magnification of the second focusing lens group upon focusing on an infinity object in a wide angle end state in a form different from the conditional expression (7). When the lateral magnification of the second focusing lens group satisfies the conditional expression (9), it is possible to suppress fluctuations in various aberrations including a spherical aberration upon focusing on an object from infinity to a short distance.

(49) When the corresponding value of the conditional expression (9) is out of the defined range, declination of an axial light beam increases and it is more difficult to correct a spherical aberration.

Moreover, when symmetry is poor with respect to a principal light beam, it is more difficult to correct a distortion or a coma aberration.

(50) To ensure the effects of the present embodiment, an upper limit value of the conditional expression (9) is set to, for example, 0.24, 0.23, 0.22, 0.20, 0.18, and further 0.16, and it is thereby possible to further ensure the effects of the present embodiment.

(51) Next, a method for manufacturing the above-described optical system will be outlined with reference to FIG. **17**. According to the present manufacturing method, a first lens group having a negative refractive power and a succeeding lens group are disposed inside a barrel along an optical axis in order from an object side (step ST**1**). Note that at this time, the succeeding lens group comprises a first focusing lens group having a positive refractive power and a second focusing lens group having a positive refractive power. Next, the zoom optical system is configured so that upon zooming from a wide angle end to a telephoto end, a distance between the adjacent lens groups changes (step ST**2**). Moreover, the zoom optical system is configured so that upon focusing from infinity to a short distance, the first focusing lens group moves toward the object side and the second focusing lens group moves toward the image side (step ST**3**).

(52) According to the zoom optical system, the camera (optical apparatus) provided with this zoom optical system and the zoom optical system manufactured by the above-described manufacturing method according to the present embodiment, it is possible to reduce the weights of the focusing lens groups, thereby achieve high speed AF and quietness during AF without increasing the size of the barrel and satisfactorily suppress aberration fluctuation upon zooming from a wide angle end state to a telephoto end state and aberration fluctuations upon focusing on an object from infinity to a short distance.

EXAMPLES

(53) Hereinafter, the zoom optical system ZL according to specific examples of the above-described embodiment will be described based on the accompanying drawings. FIG. **1**, FIG. **4**, FIG. **7**, FIG. **10** and FIG. **13** are cross-sectional views illustrating a configuration and a refractive power distribution of the zoom optical system ZL {ZL (1) to ZL (5)} according to first to fifth examples. In each cross-sectional view, moving directions of the respective lens groups on an optical axis upon zooming from a wide angle end state (W) to a telephoto end state (T) are shown by arrows. Furthermore, the moving directions of the focusing lens groups upon focusing on an object from infinity to a short distance are shown by arrows together with characters "focusing."

(54) In these drawings (FIG. **1**, FIG. **4**, FIG. **7**, FIG. **10**, FIG. **13**), each lens group is represented by a combination of a reference character G and a number and each lens is represented by a combination of a reference character L and a number. In this case, to prevent the number of types of reference characters and numbers from increasing and prevent complications, lens groups or the like are represented using a combination of reference characters and numbers independently for each example. For this reason, even when a combination of the same reference character and number is used among different examples, this does not necessarily mean that they have an identical configuration.

(55) In FIGS. **2**A-**2**C and FIGS. **3**A-**3**C, FIGS. **5**A-**5**C and FIGS. **6**A-**6**C, FIGS. **8**A-**8**C and FIGS. **9**A-**9**C, FIGS. **11**A-**11**C and FIGS. **12**A-**12**C, FIGS. **14**A-**14**C and FIGS. **15**A-**15**C, "FNO" denotes an F number, "NA" denotes a numerical aperture, "Y" denotes an image height. An F number or numerical aperture value corresponding to a maximum aperture is shown in a spherical aberration diagram, a maximum value of image height is shown in an astigmatism diagram and a distortion diagram, and each image height value is shown in a coma aberration diagram. A term "d" denotes a d-line (λ=587.6 nm), "g" denotes a g-line (λ=435.8 nm). In the astigmatism diagram, a solid line represents a sagittal image surface and a broken line represents a meridional image surface. The distortion diagram shows a distortion using the d-line as a reference and the diagram of chromatic aberration of magnification shows a chromatic aberration of magnification using the g-line as a reference.

(56) Table 1 to Table 5 will be presented hereinafter, and among these tables, Table 1, Table 2, Table 3, Table 4 and Table 5 are tables that show specification data in a first example, a second example, a third example, a fourth example and a fifth example, respectively. In each example, the d-line (wavelength λ=587.6 nm) and the g-line (wavelength λ=435.8 nm) are selected as targets for calculating aberration characteristics.

(57) In a table of [general data], "focal length (f)" represents a focal length of the entire lens system at a wide angle end (fw) and a telephoto end (ft). "F. NO" represents an F number, "2ω" represents an angle of view (unit is ° (degrees) and "ω" represents a half angle of view). "TL" represents, in an air equivalent length, a distance from a front most lens surface to a final lens surface on an optical axis upon focusing on infinity with BF added, "BF" represents an air equivalent distance (back focusing) from the lens final surface to the image surface I on the optical axis upon focusing on infinity. Note that these values are shown in each zooming state of wide angle end (W), intermediate focal length (M) and telephoto end (T) respectively.

(58) In a table of [lens data], a surface number (number in a field shown by a character "surface") represents order of optical surfaces from an object side in a direction in which a light beam travels, "R" represents a radius of curvature of each optical surface (surface on which the center of curvature is located on the image side is set as a positive value), "D" represents a surface distance which is a distance on the optical axis from each optical surface to the next optical surface (or image surface), "nd" represents a refractive index of the material of an optical member with respect to the d-line, and "vd" represents an Abbe number using the d-line of the material of the optical member as a reference. "∞" of the radius of curvature represents a flat surface or opening, and "(aperture stop S)" represents an aperture stop. The description of refractive index of air nd=1.00000 is omitted. When the lens surface is aspherical, the surface number is marked with an asterisk "*" and a paraxial radius of curvature is shown in the field of radius of curvature R.

(59) In a table of [aspherical surface data], the shape of the aspherical surface shown in [lens data] is expressed by the following expression (A). "X(y)" represents a distance (sag amount) along an optical axis direction from a tangent plane at a vertex of the aspherical surface to a position on the aspherical surface at a height y, "R" represents a radius of curvature (paraxial radius of curvature) of a reference spherical surface, "κ" represents a conic constant and "Ai" represents an ith order aspherical coefficient. "E-n" represents "×10.sup.−n." For example, 1.234E-05=1.234×10.sup.−5. Note that a second order aspherical coefficient A2 is 0 and the description thereof is omitted.

X(y)=(y.sup.2/R)/{1+
(1−κ×y.sup.2/R.sup.2).sup.1/2}+A4×y.sup.4+A6×y.sup.6+A8×y.sup.8+A10×y.sup.10+A12×y.sup.12
(A)

(60) In a table of [lens group data], a first surface (most object side surface) of each lens group and a focal length of each lens group are shown.

(61) A table of [variable distance data] shows surface distances with surface numbers where the surface distances are set as "variable" in the table showing [lens data]. Here, surface distances in each zooming state of wide angle end (W), intermediate focal length (M) and telephoto end (T) upon focusing on infinity and focusing on a short-distance object are shown separately for a case of focusing on a normal distance (infinity) and for a case of focusing on a close range (short distance). Note that the first line shows an overall focal length f in each zooming state (upon focusing on a normal distance) or lateral magnification β (upon focusing on a close range). The final line shows a surface distance of a portion where the surface distance is set as "Bf."

(62) A table of [magnification] shows the lateral magnification βF1 of the first focusing lens group and the lateral magnification βF2 of the second focusing lens group in each zooming state of wide angle end (W), intermediate focal length (M) and telephoto end (T) separately in cases of focusing on a normal distance and focusing on a close range. A table of [other specifications] shows a focal length (ff1) of the first focusing lens group and a focal length (ff2) of the second focusing lens group. The table further shows an amount of movement (MVF1) of the first focusing lens group and

an amount of movement (MVF2) of the second focusing lens group upon focusing from an infinity object to a short-distance object (shortest-distance object) in a wide angle end state.

(63) A table of [conditional expression corresponding values] is provided at the end of the description of all examples (first to fifth examples). The table shows values corresponding to the respective conditional expressions in a summarized manner for all examples (first to fifth examples).

(64) Hereinafter, "mm" is generally used for all specification values, to indicate the described focal length f, radius of curvature R, surface distance D and other lengths unless otherwise specified, whereas even when the optical system is proportionally enlarged or proportionally contracted, the equivalent optical performance can be obtained, and so the specification values are not limited to this.

(65) The description of the tables so far is common to all examples and duplicate description will be omitted hereinafter.

First Example

(66) A first example will be described using FIG. **1** to FIGS. **3**A-**3**C and Table 1. FIG. **1** is a diagram illustrating a lens configuration of a zoom optical system according to the first example. A zoom optical system ZL (1) according to the first example is constructed of a first lens group G**1** having a negative refractive power, a second lens group G**2** having a positive refractive power, an aperture stop S, a third lens group G**3** having a positive refractive power, a fourth lens group G**4** having a negative refractive power, a fifth lens group G**5** having a positive refractive power and a sixth lens group G**6** having a positive refractive power, disposed in order from an object side. Upon zooming from a wide angle end state (W) to a telephoto end state (T), the first to sixth lens groups G**1** to G**6** move in directions shown by arrows in FIG. **1** respectively, and a distance between the adjacent lens groups changes. A lens group consisting of the second to sixth lens groups G**2** to G**6** corresponds to the succeeding lens group GR. A sign (+) or (−) attached to each lens group symbol indicates a refractive power of each lens group, and the same will apply to all the following examples.

(67) The first lens group G**1** is constructed of a negative meniscus lens L**11** having a convex surface facing an object side, a negative meniscus lens L**12** having a convex surface facing the object side, a negative meniscus lens L**13** having a convex surface facing the object side and a biconvex positive lens L**14**, disposed in order from the object side.

(68) The negative meniscus lens L**11** is a hybrid lens constructed with a resin layer L**11**b provided on a surface on an image side of a glass lens body L**11**a. A surface on the image side of the resin layer L**11**b is aspherical and the negative meniscus lens L**11** is a composite type aspherical lens. In the [lens data] field which will be described later, a surface number 1 represents the surface on the object side of the lens body Lila, a surface number 2 represents the surface on the image side of the lens body L**11**a and the surface on the object side of the resin layer L**11**b (surface on which both lenses are cemented) and a surface number 3 represents the surface on the image side of the resin layer L**11**b.

(69) The negative meniscus lens L**12** is also a hybrid lens configured with a resin layer L**12**b provided on a surface on the object side of a glass lens body L**12**a. A surface on the object side of the resin layer L**12**b is aspherical and the negative meniscus lens L**12** is also a composite type aspherical lens. In the [lens data] field which will be described later, a surface number 4 represents the surface on the object side of the resin layer L**12**b, a surface number 5 represents the surface on the image side of the resin layer L**12**b and a surface on the object side of the lens body L**12**a (surface on which both lenses are cemented), and a surface number 6 represents the surface on the image side of the lens body L**12**a.

(70) The second lens group G**2** is constructed of a cemented lens consisting of a positive meniscus lens L**21** having a convex surface facing the object side and a negative meniscus lens L**22** having a convex surface facing the object side, and a biconvex positive lens L**23**, disposed in order from the

object side. The aperture stop S is provided in the vicinity of the image side of the second lens group G**2** and moves together with the second lens group G**2** upon zooming.

(71) The third lens group G**3** is constructed of a cemented lens consisting of a biconvex positive lens L**31** and a negative meniscus lens L**32** having a concave surface facing the object side.

(72) The fourth lens group G**4** is constructed of a biconcave negative lens L**41**.

(73) The fifth lens group G**5** is constructed of a positive meniscus lens L**51** having a convex surface facing the object side.

(74) The sixth lens group G**6** is constructed of a positive meniscus lens L**61** having a concave surface facing the object side and a cemented lens consisting of a negative meniscus lens L**62** having a convex surface facing the object side and a biconvex positive lens L**63**. Note that a surface on the image side of the positive meniscus lens L**61** is aspherical.

(75) In the present example, the third lens group G**3** constitutes a first focusing lens group and the fifth lens group G**5** constitutes a second focusing lens group. The third lens group G**3** moves toward the object side and the fifth lens group G**5** moves toward the image side depending on a change from focusing on a long-distance object (infinity object) to focusing on a short-distance object.

(76) The following Table 1 lists specification values of the zoom optical system according to the first example.

(77) TABLE-US-00001 TABLE 1 [General Data] Focal length (f) 10.3 (fw)-21.5 (ft) W M T F.NO 4.58461 4.97276 5.66887 2ω 55.20233 47.83147 32.93905 Air Equivalent 121.30256 111.17694 103.94431 TL Air Equivalent 22.07112 26.72635 37.73788 BF [Lens Data] Surface R D nd vd   1 66.0078 2.40 1.77250 49.61   2 17.8896 0.20 1.56093 36.64   *3 13.0203 10.39 1.00000   *4 69.5573 0.20 1.55389 38.09   5 74.5519 1.50 1.77250 49.61   6 25.3147 4.66 1.00000   7 120.000 1.30 1.77250 49.61   8 31.6192 3.48 1.00000   9 32.2527 4.63 1.71736 29.58   10 −749.923 Variable 1.00000   11 16.9525 2.04 1.72825 28.38   12 55.8636 0.80 1.91082 35.25   13 12.8077 1.51 1.00000   14 14.4747 2.31 1.51680 63.88   15 −90.0426 1.86 1.00000   16 0 Variable 1.00000 Aperture Stop S   17 23.0619 2.94 1.53172 48.78   18 −15.5169 0.90 1.90366 31.27   19 −26.4746 Variable 1.00000   20 −831.453 0.80 1.91082 35.25   21 25.1602 Variable 1.00000   22 16.4236 1.61 1.51680 63.88   23 30.0899 Variable 1.00000   24 −59.9852 1.35 1.53110 55.91 *25 −33.4579 0.50 1.00000   26 78.9399 0.80 1.91082 35.25   27 19.5552 4.48 1.48749 70.24   28 −44.7036 Variable 1.00000   29 0 2.00 1.51680 63.88   30 0 Bf 1.00000 Image ∞ Surface (I) [Aspheriacal Surface Data] 3rd Surface κ = 0.0944   A4 = −9.40E−06 A6 = −1.18E−08 A8 = 3.95E−11   A10 = 5.57E−13   4th Surface κ = −25.413   A4 = −4.18E−06 A6 = 2.67E−08   A8 = 1.51E−10   A10 = −2.82E−13 25th Surface κ = 1.00   A4 = 6.81E−05   A6 = 4.87E−07   A8 = −4.55E−09 A10 = 5.03E−11   [Lens Group Data] Group First surface Focal length G1 1 −18.7654 G2 11 51.03682 G3 17 30.51806 G4 20 −26.8004 G5 22 67.26356 G6 24 123.1616 [Variable Distance Data] W Close M Close T Close W M T range range range f(β) 10.30 13.01 21.50 −0.08318 −0.14416 −0.19832 d10 32.8753 20.3228 2.00000 32.8753 20.3228 2.00000 d16 5.0342 3.80869 2.76786 4.55905 3.16979 1.63154 d19 1.49446 1.80677 3.48694 1.96961 2.44567 4.62326 d21 0.69387 0.29529 2.00441 1.77009 1.77881 4.32648 d23 8.45918 7.54262 5.2728 7.38297 6.0591 2.95073 d28 20.65256 25.30779 36.31931 20.65256 25.30779 36.31931 Bf 0.1 0.1 0.1 0.1 0.1 0.1 [Magnification] W Close M Close T Close W M T range range range βF1 0.18476 0.12404 −0.04382 0.17725 0.11351 −0.0685 βF2 0.37405 0.2813 0.0176 0.39005 0.30335 0.05212 [Other specifications] ff1 30.518 ff2 67.264 MVF1w −0.475 MVF2w 1.07621

(78) FIGS. **2**A, **2**B and **2**C are various aberration diagrams upon focusing on infinity in a wide angle end state, an intermediate focal length state and a telephoto end state respectively of the zoom optical system according to the first example. FIGS. **3**A, **3**B and **3**C are various aberration diagrams upon focusing on a short-distance object in a wide angle end state, an intermediate focal length state and a telephoto end state respectively of the zoom optical system according to the first example.

(79) In the respective aberration diagrams in FIGS. **2**A to **2**C, "FNO" represents an F number and "Y" represents an image height. Each spherical aberration diagram shows a value of the F number

corresponding to a maximum aperture, and each astigmatism diagram and each distortion diagram show a maximum value of the image height, each lateral aberration diagram shows a value of each image height. In the respective aberration diagrams in FIGS. **3**A to **3**C, "NA" represents a numerical aperture and "Y" represents an image height. The spherical aberration diagram shows a value of the numerical aperture corresponding to the maximum aperture and the astigmatism diagram and the distortion diagram show a maximum value of the image height and the coma aberration diagram shows a value of each image height. In each aberration diagram, "d" represents a d-line (wavelength $\lambda=587.6$ nm) and "g" represents a g-line (wavelength $\lambda=435.8$ nm). In the astigmatism diagram, a solid line represents a sagittal image surface and a broken line represents a meridional image surface. Note that in the aberration diagrams shown in the following examples, reference characters similar to those of the present example will be used and duplicated description thereof will be omitted.

(80) From each aberration diagram, it can be seen that the zoom optical system according to the first example has excellent image forming performance by satisfactorily correcting various aberrations from a wide angle end state to a telephoto end state, and further has excellent image forming performance upon focusing on a short-distance object as well.

Second Example

(81) A second example will be described using FIG. **4** to FIGS. **6**A-**6**C and Table 2. FIG. **4** is a diagram illustrating a lens configuration of a zoom optical system according to the second example. A zoom optical system ZL (2) according to the second example is constructed of a first lens group G**1** having a negative refractive power and a second lens group G**2** having a positive refractive power, an aperture stop S, a third lens group G**3** having a positive refractive power, a fourth lens group G**4** having a negative refractive power, a fifth lens group G**5** having a positive refractive power and a sixth lens group G**6** having a positive refractive power, disposed in order from an object side. Upon zooming from a wide angle end state (W) to a telephoto end state (T), the first to sixth lens groups G**1** to G**6** move in directions shown by arrows in FIG. **4** respectively and a distance between the adjacent lens groups changes. A lens group consisting of the second to sixth lens groups G**2** to G**6** corresponds to the succeeding lens group GR.

(82) The first lens group G**1** is constructed of a negative meniscus lens L**11** having a convex surface facing the object side, a negative meniscus lens L**12** having a convex surface facing the object side, a negative meniscus lens L**13** having a convex surface facing the object side and a biconvex positive lens L**14**, disposed in order from the object side.

(83) The negative meniscus lens L**11** is a hybrid lens constructed with a resin layer L**11**b provided on a surface on the image side of a glass lens body L**11**a. A surface on the image side of a resin layer L**11**b is aspherical and the negative meniscus lens L**11** is a composite type aspherical lens. In the [lens data] field which will be described later, a surface number 1 represents the surface on the object side of the lens body Lila, a surface number 2 represents the surface on the image side of the lens body L**11**a and the surface on the object side of the resin layer L**11**b (surface on which both lenses are cemented) and a surface number 3 represents the surface on the image side of the resin layer L**11**b.

(84) The negative meniscus lens L**12** is also a hybrid lens constructed with a resin layer L**12**b provided on a surface of the object side of a glass lens body L**12**a. A surface on the object side of the resin layer L**12**b is aspherical and the negative meniscus lens L**12** is also a composite type aspherical lens. In the [lens data] field which will be described later, a surface number 4 represents the surface on the object side of the resin layer L**12**b, a surface number 5 represents the surface on the image side of the resin layer L**12**b and a surface on the object side of the lens body L**12**a (surface on which both lenses are cemented) and a surface number 6 represents the surface on the image side of the lens body L**12**a.

(85) The second lens group G**2** is constructed of a cemented lens consisting of a biconvex positive lens L**21** and a biconcave negative lens L**22**, and a biconvex positive lens L**23**, disposed in order

from the object side. The aperture stop S is provided in the vicinity on the image side of the second lens group G**2** and moves together with the second lens group G**2** upon zooming.

(86) The third lens group G**3** is constructed of a cemented lens consisting of a biconvex positive lens L**31** and a negative meniscus lens L**32** having a concave surface facing the object side.

(87) The fourth lens group G**4** is constructed of a biconcave negative lens L**41**.

(88) The fifth lens group G**5** is constructed of a positive meniscus lens L**51** having a convex surface facing the object side.

(89) The sixth lens group G**6** is constructed of a positive meniscus lens L**61** having a concave surface facing the object side and a cemented lens consisting of a negative meniscus lens L**62** having a convex surface facing the object side and a biconvex positive lens L**63**. Note that a surface on the image side of the positive meniscus lens L**61** is aspherical.

(90) In the present example, the third lens group G**3** constitutes a first focusing lens group and the fifth lens group G**5** constitutes a second focusing lens group. Depending on a change from focusing on a long-distance object (infinity object) to focusing on a short-distance object, the third lens group G**3** moves toward the object side and the fifth lens group G**5** moves toward the image side.

(91) The following Table 2 lists specification values of the zoom optical system according to the second example.

(92) TABLE-US-00002 TABLE 2 [General Data] Focal length (f) 10.3 (fw)-19.32 (ft) W M T F.NO 4.6301 5.23998 5.83553 2ω 56.39754 44.87543 37.36057 Air Equivalent 125.91266 113.62769 107.76397 TL Air Equivalent 20.44108 26.46282 35.19053 BF [Lens Data] Surface R D nd vd   1 66.922 2.40 1.77250 49.61   2 17.7951 0.20 1.56093 36.64   *3 13.0065 10.96 1.00000   *4 44.9602 0.20 1.55389 38.09   5 46.0476 1.50 1.77250 49.61   6 20.8512 5.49 1.00000   7 120.000 1.30 1.77250 49.61   8 36.1878 5.92 1.00000   9 37.0286 3.92 1.71736 29.58   10 −749.889 Variable 1.00000   11 51.0535 2.05 1.72825 28.38   12 −32.8904 0.80 1.91082 35.25   13 40.7464 1.22 1.00000   14 22.0824 2.28 1.51680 63.88   15 −35.2067 1.63 1.00000   16 0 Variable 1.00000 Aperture Stop S   17 28.7991 2.69 1.53172 48.78   18 −15.1315 0.90 1.90366 31.27   19 −34.7347 Variable 1.00000   20 −79.1048 0.80 1.91082 35.25   21 55.1803 Variable 1.00000   22 18.6322 1.56 1.51680 63.88   23 31.533 Variable 1.00000   24 −60.0021 1.43 1.53110 55.91 *25 −33.4796 0.50 1.00000   26 49.3873 0.80 1.91082 35.25   27 15.8208 5.23 1.48749 70.24   28 −53.1349 Variable 1.00000   29 0 2.00 1.51680 63.88   30 0 Bf 1.00000 Image ∞ Surface (I) [Aspheriacal Surface Data] 3rd Surface κ = 0.1002   A4 = −9.02E−06 A6 = −1.45E−08   A8 = 8.99E−11   A10 = 4.58E−13   4th Surface κ = −4.6078   A4 = −6.39E−06 A6 = 4.84E−08   A8 = 1.53E−10   A10 = −2.96E−13 25th Surface κ = 1.0000   A4 = 4.61E−05   A6 = 2.921E−07   A8 = −3.00E−09 A10 = 2.17E−11   [Lens Group Data] Group First surface Focal length G1 1 −20.0295 G2 11 40.65621 G3 17 50.20726 G4 20 −35.5873 G5 22 84.63536 G6 24 121.5811 [Variable Distance Data] W Close M Close T Close W M T range range range f(β) 10.29984 12.99976 19.31945 −0.05582 −0.0664 −0.0967 d10 32.5917 18.1044 2.00000 32.5917 18.1044 2.0000 d16 2.94702 2.78457 4.11328 2.3937 2.02381 2.79333 d19 1.5000 1.54877 2.3198 2.05332 2.30953 3.63975 d21 3.20723 1.00000 1.50000 3.95327 1.98746 3.21594 d23 11.4491 9.9506 8.86383 10.70306 8.96314 7.14789 d28 19.02252 25.04425 33.77196 19.03768 25.06574 33.81755 Bf 0.1 0.1 0.1 0.1 0.1 0.1 [Magnification] W Close M Close T Close W M T range range range βF1 0.42189 0.37491 0.28287 0.41447 0.36447 0.26369 βF2 0.48041 0.38803 0.21395 0.48897 0.39928 0.23315 [Other specifications] ff1 50.207 ff2 84.635 MVF1w −0.568 MVF2w 0.73087

(93) FIG. **5**A, FIG. **5**B and FIG. **5**C are various aberration diagrams upon focusing on infinity in a wide angle end state, an intermediate focal length state and a telephoto end state respectively of the zoom optical system according to the second example. FIG. **6**A, FIG. **6**B, and FIG. **6**C are various aberration diagrams upon focusing on a short-distance object in a wide angle end state, an intermediate focal length state and a telephoto end state respectively of the zoom optical system according to the second example. From each aberration diagram, it can be seen that the zoom optical system according to the second example has excellent image forming performance by

satisfactorily correcting various aberrations from a wide angle end state to a telephoto end state, and further has excellent image forming performance upon focusing on a short-distance object as well.

Third Example

(94) A third example will be described using FIG. **7** to FIGS. **9**A-**9**C and Table 3. FIG. **7** is a diagram illustrating a lens configuration of a zoom optical system according to the third example. A zoom optical system ZL (3) according to the third example is constructed of a first lens group G**1** having a negative refractive power, a second lens group G**2** having a positive refractive power, an aperture stop S, a third lens group G**3** having a negative refractive power, a fourth lens group G**4** having a positive refractive power and a fifth lens group G**5** having a positive refractive power, disposed in order from an object side. Upon zooming from a wide angle end state (W) to a telephoto end state (T), the first to fifth lens groups G**1** to G**5** move in directions shown by arrows in FIG. **7** respectively and a distance between the adjacent lens groups changes. A lens group consisting of the second to fifth lens groups G**2** to G**5** corresponds to the succeeding lens group GR.

(95) The first lens group G**1** is constructed of a negative meniscus lens L**11** having a convex surface facing the object side, a negative meniscus lens L**12** having a convex surface facing the object side, a negative meniscus lens L**13** having a convex surface facing the object side and a biconvex positive lens L**14**, disposed in order from the object side.

(96) The negative meniscus lens L**11** is a hybrid lens constructed with a resin layer L**11**b provided on a surface on an image side of a glass lens body L**11**a. A surface on the image side of the resin layer L**11**b is aspherical and the negative meniscus lens L**11** is a composite type aspherical lens. In the [lens data] field which will be described later, a surface number 1 represents the surface on the object side of the lens body L**11**a, a surface number 2 represents the surface on the image side of the lens body L**11**a and the surface on the object side of a resin layer L**11**b (surface on which both lenses are cemented) and a surface number 3 represents the surface on the image side of the resin layer L**11**b.

(97) The negative meniscus lens L**12** is also a hybrid lens constructed with a resin layer L**12**b provided on the surface on the object side of a glass lens body L**12**a. A surface on the object side of the resin layer L**12**b is aspherical and the negative meniscus lens L**12** is also a composite type aspherical lens. In the [lens data] field which will be described later, a surface number 4 represents the surface on the object side of the resin layer L**12**ba, a surface number 5 represents the surface on the image side of the resin layer L**12**b and a surface on the object side of the lens body L**12**a (surface on which both lenses are cemented) and a surface number 6 represents the surface on the image side of the lens body L**12**a.

(98) The second lens group G**2** is constructed of a positive meniscus lens L**21** having a convex surface facing the object side and a cemented lens consisting of a positive meniscus lens L**23** having a concave surface facing the object side and a negative meniscus lens L**24** having a concave surface facing the object side, disposed in order from the object side. The aperture stop S is provided in the vicinity of an image side of the second lens group G**2** and moves together with the second lens group G**2** upon zooming.

(99) The third lens group G**3** is constructed of a cemented lens consisting of a biconvex positive lens L**31** and a negative meniscus lens L**32** having a concave surface facing the object side and a biconcave negative lens L**33**. In the third lens group G**3**, the cemented lens consisting of the positive lens L**31** and the negative meniscus lens L**32** constitutes a front-side lens group G**3**A and the negative lens L**33** constitutes a rear-side lens group G**3**B. Furthermore, the front-side lens group G**3**A constitutes a first focusing lens group.

(100) The fourth lens group G**4** is constructed of a positive meniscus lens L**41** having a convex surface facing the object side. The fourth lens group G**4** constitutes a second focusing lens group.

(101) The fifth lens group G**5** is constructed of a positive meniscus lens L**51** having a concave surface facing the object side, a negative meniscus lens L**52** having a convex surface facing the object side and a biconvex positive lens L**53**. Note that a surface on the image side of the positive

meniscus lens L**51** is aspherical.

(102) In the present example, part of the third lens group G**3** on the image side (front-side lens group G**3**A) constitutes a first focusing lens group and the fourth lens group G**4** constitutes a second focusing lens group. Part of the third lens group G**3** on the image side (front-side lens group G**3**A) moves toward the object side and the fourth lens group G**4** moves toward the image side depending on a change from focusing on a long-distance object (infinity object) to focusing on a short-distance object.

(103) The following Table 3 lists specification values of the zoom optical system according to the third example.

(104) TABLE-US-00003 TABLE 3 [General Data] Focal length (f) 11.3 (fw)-19.3 (ft) W M T F.NO 4.61296 5.00943 5.68446 2ω 52.82737 44.07011 36.15833 Air Equivalent 120.87241 108.97567 108.40436 TL Air Equivalent 16.52159 24.01249 31.04985 BF [Lens Data] Surface R D nd vd 1 42.2613 2.40 1.77250 49.61 2 16.1746 0.20 1.56093 36.64 *3 13.0027 10.79 1.00000 *4 99.2765 0.20 1.55389 38.09 5 91.8259 1.50 1.77250 49.61 6 21.4633 4.89 1.00000 7 120.000 1.30 1.77250 49.61 8 59.6747 7.41 1.00000 9 43.1309 3.59 1.71736 29.58 10 −750.0000 Variable 1.00000 11 23.8089 1.88 1.51680 63.88 12 101.019 2.23 1.00000 13 −114.581 0.80 1.91082 35.25 14 −40.4733 1.43 1.72825 28.38 15 −52.685 1.28 1.00000 16 0 Variable 1.00000 Aperture Stop S 17 26.5144 2.55 1.53172 48.78 18 −14.8795 0.90 1.90366 31.27 19 −32.8111 Variable 1.00000 20 −1986.21 0.80 1.91082 35.25 21 21.4616 Variable 1.00000 22 19.6202 1.79 1.51680 63.88 23 103.813 Variable 1.00000 24 −59.9998 1.56 1.53110 55.91 *25 −33.5052 0.50 1.00000 26 34.3198 0.80 1.91082 35.25 27 15.1432 5.39 1.48749 70.24 28 −259.404 Variable 1.00000 29 0 2.00 1.51680 63.88 30 0 Bf 1.00000 Image ∞ Surface (I) [Aspheriacal Surface Data] 3rd Surface κ = 0.2869 A4 = 1.03E−05 A6 = 2.72E−08 A8 = −1.10E−10 A10 = 8.60E−13 4th Surface κ = 12.1204 A4 = 1.25E−06 A6 = −1.11E−08 A8 = 1.38E−10 A10 = −2.23E−13 25th Surface κ = 1.0000 A4 = 2.71E−05 A6 = 7.25E−08 A8 = −6.06E−10 A10 = 6.36E−12 [Lens Group Data] Group First surface Focal length G1 1 −22.49113 G2 11 38.13818 G3 17 −58.34838 G4 22 46.47508 G5 24 126.00073 [Variable Distance Data] W Close M Close T Close W M T range range range f(β) 11.2996 14.8995 19.3194 −0.05898 −0.07401 −0.09672 d10 30.4632 13.8849 2.0000 30.4632 13.8849 2.0000 d16 2.76367 2.80224 4.56673 2.11089 2.09423 3.56283 d19 1.5000 1.5000 1.5000 2.15278 2.20801 2.5039 d21 1.80903 2.00882 6.09908 2.7882 2.78763 7.10298 d23 13.6245 10.5768 8.99828 12.64533 9.79799 7.99438 d28 15.10303 22.59384 29.63121 15.10303 22.59384 29.63121 Bf 0.1 0.10008 0.10008 0.1 0.10008 0.10008 [Magnification] W Close M Close T Close W M T range range range βF1 0.43161 0.38253 0.32802 0.42303 0.37074 0.30964 βF2 0.11541 −0.06604 −0.30118 0.13648 −0.04929 −0.27958 [Other specifications] ff1 44.31219 ff2 46.47508 MVF1w −0.6528 MVF2w 0.97917

(105) FIG. **8**A, FIG. **8**B, and FIG. **8**C are various aberration diagrams upon focusing on infinity in a wide angle end state, an intermediate focal length state and a telephoto end state respectively of the zoom optical system according to the third example. FIG. **9**A, FIG. **9**B, and FIG. **9**C are various aberration diagrams upon focusing on a short-distance object in a wide angle end state, an intermediate focal length state and a telephoto end state respectively of the zoom optical system according to the third example. From each aberration diagram, it can be seen that the zoom optical system according to the third example has excellent image forming performance by satisfactorily correcting various aberrations from a wide angle end state to a telephoto end state, and further has excellent image forming performance upon focusing on a short-distance object as well.

Fourth Example

(106) A fourth example will be described using FIG. **10** to FIGS. **12**A-**12**C and Table 4. FIG. **10** is a diagram illustrating a lens configuration of a zoom optical system according to the fourth example. A zoom optical system ZL (4) according to the fourth example is constructed of a first lens group G**1** having a negative refractive power, a second lens group G**2** having a positive refractive power with an aperture stop S in the middle, a third lens group G**3** having a negative refractive power and

a fourth lens group G**4** having a positive refractive power, disposed in order from an object side. Upon zooming from a wide angle end state (W) to a telephoto end state (T), the first to fourth lens groups G**1** to G**4** move in directions shown by arrows in FIG. **10** and a distance between the adjacent lens groups changes. A lens group consisting of the second to fourth lens groups G**2** to G**4** corresponds to the succeeding lens group GR.

(107) The first lens group G**1** is constructed of a negative meniscus lens L**11** having a convex surface facing the object side, a negative meniscus lens L**12** having a convex surface facing the object side, a biconcave negative lens L**13** and a biconvex positive lens L**14**, disposed in order from the object side.

(108) The negative meniscus lens L**11** is a hybrid lens constructed with a resin layer L**11**b provided on a surface on the image side of a glass lens body L**11**a. A surface on the image side of the resin layer L**11**b is aspherical and the negative meniscus lens L**11** is a composite type aspherical lens. In the [lens data] field which will be described later, a surface number 1 represents the surface on the object side of the lens body Lila, a surface number 2 represents the surface on the image side of the lens body L**11**a and the surface on the object side of the resin layer L**11**b (surface on which both lenses are cemented), and a surface number 3 represents the surface on the image side of the resin layer L**11**b.

(109) The negative meniscus lens L**12** is also a hybrid lens constructed with a resin layer L**12**b provided on a surface on the object side of a glass lens body L**12**a. A surface on the object side of the resin layer L**12**b is aspherical, and the negative meniscus lens L**12** is also a composite type aspherical lens. In the [lens data] field which will be described later, a surface number 4 represents the surface on the object side of the resin layer L**12**b, a surface number 5 represents the surface on the image side of the resin layer L**12**b and the surface on the object side of the lens body L**12**a (surface on which both lenses are cemented), and a surface number 6 represents the surface on the image side of the lens body L**12**a.

(110) The second lens group G**2** is constructed of a cemented lens consisting of a biconvex positive lens L**21** and a biconcave negative lens L**22**, a positive meniscus lens L**23** having a concave surface facing the object side, and a cemented lens consisting of a biconvex positive lens L**24** and a negative meniscus lens L**25** having a concave surface facing the object side, disposed in order from the object side. The aperture stop S is located between the positive meniscus lens L**23** and the positive lens L**24**, provided inside the second lens group G**2** and moves together with the second lens group G**2** upon zooming. Note that as shown in FIG. **10**, the second lens group G**2** is constructed of a front-side lens group G**2**A (constructed of a cemented lens consisting of the positive lens L**21** and the negative lens L**22**), an intermediate lens group G**2**B (constructed of the positive meniscus lens L**23**) and a rear-side lens group G**2**C (constructed of a cemented lens consisting of the positive lens L**24** and the negative meniscus lens L**25**).

(111) The third lens group G**3** is constructed of a biconcave negative lens L**31** and a positive meniscus lens L**32** having a convex surface facing the object side. Note that as shown in FIG. **10**, the third lens group G**3** is constructed of a front-side lens group G**3**A (constructed of the negative lens L**31**) and a rear-side lens group G**3**B (constructed of the positive meniscus lens L**32**).

(112) The fourth lens group G**4** is constructed of a positive meniscus lens L**41** having a concave surface facing the object side and a cemented lens consisting of a biconcave negative lens L**42** and a biconvex positive lens L**43**. Note that a surface on the image side of the positive meniscus lens L**41** is aspherical.

(113) In the present example, the rear-side lens group G**2**C of the second lens group G**2** constitutes a first focusing lens group, the rear-side lens group G**3**B of the third lens group G**3** constitutes a second focusing lens group. Depending on a change from focusing on a long-distance object (infinity object) to focusing on a short-distance object, the first focusing lens group (rear-side lens group G**2**C) moves toward the object side and the second focusing lens group (rear-side lens group G**3**B) moves toward the image side.

(114) The intermediate lens group G2B (positive meniscus lens L23) that constitutes the second lens group G2 is moved so as to have a component in a direction perpendicular to the optical axis, constituting a vibration-proof lens group that corrects image blur caused by camera shake or the like.

(115) The following Table 4 lists specification values of the zoom optical system according to the fourth example.

(116) TABLE-US-00004 TABLE 4 [General Data] Focal length (f) 10.3 (fw)-19.4 (ft) W M T F.NO 4.6301 5.23998 5.83553 2ω 56.39754 44.87543 37.36057 Air Equivalent 127.19237 118.45802 118.27894 TL Air Equivalent 38.11835 45.70695 53.49651 BF [Lens Data] Surface R D nd vd   1 72.1955 2.40 1.77250 49.62   2 18.1031 0.20 1.56093 36.64   *3 12.8098 13.50 1.00000   *4 38.7281 0.20 1.55389 38.09   5 33.8000 1.50 1.80610 40.97   6 15.4815 6.41 1.00000   7 −213.939 1.30 1.69680 49.61   8 48.4224 0.10 1.00000   9 25.7571 4.15 1.71736 29.57   10 −228.544 Variable 1.00000   11 25.4457 2.55 1.72825 28.38   12 −15.8585 0.80 1.91082 35.25   13 28.6288 1.92 1.00000   14 −195.244 1.58 1.51680 63.88   15 −24.949 1.45 1.00000   16 0 Variable 1.00000 Aperture Stop S   17 21.5531 3.28 1.53172 48.78   18 −15.0486 0.90 1.91082 35.25   19 −23.5039 Variable 1.00000   20 −112.948 0.80 1.91082 35.25   21 28.2311 Variable 1.00000   22 18.6211 1.83 1.51680 63.88   23 77.6694 Variable 1.00000   24 −59.8503 1.36 1.53110 55.91 *25 −34.4312 0.60 1.00000   26 −136.828 0.80 1.91082 35.25   27 21.0189 5.60 1.48749 70.31   28 −15.2735 Variable 1.00000   29 0 2.00 1.51680 63.88   30 0 Bf 1.00000 Image ∞ Surface (I) [Aspheriacal Surface Data] 3rd Surface κ = 0.0387   A4 = −1.01E−05 A6 = −2.98E−08 A8 = 1.59E−10   A10 = 2.68E−13   4th Surface κ = 0.2082   A4 = −3.60E−06 A6 = 8.87E−08   A8 = 2.10E−10   A10 = −2.30E−13 25th Surface κ = 1.0000   A4 = 5.63E−05   A6 = 4.89E−08   A8 = −2.05E−09 A10 = 3.5E−11   [Lens Group Data] Group First surface Focal length G1 1 −16.3772 G2 11 24.84907 G3 20 −56.2908 G4 24 70.2103 [Variable Distance Data] W Close M Close T Close W M T range range range f(β) 10.31023 15.00257 19.4 −0.05436 −0.07709 −0.10236 d10 26.1646 9.84165 1.87301 26.1646 9.84165 1.87301 d16 1.80195 1.80195 1.80195 1.32479 1.00051 0.20687 d19 1.45964 2.6478 3.18161 1.9368 3.44925 4.77669 d21 0.6974 0.6974 0.6974 1.89031 1.73928 1.97347 d23 5.72006 4.5319 3.99809 4.52716 3.49002 2.72203 d28 36.69978 44.28838 52.07794 36.69978 44.28838 52.07794 Bf 0.1 0.1 0.1 0.1 0.1 0.1 [Magnification] W Close M Close T Close W M T range range range βF1 −0.29802 −0.49787 −0.68391 −0.31172 −0.53124 −0.75951 βF2 −0.67094 −1.34785 −2.55372 −0.64551 −1.32564 −2.52651 [Other specifications] ff1 26.66669 ff2 46.89864 MVF1w −0.477 MVF2w 1.1929

(117) FIG. 11A, FIG. 11B and FIG. 11C are various aberration diagrams upon focusing on infinity in a wide angle end state, an intermediate focal length state and a telephoto end state respectively of the zoom optical system according to the fourth example. FIG. 12A, FIG. 12B, and FIG. 12C are various aberration diagrams upon focusing on a short-distance object in a wide angle end state, an intermediate focal length state and a telephoto end state respectively of the zoom optical system according to the fourth example. From each aberration diagram, it can be seen that the zoom optical system according to the fourth example has excellent image forming performance by satisfactorily correcting various aberrations from a wide angle end state to a telephoto end state and also has excellent image forming performance upon focusing on a short-distance object as well.

Fifth Example

(118) A fifth example will be described using FIG. 13 to FIGS. 15A-15C and Table 5. FIG. 13 is a diagram illustrating a lens configuration of a zoom optical system according to the fifth example. A zoom optical system ZL (5) according to the fifth example is constructed of a first lens group G1 having a negative refractive power, a second lens group G2 having a negative refractive power, a third lens group G3 having a positive refractive power, an aperture stop S, a fourth lens group G4 having a positive refractive power, a fifth lens group G5 having a negative refractive power, a sixth lens group G6 having a positive refractive power and a seventh lens group G7 having a positive refractive power, disposed in order from an object side. Upon zooming from a wide angle end state

(W) to a telephoto end state (T), the first to seventh lens groups G**1** to G**7** move in directions shown by arrows in FIG. **13** respectively, and a distance between the adjacent lens groups changes. A lens group consisting of the second to seventh lens groups G**2** to G**7** corresponds to the succeeding lens group GR.

(119) The first lens group G**1** is constructed of a negative meniscus lens L**11** having a convex surface facing the object side, a negative meniscus lens L**12** having a convex surface facing the object side, a negative meniscus lens L**13** having a convex surface facing the object side and a biconvex positive lens L**14**, disposed in order from the object side.

(120) The negative meniscus lens L**11** is a hybrid lens constructed with a resin layer L**11**b provided on a surface on the image side of a glass lens body L**11**a. A surface on the image side of the resin layer L**11**b is aspherical and the negative meniscus lens L**11** is a composite type aspherical lens. In the [lens data] field which will be described later, a surface number 1 represents the surface on the object side of the lens body Lila, a surface number 2 represents the surface on the image side of the lens body L**11**a and the surface on the object side of the resin layer L**11**b (surface on which both lenses are cemented) and a surface number 3 represents the surface on the image side of the resin layer L**11**b.

(121) The negative meniscus lens L**12** is also a hybrid lens constructed with a resin layer L**12**b provided on a surface on the object side of a glass lens body L**12**a. A surface on the object side of the resin layer L**12**b is aspherical and the negative meniscus lens L**12** is also a composite type aspherical lens. In the [lens data] field which will be described later, a surface number 4 represents a surface on the object side of the resin layer L**12**ba, a surface number 5 represents the surface on the image side of the resin layer L**12**b and the surface on the object side of the lens body L**12**a (surface on which both lenses are cemented), and a surface number 6 represents the surface on the image side of the lens body L**12**a.

(122) The second lens group G**2** is constructed of a cemented lens consisting of a biconvex positive lens L**21** and a biconcave negative lens L**22**.

(123) The third lens group G**3** is constructed of a biconvex positive lens L**31**. The aperture stop S is provided in the vicinity of the image side of the third lens group G**3** and moves together with the third lens group G**3** upon zooming.

(124) The fourth lens group G**4** is constructed of a cemented lens consisting of a biconvex positive lens L**41** and a negative meniscus lens L**42** having a concave surface facing the object side.

(125) The fifth lens group G**5** is constructed of a biconcave negative lens L**51**.

(126) The sixth lens group G**6** is constructed of a positive meniscus lens L**61** having a convex surface facing the object side.

(127) The seventh lens group G**7** is constructed of a positive meniscus lens L**71** having a concave surface facing the object side and a cemented lens consisting of a negative meniscus lens L**72** having a convex surface facing the object side and a biconvex positive lens L**73**. Note that the surface on the image side of the positive meniscus lens L**71** is aspherical.

(128) In the present example, the fourth lens group G**4** constitutes a first focusing lens group and the sixth lens group G**6** constitutes a second focusing lens group. Depending on a change from focusing on a long-distance object (infinity object) to focusing on a short-distance object, the first focusing lens group (fourth lens group G**4**) moves toward the object side and the second focusing lens group (sixth lens group G**6**) moves toward the image side.

(129) The following Table 5 lists specification values of the zoom optical system according to the fifth example.

(130) TABLE-US-00005 TABLE 5 [General Data] Focal length (f) 10.3 (fw)-19.3 (ft) W M T F.NO 4.6683 4.96374 5.80239 2ω 55.25456 48.20506 35.45169 Air Equivalent 121.01438 108.39582 103.93683 TL Air Equivalent 16.95795 23.02697 29.43842 BF [Lens Data] Surface R D nd vd   1 58.6074 2.40 1.77250 49.61   2 17.5078 0.20 1.56093 36.64   *3 13.0042 9.90 1.00000   *4 50.3658 0.20 1.55389 38.09   5 56.8198 1.50 1.77250 49.61   6 21.5929 5.45 1.00000   7

119.999 1.30 1.77250 49.61   8 39.5142 7.63 1.00000   9 41.6577 3.67 1.71736 29.58   10 −749.999 Variable 1.00000   11 37.7166 1.91 1.72825 28.38   12 −96.4635 0.80 1.91082 35.25   13 32.6266 Variable 1.00000   14 18.8176 2.29 1.51680 63.88   15 −41.5207 1.71 1.00000   16 0 Variable 1.00000 Aperture Stop S   17 28.3401 2.69 1.53172 48.78   18 −14.0687 0.90 1.90366 31.27   19 −34.3736 Variable 1.00000   20 −67.0447 0.80 1.91082 35.25   21 45.6913 Variable 1.00000   22 18.0512 1.59 1.51680 63.88   23 34.0298 Variable 1.00000   24 −60.0006 1.35 1.53110 55.91 *25 −33.4648 0.91 1.00000   26 42.1746 0.80 1.91082 35.25   27 15.6452 4.94 1.48749 70.24   28 −103.065 29.88 1.00000   29 0 2.00 1.51680 63.88   30 0 0.10 1.00000 Image ∞ Surface (I)

[Aspheriacal Surface Data] 3rd Surface κ = 0.1402   A4 = −5.51E−06 A6 = −1.51E−08 A8 = 2.32E−11 A10 = 6.51E−13   4th Surface κ = −5.3009   A4 = −9.86E−06 A6 = 3.87E−08 A8 = 1.40E−10   A10 = −2.96E−13 25th Surface κ = 1.0000   A4 = 6.04E−05   A6 = 5.21E−07   A8 = −5.53E−09 A10 = 4.16E−11 [Lens Group Data] Group First surface Focal length G1 1 −20.6289 G2 11 −103.51107 G3 14 25.38363 G4 17 53.4659 G5 20 −29.73283 G6 22 71.94709 G7 24 150.4283 [Variable Distance Data] W Close M Close T Close W M T range range range f(β) 10.29989 12.99987 19.31936 −0.05435 −0.06458 −0.09437 d10 32.0027 12.9451 2.0000 32.0027 12.9451 2.0000 d13 1.21092 3.95802 1.07653 1.21092 3.95802 1.07653 d16 2.7494 2.86437 3.6529 2.29199 2.33306 2.65189 d19 1.5000 0.40476 2.07238 1.95741 0.93607 3.07339 d21 2.39681 1.0000 1.5000 2.83592 1.31879 2.31081 d23 11.2541 9.43894 8.26897 10.81499 9.12015 7.45816 d28 15.53939 22.84512 29.83997 15.55377 22.86546 29.88341 Bf 0.1 0.1 0.1 0.1 0.1 0.1 [Magnification] W Close M Close T Close W M T range range range βF1 0.52437 0.50057 0.42462 0.51772 0.49189 0.4088 βF2 0.45968 0.34278 0.20627 0.46552 0.3468 0.21654 [Other specifications] ff1 53.4659 ff2 71.94709 MVF1w −0.4718 MVF2w 0.42473

(131) FIG. **14**A, FIG. **14**B, and FIG. **14**C are various aberration diagrams upon focusing on infinity in a wide angle end state, an intermediate focal length state and a telephoto end state respectively of the zoom optical system according to the fifth example. FIG. **15**A, FIG. **15**B, and FIG. **15**C are various aberration diagrams upon focusing on a short-distance object in a wide angle end state, an intermediate focal length state and a telephoto end state respectively of the zoom optical system according to the fifth example. From each aberration diagram, it can be seen that the zoom optical system according to the fifth example has excellent image forming performance by satisfactorily correcting various aberrations from a wide angle end state to a telephoto end state, and further has excellent image forming performance upon focusing on a short-distance object as well.

(132) Finally, a table of [conditional expression corresponding values] is shown below. The table shows values corresponding to the respective conditional expressions (first to fifth examples) in a summarized manner for all the examples (first to fifth examples).

$0.01 < (-MVF1)/MVF2 < 30.0$ Conditional Expression (1)
$0.20 < ff1/ff2 < 1.70$ Conditional Expression (2)
$0.15 < (-f1)/ff1 < 1.30$ Conditional Expression (3)
$0.10 < (-f1)/ff2 < 0.95$ Conditional Expression (4)
$0.10 < (-f1)/f2 < 1.20$ Conditional Expression (5)
$-0.80 < \beta WF1 < 0.80$ Conditional Expression (6)
$-0.80 < \beta WF2 < 0.80$ Conditional Expression (7)
$(\beta WF1 + (1/\beta WF1)).\text{sup.}-2 < 0.25$ Conditional Expression (8)
$(\beta WF2 + (1/\beta WF2)).\text{sup.}-2 < 0.25$ Conditional Expression (9)

(133) TABLE-US-00006 [Conditional Expression Corresponding Value] Conditional 1st 2nd 3rd 4th 5th Expression Example Example Example Example Example (1) 0.442 0.778 0.667 0.400 1.111 (2) 0.454 0.593 0.953 0.569 0.743 (3) 0.615 0.399 0.508 0.614 0.386 (4) 0.279 0.237 0.484 0.349 0.287 (5) 0.368 0.493 0.590 0.680 −0.199 (6) 0.185 0.422 0.432 −0.298 0.524 (7) 0.374 0.480 0.115 −0.671 0.460 (8) 0.032 0.128 0.132 0.075 0.169 (9) 0.108 0.152 0.013 0.214 0.144

(134) The above-described first to fifth examples show specific cases of the present embodiment and the present embodiment is not limited to these examples.

(135) Note that the following contents can be adopted as appropriate without impairing the optical performance of the zoom optical system according to the present embodiment.

(136) As numerical examples of the zoom optical system, the systems in a 4-group configuration, a 5-group configuration, a 6-group configuration and a 7-group configuration have been presented, but the present application is not limited to these configurations, and zoom optical systems in other group configurations (e.g., 8-group configuration) can also be configured. More specifically, a configuration with a lens or a lens group added to the most object side or the most image side of the zoom optical system may be adopted. Note that the lens group refers to a part having at least one lens, separated apart by an air gap that changes upon zooming.

(137) The lens surface may be formed by a spherical or flat surface, or an aspherical surface. When the lens surface is spherical or flat, it is possible to process lenses and adjust assembly more easily, and thereby prevent degradation of optical performance caused by errors in processing and assembly adjustment, which is preferable. Even when the image surface is shifted, there is little degradation in imaging performance, which is preferable.

(138) When the lens surface is aspherical, the aspherical surface may be any one of an aspherical surface by grinding, a glass molded aspherical surface in which glass is molded into an aspherical surface shape using a mold and a composite type aspherical surface in which resin is molded into an aspherical surface shape on the surface of glass. Furthermore, the lens surface may be a diffractive surface and the lens may be a refractive index distribution type lens (gradient index lens: GRIN lens) or a plastic lens.

(139) The aperture stop may be substituted for its role by a lens frame without providing a member as an aperture stop.

(140) An anti-reflective film demonstrating high transmittance over a wide wavelength range may be applied to each lens surface to reduce flare or ghosts and achieve high contrast optical performance. This makes it possible to reduce flare or ghosts and achieve high contrast optical performance.

EXPLANATION OF NUMERALS AND CHARACTERS

(141) G**1** first lens group G**2** second lens group G**3** third lens group G**4** fourth lens group G**5** fifth lens group G**6** sixth lens group G**7** seventh lens group I Image surface S aperture stop

Claims

1. A zoom optical system essentially consisting of a first lens group having a negative refractive power and a succeeding lens group, which are disposed on an optical axis in order from an object side, wherein the succeeding lens group comprises three or more lens groups, distances between adjacent lens groups change upon zooming from a wide angle end to a telephoto end, the succeeding lens group includes a first focusing lens group having a positive refractive power and a second focusing lens group having a positive refractive power, in which the second focusing lens group is placed on an image side of the first lens group, the first focusing lens group moves toward the object side and the second focusing lens group moves toward the image side upon focusing from infinity to a short distance, and the following conditional expressions are satisfied:

$0.20 < ff1/ff2 < 1.40$ and

$0.10 < (-f1)/ff2 < 0.53$ where, f1: a focal length of the first lens group, ff1: a focal length of the first focusing lens group, and ff2: a focal length of the second focusing lens group.

2. The zoom optical system according to claim 1, wherein the following conditional expression is satisfied:

$0.01 < (-MVF1)/MVF2 < 30.0$ where, MVF1: an amount of movement of the first focusing lens group upon focusing on an object from infinity to a short distance MVF2: an amount of movement of the second focusing lens group upon focusing on an object from infinity to a short distance where movement of the first and second focusing lens groups toward the image side is set as positive, and

movement of the first and second focusing lens groups toward the object side is set as negative.

3. The zoom optical system according to claim 1, wherein the following conditional expression is satisfied:

$0.15 < (-f1)/ff1 < 1.30$.

4. The zoom optical system according to claim 1, wherein the second focusing lens group consists of one convex lens.

5. The zoom optical system according to claim 1, wherein the first focusing lens group consists of a cemented lens consisting of a convex lens and a concave lens.

6. The zoom optical system according to claim 1, wherein the succeeding lens group comprises a second lens group and a third lens group having a positive refractive power, disposed in order from the object side, and the following conditional expression is satisfied:

$0.10 < (-f1)/f2 < 1.20$ where, f2: a focal length of the second lens group.

7. The zoom optical system according to claim 1, wherein the first lens group comprises three negative lenses disposed in order from the object side.

8. The zoom optical system according to claim 1, wherein the following conditional expression is satisfied:

$-0.80 < \beta WF1 < 0.80$ where, βWF1: lateral magnification of the first focusing lens group upon focusing on an infinity object in a wide angle end state.

9. The zoom optical system according to claim 1, wherein the following conditional expression is satisfied:

$-0.80 < \beta WF2 < 0.80$ where, βWF2: lateral magnification of the second focusing lens group upon focusing on an infinity object in a wide angle end state.

10. The zoom optical system according to claim 1, wherein the following conditional expression is satisfied:

$(\beta WF1 + (1/\beta WF1)).\text{sup.}{-2} < 0.25$ where, βWF1: lateral magnification of the first focusing lens group upon focusing on an infinity object in a wide angle end state.

11. The zoom optical system according to claim 1, wherein the following conditional expression is satisfied:

$(\beta WF2 + (1/\beta WF2)).\text{sup.}{-2} < 0.25$ where, βWF2: lateral magnification of the second focusing lens group upon focusing on an infinity object in a wide angle end state.

12. An optical apparatus comprising the zoom optical system according to claim 1.

13. A zoom optical system comprising a first lens group having a negative refractive power and a succeeding lens group, which are disposed on an optical axis in order from an object side, wherein distances between the adjacent lens groups change upon zooming from a wide angle end to a telephoto end, the succeeding lens group comprises a first focusing lens group having a positive refractive power and a second focusing lens group having a positive refractive power, the first focusing lens group and the second focusing lens group move respectively along different loci, and the following conditional expressions are satisfied:

$0.20 < ff1/ff2 < 1.40$ and

$0.10 < (-f1)/ff2 < 0.53$ where, f1: a focal length of the first lens group, ff1: a focal length of the first focusing lens group, and ff2: a focal length of the second focusing lens group.

14. The zoom optical system according to claim 13, wherein the following conditional expression is satisfied:

$0.15 < (-f1)/ff1 < 1.30$.

15. The zoom optical system according to claim 13, wherein the succeeding lens group comprises a second lens group and a third lens group having a positive refractive power, disposed in order from the object side, and the following conditional expression is satisfied:

$0.10 < (-f1)/f2 < 1.20$ where, f2: a focal length of the second lens group.

16. An optical apparatus comprising the zoom optical system according to claim 13.

17. A method for manufacturing a zoom optical system comprising: arranging, in a lens barrel and

on an optical axis in order from an object side, a first lens group having a negative refractive power and a succeeding lens group, arranging the first lens group and the succeeding lens group so that a distances between adjacent lens groups change upon zooming from a wide angle end to a telephoto end, configuring the succeeding lens group to comprise a first focusing lens group having a positive refractive power and a second focusing lens group having a positive refractive power, the method further comprising one of the following features A or B, the feature A including: the zoom optical system essentially consisting of the first lens group and the succeeding lens group, configuring the succeeding lens group to comprise three or more lens groups, arranging the second focusing lens group to be on an image side of the first lens group, arranging the first focusing lens group to move toward the object side and the second focusing lens group to move toward the image side upon focusing from infinity to a short distance, and satisfying the following conditional expressions:
$0.20 < ff1/ff2 < 1.40$ and
$0.10 < (-f1)/ff2 < 0.53$ where, f1: a focal length of the first lens group, ff1: a focal length of the first focusing lens group, and ff2: a focal length of the second focusing lens group, the feature B including: arranging the first focusing lens group and the second focusing lens group to move respectively along different loci, and satisfying the following conditional expressions:
$0.20 < ff1/ff2 < 1.40$ and
$0.10 < (-f1)/ff2 < 0.53$ where, f1: a focal length of the first lens group, ff1: a focal length of the first focusing lens group, and ff2: a focal length of the second focusing lens group.