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COMBINED CEILING FAN AND LIGHT FITTING

TECHNICAL FIELD

15 The invention described herein relates to a combined light fitting and ceiling fan having blades that are compactly folded when the fan is not in use and that move outwardly when the fan is started. More particularly the invention relates to improved fan blades for such an appliance.

BACKGROUND ART

20 Ceiling fans have long been recognized and used as an inexpensive way to provide movement of air within rooms of buildings. They can be simple to use and install, safe, and inexpensive to buy and run when compared to such alternatives as for example refrigerated and evaporative air conditioning units. They can often provide a surprisingly effective alternative to air
25 conditioning as the air movement they generate can evaporate skin perspiration with a resulting cooling effect.

 It is known to combine ceiling fans with lighting means, as firstly it is a common requirement to provide ceiling mounted light sources, and secondly it is convenient to provide a single power supply to operate a combined fan and
30 light fitting.

 Less commonly, it has also been known to provide a combined light fitting and ceiling fan with some form of folding or retracting blade arrangement. Le Velle has described three versions. US Patent 1445402 discloses a light fitting and ceiling fan in which blades move outwards under
35 centrifugal force when the fan is switched on, and are retracted by springs when the fan is switched off. US Patents 1458348 and 2079942 disclose improved versions, in which (unlike the early version of Patent 1445402) the

inward and outward movements of the blades are synchronized.

Synchronizing blade movement is important for preserving satisfactory balance of the rotating parts of the fan. More recently, a combined light fitting and ceiling fan has been disclosed by Villella (see international patent publication WO 2007/006096) with a concealed and simple blade movement synchronizing arrangement that lends itself to modern design.

A problem in the design of a combined light fitting and ceiling fan is to provide blades that when in use can provide useful air moving performance without requiring excessive power and that when not in use can fold into a reasonably compact overall form. The present invention addresses this problem.

References above and elsewhere in this specification to certain patents are not intended as or to be taken as admitting that anything therein forms a part of the common general knowledge in the art in any place.

SUMMARY OF THE INVENTION

A combined ceiling fan and light fitting will in this specification be referred to as a fan/light for convenience and brevity.

The invention relates to fan/lights having a plurality of fan blades that move outwardly to operating positions during fan operation and inwardly to stowed positions when fan operation ceases. Movement of the fan blades outwardly may be by action of centrifugal force when the blades are rotated about a fan axis by a motor. Retraction of the fan blades to their stowed positions may be by action of resilient means, for example one or more springs.

The blades are adapted and arranged when in their operating positions to move air downward as they rotate, and when in their stowed positions to lie within a defined radius from the fan axis, such as the radius of a translucent enclosure of circular form (when seen in plan view) for light emitting devices such as incandescent lamps. Each blade when stowed may overlap at least one other blade.

Preferred forms and relative positionings of blades are disclosed that are believed to provide a useful balance between the requirements of reasonable air movement and compact stowage of the blades when not in use. These forms are particularly characterized by certain distributions of

incidence, blade chord (distance measured from leading edge to trailing edge) and dihedral. They are preferably of aerofoil cross section with such camber that lower blade surfaces are concave and upper blade surfaces convex.

More specifically, the invention provides in a first aspect a combined
5 ceiling fan and light fitting having a plurality of fan blades, wherein:

each blade is pivotally mounted so as to be pivotable about an upright
pivot axis of the blade between a stowed position and a deployed position;

each blade when in its stowed position lies within a specified radius
from an upright fan rotation axis and above a light fitting portion and has an air
10 moving portion that in the deployed position of the blade extends beyond said
specified radius; and

each blade is generally elongate and arcuate when seen in plan view
and in its stowed position extends peripherally within said specified radius
between its pivot axis and a tip end of the blade and partially overlies a
15 neighbouring one of the blades in its own stowed position;

the combined ceiling fan and light fitting characterized in that:

- (a) each blade initially rises in height above a datum height with increasing
distance along the blade from its pivot axis end so that the blade when
in its stowed position overlies the pivot axis end of the neighbouring
20 blade in its own stowed position and
- (b) with increasing distance from a pivot-axis end of the air moving portion
towards the tip end of the blade the leading edge of the air moving
portion first increases in height above the said datum height and then
turns downwardly whereby to limit the height of the tip end above the
25 datum height.

The term "neighbouring blade" here means a blade that is first found by
moving peripherally forward (i.e. in the direction of fan rotation) from one
blade.

The phrase "turns downwardly" here does not necessarily mean that
30 with increasing distance toward the tip end from such turning down the blade
begins to actually descend. Rather it means that the blade increases in height
at a lesser rate than before the turning down, which may still be positive
although that is not to preclude a zero or negative rate of height increase.

Thus, the leading edge of the air moving portion of each blade may have a peak height above the datum height at a position between the pivot-axis end of the air moving portion and the tip end of the blade.

Further, the height above the datum height of the leading edge of the air moving portion may decline from said peak height with increasing distance along the leading edge toward the tip end of the blade.

The "specified radius" may be approximately a radius of a light fitting portion that is comprised in the combined ceiling fan and light fitting and located below the blade and that is of circular shape when seen in plan view.

The "datum height" may, purely for example, be the height of an upper surface of a horizontal platelike member to which each of the blades is pivotably mounted as in the case of the construction described by Villella.

The air moving portion of each blade may have a trailing edge that when seen in plan view is approximately a circular arc which when the blade is in its stowed position said is substantially centred on the fan rotation axis. This arrangement allows effectively use of the available space above a light fitting portion that is round when seen in plan view.

Preferably, for each blade when in its stowed position the radial distance between the leading and trailing edges of the air moving portion reduces progressively (i.e. the blade tapers as seen in plan view) from a maximum value partway along the length of the air moving portion towards the blade tip end.

More preferably, when all blades are in their stowed positions there is for each blade a first point on the leading edge of its air moving portion where the blade overlies its neighbouring blade which first point when seen in a notional radial plane including the fan rotation axis lies at a greater radius than a second point in the same notional plane that is on the leading edge of the overlain neighbouring blade.

Still more preferably, the said first point may be at a height above the datum height not exceeding the height of the said second point.

These arrangements can enhance the compactness of stowage of the blades.

It is preferred that the air moving portion of each blade has in the deployed position of the blade a maximum angle of incidence to the horizontal

at a position partway along the air moving portion the angle of incidence decreasing with increasing distance from that position of maximum incidence towards the tip end of the blade.

Preferably also, the air moving portion has a positive angle of incidence to the horizontal at its pivot-axis end.

The position partway along the air moving portion of each blade at which its incidence to the horizontal is a maximum when the blade is in its deployed position may be radially inboard of a position at which the blade chord measured along an arc centred on the fan rotation axis is at a maximum value. It is thought (but not asserted) that this feature may smooth the distribution of downward thrust on the air along the blade, so reducing induced drag on the blade.

Although adaptable to other numbers of blades, for example three or five, the number of blades is preferably four with the blades' pivot axes being spaced 90 degrees apart from each other peripherally.

That section of each blade between its pivot axis and its tip end when the blade is in its stowed position may subtend an angle of about 160 to 170 degrees at the fan rotation axis. Values in this range allow reasonable blade areas within the available stowage space above the light fitting portion, but without at any point requiring the stacking of more than two blades. This assists in obtaining compact blade stowage.

Preferably, each blade pivots through an angle of about 180 degrees to move from its stowed position to its deployed position. This gives a satisfactory blade-swept area for a given blade size.

Preferably, the air moving section of each blade is upwardly cambered (i.e. concave downwards) between its leading and trailing edges when seen in cross-section on a cylindrical surface centred on the fan rotation axis and intersecting the air moving section at a radius between the specified radius and the blade tip end.

It is also preferred for efficient air moving that the air moving section of each blade has a rounded leading edge and a sharp trailing edge over at least part of its along-blade length when seen in cross-section on a cylindrical surface centred on the fan rotation axis and intersecting the air moving section at a radius between the specified radius and the blade tip end.

The minimum height difference between each blade and its neighbouring blade when the blades are in their stowed positions may advantageously occur approximately where the blade overlies its neighbouring blade. If an overlying blade sags slightly, as may be the case with blades moulded from certain plastics if left unused for some time, this arrangement has been found to support the outer part of the blade reasonably well once contact between a blade and its underlying neighbour has been made.

The invention provides in another aspect a combined ceiling fan and light fitting having a plurality of elongate and arcuate planform blades that can move pivotally about upright axes between firstly stowed positions above a light fitting enclosure and secondly deployed positions in which the blades extend outwardly beyond the light fitting, characterized in that leading edges of the blades when in their deployed positions firstly rise with increasing radius beyond the light fitting enclosure first and thereafter are cranked downwardly.

In this aspect, when the blades are in their stowed positions each blade overlies a part of its neighbouring blade which part is received in a gap above the light fitting enclosure and below the underside of the overlying blade said gap existing by virtue of the cranked shape of the overlying blade.

Each blade may be pivotally mounted to a rotating platelike member with said gap lying above said platelike member.

In a third aspect the invention provides a combined ceiling fan and light fitting having air moving blades that in use exhibit gullwing dihedral. It is thought that such a dihedral form may be advantageous in itself even apart from its ability to enable compact stowage of retracting blades. "Gullwing dihedral" is to be taken as meaning that a lifting blade or wing rises between its root end and a point or region along its length toward its tip end and then either falls, remains level or rises more slowly.

In a further aspect the invention provides a combined ceiling fan and light fitting having a plurality of fan blades, wherein:

each blade is pivotally mounted so as to be pivotable about an upright pivot axis of the blade between a stowed position and a deployed position;

each blade when in its stowed position lies within a specified radius from an upright fan rotation axis and above a light fitting portion and has an air moving portion that in the deployed position of the blade extends beyond said specified radius; and

5. each blade is generally elongate and arcuate when seen in plan view with concave and convex sides and in its stowed position extends peripherally within said specified radius between its pivot axis and a tip end of the blade, characterized in that:

(a) each blade when deployed is so positioned that a concave side of the blade faces forward in the blade's direction of rotation and so that a radially outer portion of the blade's length extends both outwardly and forwardly;

(b) there is a first position partway along the air moving portion of the blade at which the blade's chord as measured in a peripheral direction has a maximum value and a second position partway along the air moving portion of the blade at which the blade has a maximum positive angle of incidence to the horizontal; and

(c) the first position is at a greater radius than the second position.

That is, the distributions of incidence and chord disclosed herein are believed advantageous in themselves apart from the issue of blade stowage.

The invention further provides a blade adapted for use in fan/lights as disclosed.

It is explicitly intended that the specific four-blade embodiment described in detail below be taken to be a claimable aspect of the invention both as to the proportions of the blades and their relative positions when in their stowed and operating positions.

The invention is preferably applied in fan/lights having certain features of the construction described in International Patent Publication WO 2007/006096 (based on International Patent Application No. PCT/AU2006/000981 by Joe Villella).

In a still further aspect of the invention there is further provided a fan/light comprising a plurality of retractable fan blades, wherein:

each said blade is pivotally mounted to a fan member that is rotatable about an upright fan rotation axis so that said blade is pivotable between a retracted position and an operating position about an upright blade pivot axis of said fan member;

5 each said blade has an elongate and generally arcuate air moving blade portion that when said blade is in the retracted position of said blade lies within a space bounded by:

- (a) an inner cylindrical surface coaxial with said fan rotation axis and touching an inner edge of said blade portion;
- 10 (b) an outer cylindrical surface coaxial with said fan rotation axis and touching an outer edge of said blade portion;
- (c) a first radial plane containing said fan rotation axis and said blade pivot axis; and
- (d) a second radial plane containing said fan rotation axis and that touches
15 a tip of the blade,

so that associated with every point on said blade portion is an angle theta being an angle between said first radial plane and a radial plane containing the fan rotation axis and that point; and

20 within a continuous section of the blade portion that lies between said first and second radial planes, said inner edge increases in height above a datum height with increasing theta, and a radial projection of said inner edge onto a cylindrical surface coaxial with said fan rotation axis is concave downwards.

25 Preferably, within said continuous section of said blade said inner edge increases in height above said datum height with increasing theta until a maximum value of the inner edge height is first reached at a point thereon whose value of theta is less than the value of theta at the blade tip.

30 Within said continuous section and for theta values greater than the smallest value at which said inner edge has its maximum height above said datum height, the height of said inner edge may decrease with increasing theta. This particular embodiment corresponds to the preferred embodiment described in detail herein.

In such a fan/light the other preferred features proportions and relative positioning of the blades as described herein may also be applied, including as to the blade trailing edge shape.

Further features, preferences and inventive concepts are disclosed in the following detailed description and appended claims.

In this specification, including in the appended claims, the word "comprise" (and derivatives such as "comprising", "comprises" and "comprised") when used in relation to a set of integers, elements or steps is not to be taken as precluding the possibility that other integers elements or steps are present or able to be included.

In order that the invention may be better understood there will now be described, non-limitingly, preferred embodiments of the invention as shown in the attached Figures, of which:

Figure 1 is a perspective view from above of a fan/light with retractable fan blades according to the invention, shown with its blades deployed to their operating positions;

Figure 2 is a perspective view from below of the fan/light shown in Figure 1 with its blades deployed to their operating positions;

Figure 3 is a perspective from above of the fan/light shown in Figure 1, now with its fan blades shown in their folded, non-operating positions;

Figure 4 is a perspective view from below of the fan/light shown in Figure 1, with its fan blades shown in their folded, non-operating positions;

Figure 5 is a plan view of the fan/light of Figure 1, with its fan blades shown deployed to their operating positions;

Figure 6 is a plan view of the fan/light of Figure 1, with its fan blades shown in their folded, non-operating positions;

Figure 7 is a side view of the fan/light of Figure 1, with its fan blades shown deployed to their operating positions;

Figure 8 is a side view of the fan/light of Figure 1, with its fan blades shown in their folded, non-operating positions;

Figure 9 is a perspective view from below of a subassembly of a fan/light with retractable fan blades described in International Patent Publication No. WO 2007/006096 by Villella;

Figure 10 is a schematic plan view of the fan/light shown in Figure 1 showing one blade in both deployed and retracted positions and the other blades in retracted positions and chain-dotted lines only;

Figure 11 is a schematic plan view of the fan/light shown in Figure 1 with all blades shown in chain-dotted lines in retracted positions and one blade also shown in its deployed position the view further showing positions of a set of cylindrical surfaces intersecting, and located at radially spaced stations along, the extended blade;

Figure 12 is a set of sections (labeled a – l) on radial planes as defined in Figure 10 of retracted blades of the fan/light shown schematically in Figure 10;

Figure 13 is a graph of heights above a datum height of inner and outer edges of a blade of the fan/light shown in Figure 1, as a function of circumferential position when the blade is in a retracted position;

Figure 14 is a graph of radial distance between inner and outer edges of a blade of the fan/light shown in Figure 1, as a function of circumferential position when the blade is in a retracted position;

Figure 15 is a graph of heights above a datum height of inner and outer edges of all blades of the fan/light shown in Figure 1, as a function of circumferential position when the blades are in their retracted positions;

Figure 16 is a set of cross-sections of the extended blade shown in Figure 11 taken on planes tangential to the arcs shown therein an numbered 1 to 8;

Figure 17 is a graph of an angle of incidence to the horizontal of the extended fan blade shown in Figure 11 as a function of radial position on the blade;

Figure 18 is a graph of the chord of the extended blade shown in Figure 11 as a function of radial position on the blade.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Figures 1 to 8 show a fan/light 10 according to the invention. Fan/light 10 has a non-rotating bowl-like translucent enclosure 12 in which is mounted at least one electric lamp (not shown), and is supported from a ceiling by a tubular support 13 in known manner. Fan/light 10 also has fan blades 1, 2, 3 and 4 that are rotatable by an electric motor (not shown) about an upright axis

15 coaxial with tubular support 13. The electric motor and the lamp are operable separately or together from a source of electric power that is supplied through the tubular support 13. The motor is of a known type, widely used in ceiling fans, that has a rotating external casing (not shown) with a central cavity in which is received the tubular support 13. Enclosure 12 is circular in plan view, centered on axis 15.

Blades 1 - 4 each extend outwardly to the operating positions shown in Figures 1, 2, 5 and 7 when the motor is switched on, and retract (fold) into positions shown in Figures 3, 4, 6 and 8 when the motor is switched off. The sense of rotation is as shown by arrow 7. Each one of blades 1 - 4 is pivotally supported on a blade support plate 14 that supports and rotates with blades 1 - 4, is disc-shaped, is coaxial with the rotation axis 15 of the motor and is secured to the motor's casing. A decorative dust cover 18 is secured on the support 4 above the blades 1 - 4 when they are in the folded positions shown in Figures 3, 4, 6 and 8.

Pivoting of blades 1 - 4 on blade support plate 14 is respectively about axes 21, 22, 23 and 24 parallel to the axis 15 of rotation of the motor. When the motor is switched on, blades 1 - 4 pivot outwardly under the influence of centrifugal force, pivoting around their respective pivot axes 21 - 24, until the operating positions shown in Figures 1, 2, 5 and 7 are reached. When the motor is switched off, blades 1 - 4 are retracted to their stowed positions as shown in Figures 3, 4, 6 and 8, again pivoting about their respective axes 21 - 24.

In international patent No. publication WO 2007/006096 (based on International Patent Application No. PCT/AU2006/000981 by Villella), which is incorporated herein in its entirety by reference, there is described a fan/light generally in accordance with the above principles and arrangement, albeit with three blades instead of the four blades 1 - 4 of fan/light 10. The present invention in its preferred embodiment is made in accordance with the principles and arrangement set out in Villella's disclosure save for the use of the four blades 1 - 4 instead of three.

In particular, synchronization of the pivoting movement of blades 1 - 4 and their retraction, may be by means of a simple adaptation to four blades of the approach disclosed by Villella, now briefly described. Figure 9 (similar to

Figure 7 of Villella's publication) shows a subassembly 30 of Villella's fan/light comprising a motor 34, blade support plate 36 and three blades 31, 32 and 33. (Note: The item numbers used herein to describe subassembly 30 are not the same as those used in the cited Villella publication.) Blade support plate
5 36 is ring shaped and secured to motor 34 (of the rotating casing type previously mentioned) so as to rotate therewith in its own plane.

Secured below blade support plate 36 is a sun gear 38. (The term "sun gear" is here used as it is in the art of so-called planetary gearing systems, where it refers to a gear that meshes with a number of "planetary" gears
10 arrayed around its periphery.) Sun gear 38 is coaxial with the motor 34 when support plate 36 is mounted to motor 34, and is able to rotate about its axis relative to support plate 36. Meshing with sun gear 38 are planetary gears 41, 42 and 43, each of which rotates as its associated one of blades 31 - 33 pivots between its stowed and operating positions. Each of gears 41 - 43 is
15 secured to a short shaft (not visible) that passes downwardly from its associated one of blades 31 - 33 and can rotate within support plate 36. The gears 41 - 43 are equispaced around the periphery of sun gear 38 and are themselves all at the same radius as each other from the rotation axis 35 of motor 34. The effect of this arrangement is that provided blades 31 - 33 are
20 identical and identically positioned in their working positions relative to support plate 36, they will be kept synchronized always when they pivot between their operating and retracted positions.

To retract blades 31 - 33 when motor 34 is switched off, coil springs 44 are provided. One end of each spring is secured to a formation 46 depending
25 from support plate 36 and the other end is secured to a formation 48 depending from sun gear 38. Coil springs 44 are arranged to be in tension when blades 31 - 33 are in their retracted position and are extended as centrifugal force urges blades 31 - 33 out when motor 34 is started. When motor 34 is stopped, springs 44 urge sun gear 38 to rotate relative to support
30 plate 34 so as to retract the blades 31 - 33.

For further information on, and options relating to, this arrangement for blade synchronization and retraction, refer can be made to the cited publication of Villella.

The way to adapt this arrangement to the four blades 1 – 4 of the embodiment of the present invention here described will be readily apparent to persons skilled in the art. There would be provided four planetary gears (not shown, but equivalent to gears 41 – 43) instead of three, equispaced around the sun gear (not shown, but equivalent to sun gear 38) and each associated with one blade.

In the following description, it will be assumed that blades 1 – 4 are pivotally mounted to support plate 14 essentially similar to support plate 36 and synchronized and retracted in the same way as blades 31 – 33 of subassembly 30. However, it is emphasized that the aerodynamic design of blades 1 – 4 and the way that they “nest” together when retracted are by no means limited to this particular fan/light construction. The configuration and arrangement of blades 1 – 4 could be applied to fan/lights of other constructions and to fans requiring retractable blades and without any lighting capability.

The blades 1 – 4 and their arrangement in fan/light 10 will now be described. Blades 1 – 4 are intended to provide fan/light 10 with a useful balance between satisfactory air-moving performance, compactness when the blades are in their stowed (i.e. retracted or folded) position, together with a diameter of the translucent enclosure 12 that is large enough to provide a reasonably diffuse lighting effect. The blades 1 – 4 are intended to lie substantially above the translucent enclosure 12 when retracted. In the embodiment shown and described herein, the enclosure 12 has a diameter that is about 39% of the overall diameter of fan/light 10 with its blades 1 – 4 extended for operation. The diameter of the hub of a conventional ceiling fan or fan/light without retractable blades is typically smaller than 39% of the overall diameter over the blades. The larger the diameter of enclosure 12 for a given overall diameter, the easier it is to meet the requirement of compact folding, with blades 1 – 4 above enclosure 12, but the more difficult it is to provide satisfactory air moving performance at normal fan rotational speeds. A range of from about 36% to about 42% for the above ratio is believed to be possible by straightforward adaptation of the blade shapes as described herein, but a figure in the region of 38% to 40% is preferred.

The geometry of blades 1 – 4 will be described below by reference to quantities and sections defined in Figures 10 and 11. In the schematic plan view of Figure 10, enclosure 12 is represented simply by its circular outer peripheral edge 26. Blades 1 – 4 are all shown in outline in their retracted positions, blade 1 in solid lines and the others in chain-dotted lines, and blade 1 is also shown in solid lines in its deployed position. Blades 1 – 4 are substantially identical to each other and are generally scimitar-shaped, i.e. of arcuate form so as to lie, when retracted, within the enclosure peripheral edge 26 and around the motor (not shown but centred on axis 15). The pivot axes 21 - 24 are adjacent to root ends 51 – 54 respectively (Figure 11) of blades 1 – 4 and in their retracted position the blades 1 – 4 extend clockwise to tips (free ends) 61 – 64 respectively. Item numbers with the postscript "a" are for blade 1 in its deployed position and item numbers with the postscript "b" are for blade 1 in its retracted position.

Blades 1 – 4 of fan/light 10 are shown (by arrow 7) as rotating clockwise when seen from above. It is to be understood however, that counter-clockwise rotation could equally well be chosen, in which case the term "counter-clockwise" would be applicable where in the present description "clockwise" now appears, including in the definitions given below of the terms "next blade" and "previous blade". (Note that for counter-clockwise rotation, the blades would be made of opposite hand to blades 1 – 4, as it is preferred that each blade's leading edge be its concave one.)

In relation to any given one of blades 1 – 4, the term "next blade" refers to the blade whose pivot axis is 90 degrees in the rotation direction (here clockwise) from the pivot axis of the given blade, and the term "previous blade" refers to the blade whose pivot axis is 90 degrees in a counter-direction opposite to the rotation direction (i.e. counter-clockwise here) from the pivot axis of the given blade. Thus, in relation to blade 1, the next blade is blade 2 and the previous blade is blade 4. The blade shape will be described mainly by reference to blade 1 for convenience, noting that blades 1 – 4 are substantially identical.

To show how blades 1 - 4 are arranged relative to each other in nesting fashion when retracted, it will be convenient to use sectional views on radial planes, i.e. planes that include the fan axis 15. Such a plane 42 is shown in

Figure 10 and is shown to be at an angle θ (theta) to a similar plane 44 that includes both axis 15 and axis 21 of blade 1.

For discussion of the blade shape from the point of view of aerodynamic characteristics when in the deployed position, it will be useful to consider blade sections taken on surfaces that are cylindrical, coaxial with fan axis 15, and located at stations radially spaced apart along a blade. Arcs numbered 1 to 8 in Figure 11 indicate such stations on blade 1. Stations 1 and 8 are respectively at radii of 39% and 97% of the overall fan radius (i.e. substantially at the edge of enclosure 12) with stations 2 – 7 radially equispaced between stations 1 and 8.

Each of blades 1 – 4 pivots through 180 degrees between its retracted and operating positions. From axis 21 to tip 61, representative blade 1 when retracted extends from $\theta = 0$ degrees to $\theta =$ approximately 168 degrees. The angle 168 degrees is chosen to be close to, but below, 180 degrees so as to provide a blade 1 whose tip 61 is well clear of enclosure peripheral edge 26 when blade 1 is deployed, but with no more than two of blades 1 – 4 overlapping each other at any point when the blades are retracted. This is important in keeping the overall height of the group of blades 1 – 4, when retracted, to a compactly small value. Note that if tip 61 were at $\theta = 180$ degrees, all three of blades 1, 2 and 3 would overlap at $\theta = 180$ degrees.

As can be seen in Figures 1, 5 and 7, representative blade 1 has two distinct portions, namely a root-end portion 80 and a blade portion 82 which in the operating position extends outwardly of peripheral edge 26 of enclosure 12 and is aerodynamically shaped to facilitate air movement. Blade portion 82 is supported cantilever-fashion from blade portion 80 which is pivotably secured to blade support plate 14. In the preferred embodiment, portions 80 and 82 are formed as a single part, for example by injection molding in a suitable plastics material.

Root end portion 80 comprises a plate 84 that lies above and, approximately parallel to support plate upper surface 46. A hole 86 in plate 84 permits a stub shaft (not shown) to pass through it and through to the underside of support plate 14 to be secured there to a planet gear (not shown) of the blade synchronization mechanism as described previously. Root end

portion 80 further comprises a blade end plate formation 88 whose function is to provide a suitably strong connection between portions 80 and 82 with blade portion 82 inclined at an angle of incidence to plate 84 (see below).

Figure 12 shows a set of 12 radial sections (i.e. on planes 42) of representative blade 1 and its next and previous blades 2 and 4 in their retracted positions, each section being labeled with its correct value of theta for blade 1. Radii from fan axis 15 increase to the right in sections (a) to (l). In each section, blade support plate 14 is shown, with its outer edge 90 at the same lateral position on each page to facilitate comparison between the sections. Outer edge 90 lies radially just within but is close to the enclosure peripheral edge 26 (not shown in Figure 12).

Sections (a) to (c) of Figure 12 show how portion 80 of blade 1 transitions to the cantilevered air-moving portion 82.

As can be best seen in Figure 10, outer edge 94 of portion 82 of representative blade 1 is very close to a circular arc except near the rounded tip 61, that arc being centred on fan axis 15 when blade 1 is retracted and having a radius very close to the radius of enclosure peripheral edge 26. Accordingly outer edge 94 of portion 82 of blade 1 lies at almost exactly the same radius as the outer edges of next and previous blades 2 and 4, except near tip 61, as shown in sections (d) to (l) of Figure 12.

Figure 10 and sections (a) to (f) of Figure 12 show that previous blade 4 overlies representative blade 1 between $\theta = 0$ degrees and slightly less than $\theta = 90$ degrees, but without contact between blades 1 and 4. Between $\theta = 90$ degrees and $\theta = 165$ degrees (sections (g) to (l)) blade 1 itself overlies next blade 2, without contact between blades 1 and 2.

Figure 13 is a graph showing the heights of inner edge 92 and outer edge 94 of representative blade 1 above surface 46 of support plate 14 as a function of angle theta. Inner edge 92 is higher than outer edge 94 for a given value of theta, consistently with blade 1 having an angle of incidence to the horizontal so as to move air downward when deployed (see below). Absolute height figures are used in Figure 13, for a fan/light 10 having an overall swept diameter with blades 1 – 4 deployed of 1200mm.

Figure 14 is a graph showing the radial distance between inner edge 92 and outer edge 94 of representative blade 1 when in its retracted position

as a function of angle theta. Absolute radial distances are used in Figure 13, for a fan/light 10 having an overall swept diameter with blades 1 – 4 deployed of 1200mm. The curve between data points has not been extended to the data point for theta = 165 degrees because that point is affected by rounding of tip 61:

Figure 15 is a graph showing the same data as Figure 13, but now for all of blades 1 – 4, in their respective peripheral angle (theta) positions. The initials "LE" and "TE" are used for inner and outer edges 92 and 94 respectively in Figure 15, because the inner edge of a blade is its leading edge and the outer edge is its trailing edge, when in the deployed position. Note that the blade pivot axes 21, 22, 23 and 24 are at angles theta of 0 degrees, 90 degrees, 180 degrees and 270 degrees, respectively.

Figure 12 – 15 together illustrate how blades 1 – 4 in their retracted positions "nest" compactly together without any two blades contacting each other. It has been found that the arrangement shown can also give satisfactory air moving performance.

As illustrated by the edge heights in Figures 13 and 15, representative blade 1 rises smoothly from its pivot axis 21 (at theta = 0 degrees) to a point (at about theta = 90 degrees) where it must overlap and clear the next blade 2. However, instead of continuing further upward at the same rate towards its tip 61, blade 1 ceases to rise any higher, as shown by the leveling off and then decreasing of the height of inner edge 92 with increasing theta. This arrangement limits the overall height 96 (Figure 12) above support plate 14 of the group of blades 1 – 4 when retracted. The maximum value of height 96 occurs for representative blade 1 at about theta = 105 degrees.

It will be noted in Figure 13 and 15 that, after remaining approximately constant between about theta = 90 degrees and theta = 120 degrees, outer edge height 94 increases again beyond about theta = 120 degrees. As can be seen from sections (j) to (l) in Figure 12, and from the slight protrusion of blade 1 shown in Figure 4, this optional feature means that some slight sacrifice of compactness in the blade nesting arrangement is incurred (although without any increase in overall height 96), it is believed to be aerodynamically desirable, as set out later herein, and so is preferred.

Figure 13 can be interpreted as a partial picture of blade 1 as it would appear if projected on an imaginary cylindrical surface coaxial with fan axis, with that surface then being laid flat. It is apparent that blade 1 in such a picture resembles a gull wing, or an aircraft wing with a particular form of varying dihedral, firstly rising with increasing distance from its root end and from a certain point rising no further or at a lesser rate towards its tip end.

Figure 15 shows that the inner edge height 92 of representative blade 1 becomes lower than the leading edge height of its next blade 2 for values of theta greater than about 150 degrees. This can be seen in sections (k) and (l) of Figure 12. It does not mean that there is contact between blades 1 and 2 because the reduction in radial width of blade 1 means that inner edge 92 of blade 1 is radially outward of the corresponding edge of blade 2.

In addition to folding neatly, the blades 1 – 4 must move air downwards reasonably efficiently when deployed and rotating about fan axis 15, so the shapes of blades 1 – 4 as they affect air movement will now be discussed. The arcs in Figure 11 that are numbered 1 – 8 represent a set of spaced apart cylindrical surfaces coaxial with axis 15 and radially spaced apart. Although the downward air flow through fan/light 10 will not in general be precisely axial (i.e. parallel to axis 15) and therefore occur on such surfaces, a reasonable way to discuss blade shape is by reference to the intersections with the cylindrical surfaces 1 – 8 of representative blade 1 when in its deployed position.

It is also helpful in the following discussion of the representative blade 1 when it is deployed to make mention of values of the angle theta that was used above in describing its geometry when retracted. Theta is in effect a measure of position along the scimitar-shaped blade 1. In Figure 11, there is shown a non-physical point 101 that if blade 1 were to be retracted would fall on axis 15, and that when blade 1 is deployed is displaced by 180 degrees from axis 15 about the blade pivot axis 21. The value of angle theta corresponding to a particular feature on deployed blade 1 can be found using the schematic plan view of Figure 11 by constructing firstly a line joining point 101 to the feature in question and secondly a line 102 joining point 101 and passing through axes 21, 15 and 23. Theta is the angle between these two lines.

Figure 16 shows cross sectional views of blade 1 taken on chords 100 (see Figure 10) that are tangent to the cylindrical surfaces of stations 1 to 8. These are close approximations to the shapes of the cylindrical surfaces of intersection between stations 1 to 8 and blade 1, as those surfaces would appear if laid flat. In the sections of Figure 16, blade 1 moves right to left, so the leading edge 92 and trailing edge 94 are positioned as shown. Although trailing edge 94 is of course not straight in reality, the views in Figure 16 are so positioned that the trailing edge 94 in all sections is vertically aligned to facilitate comparisons among them.

Figure 17 is a graph showing α (α), the angle of incidence to the horizontal of representative blade 1 at stations 2 to 8, the meaning of α being illustrated in the section for station 7 in Figure 16. The values of α plotted in Figure 17 are not taken from the approximate sections of Figure 16, but are estimates of the values that would be obtained in the manner shown if the sections of Figure 16 were laid-flat developments of the true surfaces of intersection between the cylindrical surfaces numbered 2 to 8 and blade 1.

Figure 18 is a graph showing values of the true chord (i.e. distance measured directly from leading edge 92 to trailing edge 94) of blade 1 at intersections with the cylindrical surfaces numbered 1 to 8. The chord values are not taken from the approximate sections of Figure 16, but are estimates of the values that would be obtained if the true surfaces of intersection between blade 1 and the cylindrical surfaces numbered 1 to 8 were obtained and laid flat.

It has been found that fan/light 10 with blades 1 – 4 having the geometry shown does move air reasonably satisfactorily despite the comparatively large ratio of the diameter of enclosure 12 to the overall diameter swept by the deployed blades 1 – 4 and the scimitar-like shape (in plan view) of the blades.

Generally, the blades 1 – 4 thrust air downward (and themselves experience a corresponding reactive lifting force) as they rotate. The effectiveness of a blade in this (for a given speed of rotation) is believed to be dependent on, at least, its aerofoil-type cross sectional shape, its incidence to the horizontal, its size (for example its chord as measured from leading edge

to trailing edge), the distribution of these along the blade's length (span) and its shape as seen in plan view.

As seen in the cross-sections of representative blade 1 in Figure 16, blades 1 – 4 have an aerofoil-type cross-sectional shape, being cambered so that their lower faces are concave and their upper faces are convex. Their leading edges (eg leading edge 92 of representative blade 1) are rounded and their trailing edges (eg edge 94 of representative blade 1) are sharp. Generally, blades 1 – 4 are preferred to have cambered aerofoil sections.

Representative blade 1 has positive incidence to the horizontal (and is of cambered aerofoil cross-section) near its pivot end where, when deployed, it crosses the enclosure peripheral edge 26, and this is believed to be one factor in its air-moving performance. This positive incidence (alpha greater than zero) is apparent in the section numbered 1 in Figure 16.

It is thought desirable that the lift distribution (and the consequent distribution of air moving effect) along the length of a blade should be generally smoothly varying and in particular that there should be no strong concentration of the effect close to the outer (tip) end. Such a concentration is thought to produce a tendency for high pressure air below the tip area to "leak" upward over the tip end (61 in representative blade 1) to the area above the tip area, merely agitating the air locally (and wasting power) rather than moving it bodily downward. Therefore, the distribution of incidence angle alpha shown in Figure 17 shows that the peak blade incidence of about 20 degrees is at about the radius of station 3 (see Figure 11) and smoothly decreases with increasing radius to about 10 degrees at station 8. (Station 3 corresponds very approximately to $\theta = 60$ degrees.)

The incidence distribution shown in Figure 17 is due in part to the optional upsweeping of the blade trailing edge beyond about $\theta = 120$ degrees that was discussed above. Although a slightly more compact nesting of blades 1 – 4 is achievable if this upsweeping is not incorporated, it does appear to be beneficial to the blades' performance due to its effect on the incidence distribution achieved.

A further way to influence the lift distribution along the blade is by control of its width (chord) distribution. If one imagines a scimitar shaped blade of constant width along its length (for example for all values of the θ)

deployed in the way shown for blades 1 – 4 in Figure 11, an effect of the scimitar shape would be that the blade chord, as measured in the circumferential direction with the blade deployed, would be highest at the blade tip and root end and lower therebetween. To offset this effect and so
5 limit the tendency to concentrate the lifting effect at the tip and root ends, blades 1 – 4 are not of constant width. Referring to Figure 14, the blade width as seen in plan view) is greatest at about $\theta = 90$ degrees and progressively reduces towards the tip end (61 for representative blade 1). As
10 can be seen in Figure 11, $\theta = 90$ degrees corresponds approximately to station 5. This reduction serves the dual purposes of compact nesting of the blades when retracted (as discussed above) and obtaining the desired blade lift distribution.

Figure 18 shows the blade chord increasing from a minimum in the region of stations 2 and 3 before falling away at station 8 due to tip rounding.
15 However, the rate of increase in chord with radius is less than it would be if the blade width did not vary with angle θ in the way described herein. See also Figure 16, where the alignment of the sections numbered 1 to 8 on the page allows the distribution of chord with radius to be seen.

As mentioned above the blades may be made conveniently by injection
20 molding in suitable plastics materials. As unobtrusiveness is a desired feature of fan/lights according to the invention, one way of enhancing this is to provide that the blades be formed from a transparent or at least translucent material. This feature is believed to be inventive in itself.

Although the blade stowage arrangement and method described herein
25 provides for stowage of the blades without contact between blades, the described stowage positions of the blades are such that slight sagging of one blade so as to contact another may not cause failure to deploy. It will be noted in Figure 12 that the sectional view showing the smallest clearance between blade 1 and its next blade 2 is section (g), corresponding to $\theta = 90$
30 degrees. This is thought to be a suitable position for minimum clearance and so for first contact between blades 1 and 2 to occur if after a period of stowage without fan use, blade 1 should sag slightly. It is thought that after such contact between blades 1 and 2, the tendency to further sagging would be limited and the moment arm about axis 21 of any friction force due to blade

contact less than for contact between tip 61 of blade 1 and the underlying blade 2, thus, limiting the possibility of a failure of blade 1 to deploy on fan startup.

5 The possibility of blades that are comparatively thin (so that they may sag over time if not used) also means that the blades when in use may flex upwardly toward their tip ends. This can it is believed advantageously direct air slightly more outwardly as well as downwardly than if the blades were rigid.

10 The particular shape of the translucent lower section 9 of enclosure 2 is by no means the only possible one. Even a shape that is not of the circular shape in plan, as shown in the Figures 1 to 7 could be used as an alternative aesthetic choice.

15 A further invention will now be disclosed. In fan/lights such as those described by Villélla in his aforementioned PCT application, the "sun gear" may comprise a single member to which toothed segments are secured for engagement with the "planet gears", instead of a complete gear. This possibility, which it has been found can reduce manufacturing costs arises because suitable sun and planet gear proportions can be chosen which do not require the sun gear to rotate far enough during deployment and retraction for any one tooth thereof to encounter more than one planet gear.

20 It will be readily apparent to persons skilled in the art that many other variations and choices can be made to the fan/light described above without exceeding the scope of the invention as stated.

CLAIMS

1. A combined ceiling fan and light fitting having a plurality of fan blades, wherein:

5 each blade is pivotally mounted so as to be pivotable about an upright pivot axis of the blade between a stowed position and a deployed position;

each blade when in its stowed position lies within a specified radius from an upright fan rotation axis and above a light fitting portion and has an air moving portion that in the deployed position of the blade extends beyond said specified
10 radius; and

each blade is generally elongate and arcuate when seen in plan view and in its stowed position extends peripherally within said specified radius between its pivot axis and a tip end of the blade and partially overlies a neighbouring one of the blades in its own stowed position;

15 characterized in that:

(a) each blade initially rises in height above a datum height with increasing distance along the blade from its pivot axis end so that the blade when in its stowed position overlies the pivot axis end of the neighbouring blade in its own stowed position and

20 (b) with increasing distance from a pivot-axis end of the air moving portion towards the tip end of the blade the leading edge of the air moving portion first increases in height above the said datum height and then turns downwardly whereby to limit the height of the tip end above the datum height.

25 2. A combined ceiling fan and light fitting according to claim 1 wherein said specified radius is approximately a radius of a light fitting portion that is comprised in the combined ceiling fan and light fitting and located below the blade and that is of circular shape when seen in plan view.

30 3. A combined ceiling fan and light fitting according to claim 1 or 2 wherein the leading edge of the air moving portion of each blade has a peak height above the

datum height at a position between the pivot-axis end of the air moving portion and the tip end of the blade.

4. A combined ceiling fan and light fitting according to claim 3 wherein the height above the datum height of the leading edge of the air moving portion declines from said peak height with increasing distance along the leading edge toward the tip end of the blade.

5. A combined ceiling fan and light fitting according to any one of claims 1 to 4 wherein the air moving portion of each blade has a trailing edge that when seen in plan view is approximately a circular arc which when the blade is in its stowed position said is substantially centred on the fan rotation axis.

6. A combined ceiling fan and light fitting according to claim 5 wherein for each blade when in its stowed position the radial distance between the leading and trailing edges of the air moving portion reduces progressively from a maximum value partway along the length of the air moving portion towards the blade tip end.

7. A combined ceiling fan and light fitting according to claim 6 wherein when all blades are in their stowed positions there is for each blade a first point on the leading edge of its air moving portion where the blade overlies its neighbouring blade which first point when seen in a notional radial plane including the fan rotation axis lies at a greater radius than a second point in the same notional plane that is on the leading edge of the overlain neighbouring blade.

8. A combined ceiling fan and light fitting according to claim 7 wherein the said first point is at a height above the datum height not exceeding the height of the said second point.

9. A combined ceiling fan and light fitting according to any one of claims 1 to 8 wherein the air moving portion of each blade has in the deployed position of the blade a maximum angle of incidence to the horizontal at a position partway along the air moving portion the angle of incidence decreasing with increasing distance from that position of maximum incidence towards the tip end of the blade.

10. A combined ceiling fan and light fitting according to any one of claims 1 to 9 wherein the air moving portion has a positive angle of incidence to the horizontal at its pivot-axis end.

11. A combined ceiling fan and light fitting according to claim 9 or 10 wherein the position partway along the air moving portion of each blade at which its incidence to the horizontal is a maximum when the blade is in its deployed position is radially inboard of a position at which the blade chord measured along an arc centred on the fan rotation axis is at a maximum value.

12. A combined ceiling fan and light fitting according to any one of claims 1 to 11 wherein the number of blades is four and the blades' pivot axes are spaced 90 degrees apart from each other peripherally.

13. A combined ceiling fan and light fitting according to claim 12 wherein that section of each blade between its pivot axis and its tip end when the blade is in its stowed position subtends an angle of about 160 to 170 degrees at the fan rotation axis.

14. A combined ceiling fan and light fitting according to claim 12 or 13 wherein each blade pivots through an angle of about 180 degrees to move from its stowed position to its deployed position.

15. A combined ceiling fan and light fitting according to any one of claims 1 to 14 wherein the air moving section of each blade is upwardly cambered (i.e.

concave downwards) between its leading and trailing edges when seen in cross-section on a cylindrical surface centred on the fan rotation axis and intersecting the air moving section at a radius between the specified radius and the blade tip end.

5

16. A combined ceiling fan and light fitting according to any one of claims 1 to 15 wherein the air moving section of each blade has a rounded leading edge and a sharp trailing edge over at least part of its along-blade length when seen in cross-section on a cylindrical surface centred on the fan rotation axis and intersecting the air moving section at a radius between the specified radius and the blade tip end.

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17. A combined ceiling fan and light fitting according to any one of claims 1 to 16 wherein the minimum height difference between each blade and its neighbouring blade when the blades are in their stowed positions occurs approximately where the blade overlies its neighbouring blade.

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18. A combined ceiling fan and light fitting having a plurality of elongate and arcuate planform blades that can move pivotally about upright axes between firstly stowed positions above a light fitting enclosure and secondly deployed positions in which the blades extend outwardly beyond the light fitting, characterized in that leading edges of the blades when in their deployed positions firstly rise with increasing radius beyond the light fitting enclosure first and thereafter are cranked downwardly.

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19. A combined ceiling fan and light fitting according to claim 20 wherein when the blades are in their stowed positions each blade overlies a part of its neighbouring blade which part is received in a gap above the light fitting enclosure and below the underside of the overlying blade said gap existing by virtue of the cranked shape of the overlying blade.

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- 27 -

20. A combined ceiling fan and light fitting according to claim 18 or 19 wherein each blade is pivotally mounted to a rotating member and said gap lies above said platelike member.

21. A combined ceiling fan and light fitting having a plurality of fan blades, wherein:

each blade is pivotally mounted so as to be pivotable about an upright pivot axis of the blade between a stowed position and a deployed position;

each blade when in its stowed position lies within a specified radius from an upright fan rotation axis and above a light fitting portion and has an air moving portion that in the deployed position of the blade extends beyond said specified radius; and

each blade is generally elongate and arcuate when seen in plan view with concave and convex sides and in its stowed position extends peripherally within said specified radius between its pivot axis and a tip end of the blade

characterized in that:

(a) each blade when deployed is so positioned that a concave side of the blade faces forward in the blade's direction of rotation and so that a radially outer portion of the blade's length extends both outwardly and forwardly;

(b) there is a first position partway along the air moving portion of the blade at which the blade's chord as measured in a peripheral direction has a maximum value and a second position partway along the air moving portion of the blade at which the blade has a maximum positive angle of incidence to the horizontal; and

(c) the first position is at a greater radius than the second position.

22. A combination ceiling fan and light fitting comprising a plurality of retractable fan blades, wherein:

- 28 -

each said blade is pivotally mounted to a fan member that is rotatable about an upright fan rotation axis so that said blade is pivotable between a retracted position and an operating position about an upright blade pivot axis of said fan member;

5 each said blade has an elongate and generally arcuate air moving blade portion that when said blade is in the retracted position of said blade lies within a space bounded by:

(a) an inner cylindrical surface coaxial with said fan rotation axis and touching an inner edge of said blade portion;

10 (b) an outer cylindrical surface coaxial with said fan rotation axis and touching an outer edge of said blade portion;

(c) a first radial plane containing said fan rotation axis and said blade pivot axis; and

(d) a second radial plane containing said fan rotation axis and that
15 touches a tip of the blade,

so that associated with every point on said blade portion is an angle θ being an angle between said first radial plane and a radial plane containing the fan rotation axis and that point; and

within a continuous section of the blade portion that lies between said first
20 and second radial planes, said inner edge increases in height above a datum height with increasing θ , and a radial projection of said inner edge onto a cylindrical surface coaxial with said fan rotation axis is concave downwards.

23. A fan blade adapted for use in a combined ceiling fan and light fitting
25 according to any one of claims 1 to 22.

24. A fan blade according to claim 23 that is sufficiently flexible to bend upward towards its tip end when used in a ceiling fan.

30 25. A combined ceiling fan and light fitting having a plurality of fan blades, wherein:

- 29 -

each blade is pivotally mounted so as to be pivotable about a pivot axis of the blade between a stowed position and a deployed position;

each blade when in its stowed position lies within a specified radius from a fan rotation axis and above a light fitting portion and has an air moving portion that
5 in the deployed position of the blade extends beyond said specified radius; and

each blade is generally elongate and arcuate when seen in plan view and in its stowed position extends peripherally within said specified radius between its pivot axis and a tip end of the blade and partially overlies a neighbouring one of the blades in its own stowed position;

10 characterized in that:

(a) each blade initially rises in height above a datum height with increasing distance along the blade from its pivot axis end so that the blade when in its stowed position overlies the pivot axis end of the neighbouring blade in its own stowed position and

15 (b) with increasing distance from a pivot-axis end of the air moving portion towards the tip end of the blade the leading edge of the air moving portion first increases in height above the said datum height and then turns downwardly whereby to limit the height of the tip end above the datum height.

20 26. A combined ceiling fan and light fitting having a plurality of elongate and arcuate planform blades that can move pivotally about axes between firstly stowed positions above a light fitting enclosure and secondly deployed positions in which the blades extend outwardly beyond the light fitting, characterized in that leading edges of the blades when in their deployed positions firstly rise with increasing
25 radius beyond the light fitting enclosure first and thereafter are cranked downwardly.

27. A combined ceiling fan and light fitting having a plurality of fan blades, wherein:

30 each blade is pivotally mounted so as to be pivotable about a pivot axis of the blade between a stowed position and a deployed position;

- 30 -

each blade when in its stowed position lies within a specified radius from a fan rotation axis and above a light fitting portion and has an air moving portion that in the deployed position of the blade extends beyond said specified radius; and

5 each blade is generally elongate and arcuate when seen in plan view with concave and convex sides and in its stowed position extends peripherally within said specified radius between its pivot axis and a tip end of the blade

characterized in that:

(a) each blade when deployed is so positioned that a concave side of the blade faces forward in the blade's direction of rotation and so that a radially
10 outer portion of the blade's length extends both outwardly and forwardly;

(b) there is a first position partway along the air moving portion of the blade at which the blade's chord as measured in a peripheral direction has a maximum value and a second position partway along the air moving portion of the blade at which the blade has a maximum positive angle of incidence to the
15 horizontal; and

(c) the first position is at a greater radius than the second position.

28 A combination ceiling fan and light fitting comprising a plurality of retractable fan blades, wherein:

20 each said blade is pivotally mounted to a fan member that is rotatable about a fan rotation axis so that said blade is pivotable between a retracted position and an operating position about a blade pivot axis of said fan member;

each said blade has an elongate and generally arcuate air moving blade portion that when said blade is in the retracted position of said blade lies within a
25 space bounded by:

(a) an inner cylindrical surface coaxial with said fan rotation axis and touching an inner edge of said blade portion;

(b) an outer cylindrical surface coaxial with said fan rotation axis and touching an outer edge of said blade portion;

30 (c) a first radial plane containing said fan rotation axis and said blade pivot axis; and

- 31 -

(d) a second radial plane containing said fan rotation axis and that touches a tip of the blade,

so that associated with every point on said blade portion is an angle θ being an angle between said first radial plane and a radial plane containing the fan rotation axis and that point; and

within a continuous section of the blade portion that lies between said first and second radial planes, said inner edge increases in height above a datum height with increasing θ , and a radial projection of said inner edge onto a cylindrical surface coaxial with said fan rotation axis is concave downwards.

10