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# USING THE CASIMIR FORCE FOR THE CONTROLLED MOTION OF MACROBODIES

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**Abstract**

Considered the Casimir effect for construction «angle bar». Theoretically discovered uncompensated force in the direction from the top of the angle bar to its opening angle. Assessment of the magnitude of this force.

**Keywords**: the Casimir effect, virtual photons, virtual particles, thrust force, tractive force, «angle bar», wedge,photon vacuum, experiments on the Casimir effect.

In 1948, Kazimir was theoretically predicted effect, later called his name [1]. The effect is that for each of the two placed opposite to each other flat, parallel conducting plates in a vacuum, normal to him, there are forces not gravitational origin, seeking to draw them closer (Fig 1).

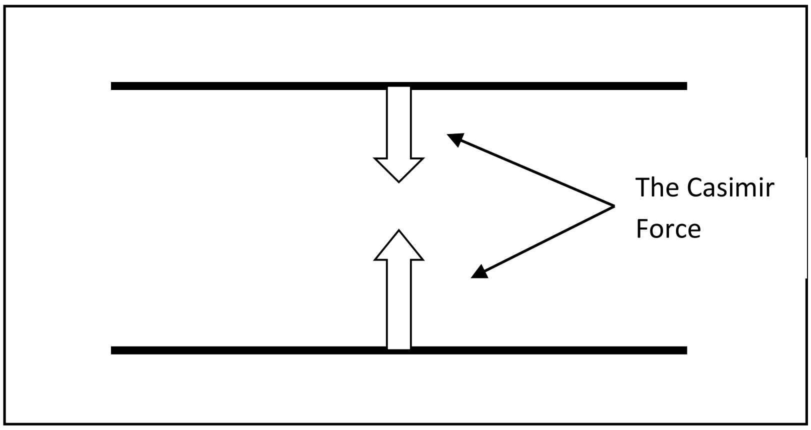



Fig 1

Classic Casimir effect.

Modern explanation of the emergence of these forces is that they are caused by a difference in pressure of virtual photons on a plate inside and out. According to the laws of quantum mechanics, between the plates can be only photons with such wavelengths that are multiples are placed in the gap between the plates. Thus, the gap is missing the main part of virtual photons present in free space, and with arbitrary wavelengths. As a result, the pressure on the plate outside significantly higher than the internal pressure which causes the appearance of the Casimir force.

**2.** The Casimir force for 2 flat conductive surface, per unit area, equal:

$$Fc = -\frac{\pi^2}{240} * \frac{\hbar c}{d^4} \quad , \qquad (1)$$

where "-" means that there is an attraction plates to each other, ħ – Planck's constant, c is the speed of light, and d is the distance between plates [2].

Numerically $F_c$ [dyn**]= $1.3*10^{-18} * S/d^4$ , where S and d are measured in [cm]. For example, for plates with an area of 1 $cm^2$ and d= 10 nm, the power will be approximately $10^6$ dyn, i.e. the pressure on the plate will be of the order of atmospheric !

The value of the Casimir force confirmed in experiments, beginning in 1958, [3] and coincides with the theoretical value for a wide range of geometries: flat plate, the plate and the sphere, two cylinders, nanoconstruction etc. (see, for example, N 7-15 in the list of references to [4] and N 13-21 in the list of references to [5]).

Today the accuracy of experiments comes to percent from theoretical values, that confirms the existence of the Casimir force, as a physical phenomenon and also the correctness of the calculation of its value.

**3.** To study the properties of the Casimir force, in particular, is actively used the geometry of the “sphere + plane” (Fig 2), [4], [5], [6].

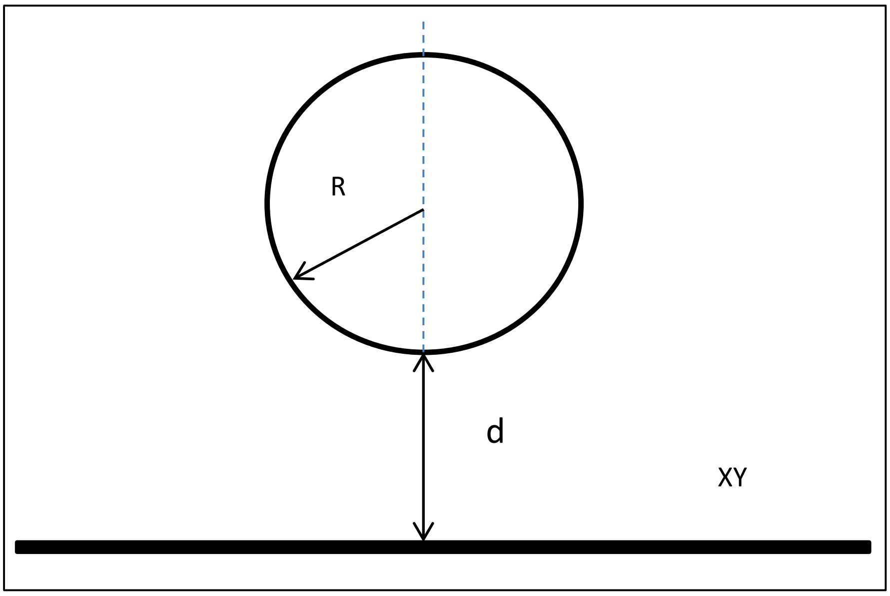



Fig 2

The geometry of the “sphere + plane”

The theoretical value of the Casimir force for the sphere and the plane (for the case d << R) is given by the expression [5].:

$$Fc = -\frac{\pi^3}{360} * \frac{\hbar c}{d^3} * R \qquad (2).$$

This formula can be derived from (1) with the most common and natural approximations, known as PFA (Proximity Force Approximation), or PAA (Pairwise Additive Approximation), the calculation method of [5], [6].

Using the standard method of integration on the sphere, infinitesimal element of its surface $dS = R^2 * \sin(\theta) * d\theta * d\varphi$, replaceable infinitely small, considered due to the size of the flat, tetragon, $dS'$, with the normal, directed by radius at an angle $\theta$ to the Z-axis. The whole sphere is treated as a body, formed an infinite number of infinitesimal tetragons. For natural reasons is considered only the lower hemisphere, i.e. the angle range: $\theta$= [0…π/2] and $\varphi$= [0…2π).

Every element $dS'$ projected onto a plane parallel to the XY plane in the element $dS''$. Next, using the expression (1), the computation of the force, considering as plates element $dS''$ and equal to him (in the square) element $dS_{XY}$ , XY plane underneath. Distance $d_{tek}$ is the distance between the XY-plane and the current element $dS'$ and, therefore, varies from d0 to d0+R. The direction of the Casimir force is normal to the element $dS'$, i.e. the angle $\theta$ outwards (Fig 3).

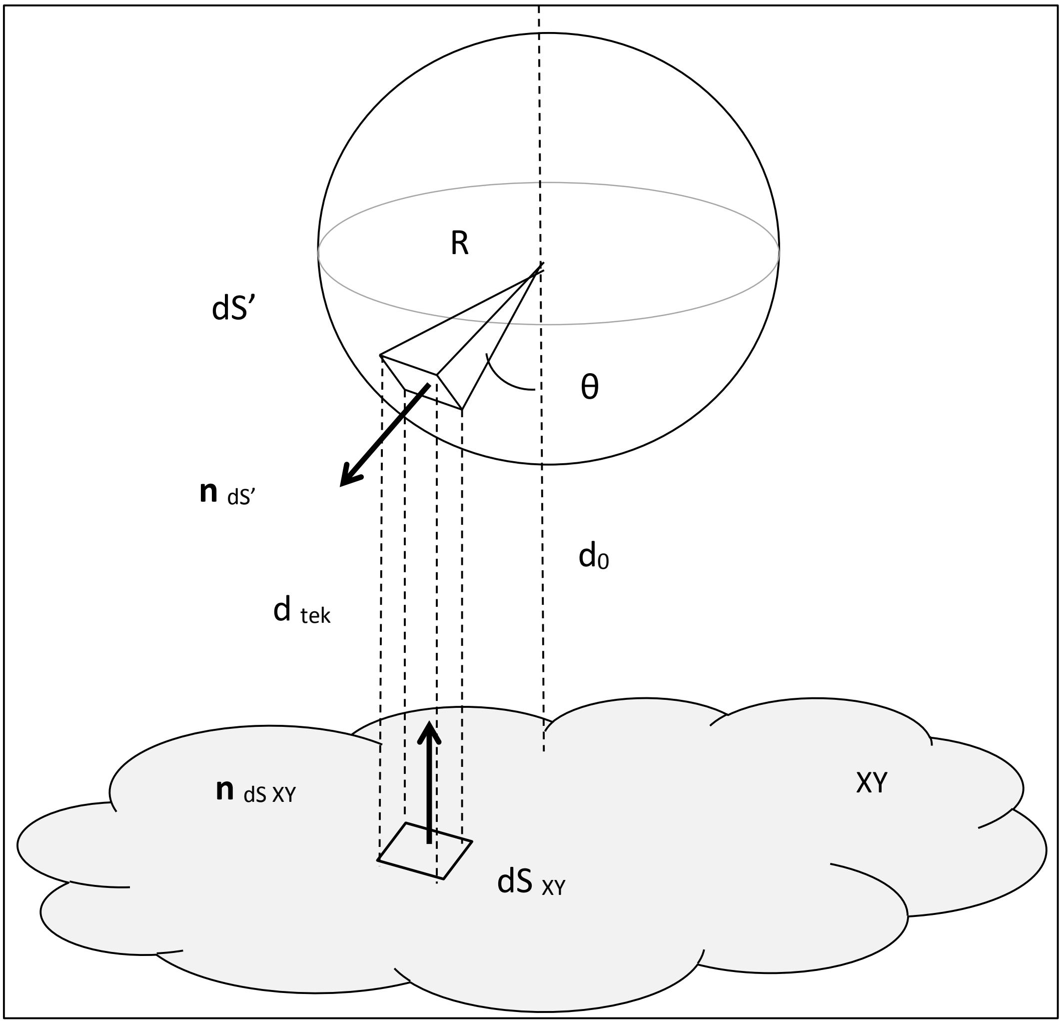



Fig 3

Calculation of the Casimir force in the geometry of the “sphere + plane”

After integration (and by restricting d<<R), we obtain a simple analytical expression for the Casimir force between a sphere and a plane (2).

It should be noted that the condition d<<R is used only to obtain a compact analytical expressions, i.e. to simplify calculations and further intelligence, and not as a physical constraint affecting the property or the existence of the Casimir force in this geometry.

We also note the important fact, which of the infinite number of elements $dS'$ this hemisphere, only **ONE**, namely the element at the bottom of its points, parallel to the XY plane. Thus, only one element is observed for the geometry of plane-parallel plates source Casimir effect.

**4.** Experiments with different geometries demonstrates the presence of forces, comparable in order of magnitude with the Casimir forces for plane-parallel plates of comparable size. This directly indicates that the Casimir force exists and is close intensity, as between parallel, and between non-parallel surfaces, i.e., by and large - always and everywhere.

As for the geometry of the “sphere + plane”, and for other geometries, the values measured Casimir forces were equal to the calculated with an accuracy of 1%, for example [7].

Thus, based on experiments, it can be argued that the Casimir force between a sphere and a plane there and can be correctly calculated using expression (2),

Formula (2) is a direct consequence of application (1) to the surfaces with curvature and located at arbitrary angles to each other. This follows from the fact that in the geometry of the “sphere + plane”, the angle between the normal to the element $dS'_j$ and axis Z changes from: $\theta$= 0 to (π/2) (the Z-axis is normal to the plane of XY).

Thus, the coincidence of the results of several experiments with the calculation made by (2), confirmed a basic applicability of the expression (1) for the calculation of the Casimir forces in arbitrary geometries.

**5.** Now let's ask ourselves about the direction of the Casimir forces in geometry flat, but not parallel plates.

As noted above, the expression (1) works in the case of arbitrary geometry and curvature, so it works in the simplest case: in case of planes, each at an arbitrary angle to each other.

Place the plate in the following way: one from the same party will bring them into contact, and the opposite party shall dissolve in hand (Fig 4). We got the "angle bar". This design, resembles in terms of the letter "V" and has an arbitrary length in depth of the picture.

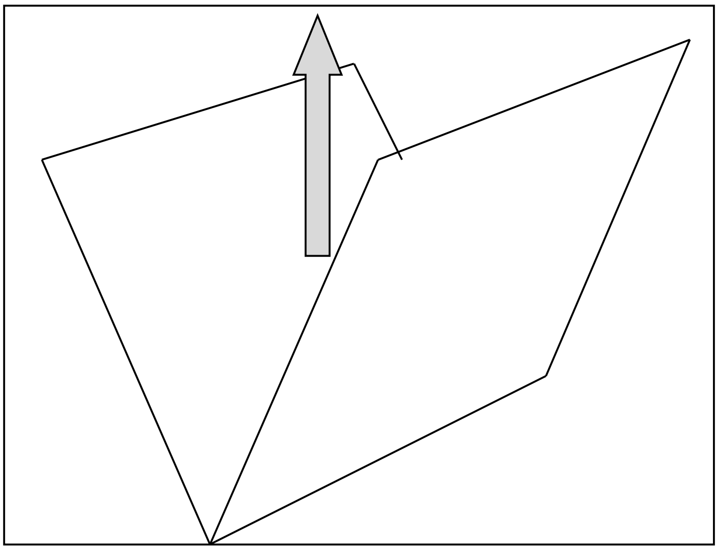


Fig 4.

The design of the "angle bar".

The Casimir force is the result of influence of virtual photons to the site *dS*. When absolutely elastic shock (which is the reflection of a photon) only changes the normal component of momentum $\mathbf{P}_{photon}$, and tangential component remains unchanged. Thus, the vector of momentum $\mathbf{P}_c$ , passed to the *dS* directed along the normal to the surface. We also note the fact that the direction of movement of the photon: top-down or bottom-up does not affect the direction of the momentum of the $\mathbf{P}_c$ (Fig. 5).

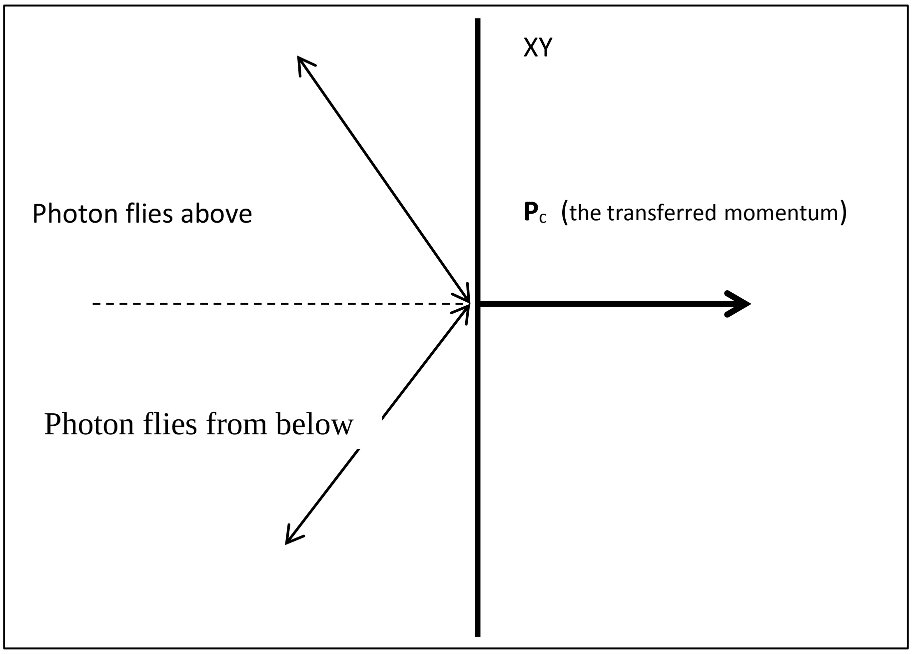



Fig. 5

The impulse is transmitted always in the same direction, regardless of the direction of motion of photons: bottom up or top-down.

Given the above facts and conclusions from them, we come to the conclusion that on each plane, forming this "V", "angle bar":

1. Acts Casimir force is fully similar to how it works on any item sphere $dS'$, not parallel to the XY plane.
2. For the reasons mentioned above, the force acts on each plane normal to it and directed inside the "angle bar".

After decomposition of the Casimir forces $F_c$ (acting on each of the plates) on the components $F_x$ and $F_z$ , we see that:

- x-components of the forces applied to the plates of the area, equal, and directed towards each other. Thus, they are clean Casimir force and aim to bring together the plate.

- z-components of force are SUMMARIZED, resulting in unbalanced forces along the z-axis (Fig. 6).

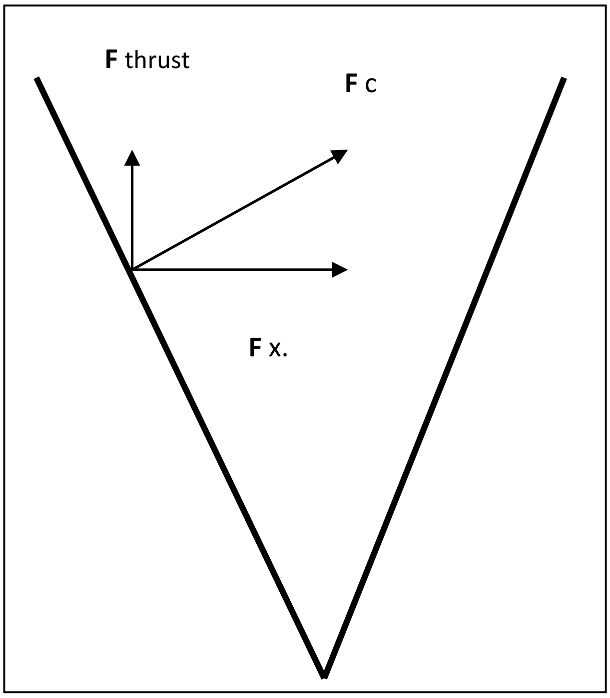



Fig. 6.

The breakdown of the Casimir force (to the left of the surface)

Thus, we came to the conclusion that "angle bar", along the z-axis, is subjected to constant force, created pressure on this macro design of virtual particles (in this case - photons) and this force is directed from the top of the "angle bar" to its solution

We will call this force " thrust" ($\mathbf{F}_{\text{thrust}}$).

**6.** As new effects should be assessed from the point of view of their compliance with the laws of conservation, must immediately and definitely be noted that the existence of a thrust not violate these laws.

The fact that we consider certainly OPEN system, for which the "angle bar" is the only one of its parts and, by itself, does not create any forces.

The emergence **F** $_{thrust}$ due to the interaction of the area with virtual photons, i.e. with vacuum photons Universe that (virtual photons) always exist in space and may not be fully shielded in principle.

To remove difficulties in understanding the essence of the result, it is enough to indicate the almost complete analogy in principle described construction and conventional sails. Both of these designs are just obstacles, are appropriately designed and placed in space, where there is external to him a movement of material elements.

These external elements have the energy and momentum, which is due to global processes, laws, and interactions wearing a fully independent in relation to such private phenomenon as the placement of the "angle bar", or sails in the given point of space-time.

Thus, the force applied to the barrier (the sail or "angle bar"), is a consequence of the pressure of external items on the barrier and does not violate any laws of conservation.

**Now, the "angle bar" is construction, transforming the movement of virtual photons in the managed by vector and thrust the movement of the bodies, i.e. the controlled propulsion.**

**7.** Computing thrust "angle bar" with the (1), in PFA approach (paragraph 3), we get:

$$\mathbf{F}\text{ thrust } = -\frac{\pi^2 \hbar c b}{1440} * \frac{\cos 2\alpha}{(\cos\alpha)^4} * \left(\frac{1}{L\,min^3} - \frac{1}{L\,max^3}\right) \qquad (3)$$

where **b** is the length of the "angle bar" (the letters V "into" pages), $L_{min}$ - the distance between the sides of the area on level $Z_{min}$, $L_{max}$ - the distance between the sides of the area on level $Z_{max}$ . These values are shown in Fig. 7.

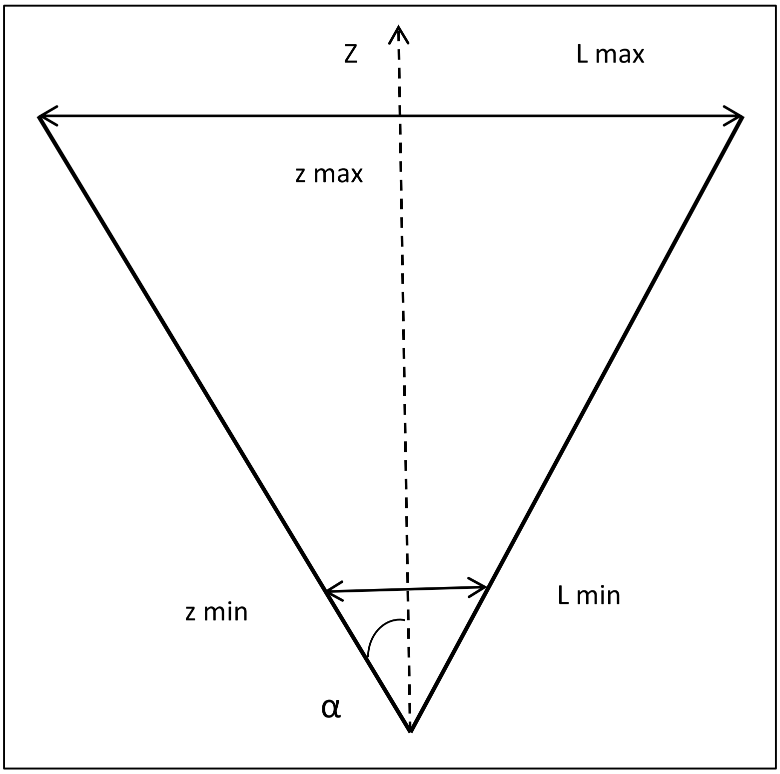



Fig. 7.

For the derivation of the formula (3).

This formula works in the angle range: $0<\alpha<(\pi/4)$. For an angle of $\alpha= 0$ it comes to expression (1) for plane-parallel plates. At angle $\alpha>=(\pi/4)$ approximation PFA for this geometry is not working.

By dependency $\mathbf{F}_{thrust}$ from $(\frac{1}{L\,min^3} - \frac{1}{L\,max^3})$ it is obvious that the value of $L_{max}$, in fact, does not matter, because $L_{max} >> L_{min}$.

Thus, for practical calculations and estimates, we have the following expression (taking $\alpha$~0):

$\mathbf{F}_{thrust}$ [dyn] ~ 217 * b / $(L_{min})^3$, where b is measured in [cm] and $L_{min}$ in [nm].

The value of $L_{min}$ is bounded below the level of "cutting" which is defined technologically:

- precision of manufacture of plates (roughness, degree of flatness) and

- The MINIMUM wavelength photons, which can effectively reflect the substance from which made the "angle bar".

Special attention should be paid to the fact, by dependency $\mathbf{F}_{thrust}$ from $(\frac{1}{L\,min^3})$, the thrust is EXTREMELY sensitive to minor changes $L_{min}$.

The change in (3) other technological parameters, i.e.:

- increasing the reflectivity of the surface and/ or expansion of the range of effectiveness of the reflector in the area of high frequencies and

- the increase in the total length of the "angle bar" (parameter "b" - length V "into the page"),

will increase linearly $\mathbf{F}_{thrust}$.

**8.** To understand where we are (technologically) at the moment, it can be noted that advanced, but not unique modern technology of microelectronics, with appropriate revision, most likely will be able to create propulsion (panel) with dimensions meter by meter and small thickness. Their thrust is equal to the units - tens of dyn's, which is quite possible to use them as propulsion of low-thrust for space constructions.

The panel may look as an Assembly of parts: "VVV...VVV", and the propulsion - as a set of such panels fixed to a managed independent suspensions (Fig. 8).

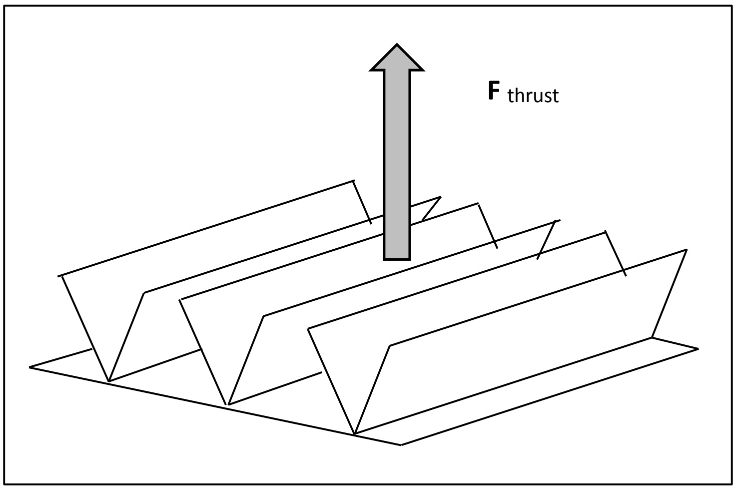
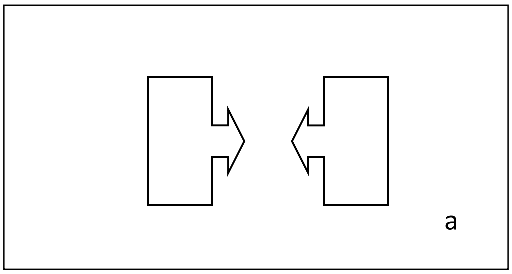



Fig. 8.

Panel design of "angle bar".

Note that for full control of the vector and the thrust of the new devices will be enough two equal panels (Fig. 9).



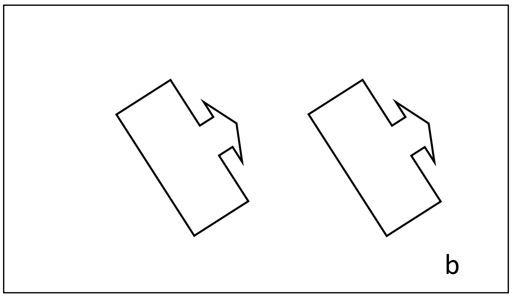



Fig. 9.

The propulsion is based on panels with "angle bar":

a - nothing is moving, b - the movement in any direction

To assess the thrust of the area use the following values:

- material: aluminium (**Al**), density ρ= 2.69 [g/cm$^3$],

- half angle of the "angle bar", α - minimum, units of angular degrees,

- $L_{max}$ >> $L_{min}$,

- the length of the area (the length of one of the sections forming the letter V), L>~ 100 [µm = micrometer],

- "angle bar" fills the entire area possible panel size 1[m] x 1[m] (Fig. 8) so that the distance between corresponding elements in parallel over 200 [µm]. Thus, its total length is b= 500 000 [cm] (5 km)/

To estimate the Angle thrust, the reflection coefficient for all wavelengths is assumed to be 1,

As a result, for Lmin =200 [nm]), we get $\mathbf{F}_{thrust}$ ~ 14 [dyn]. (1 dyn= 1 g*cm/s$^2$ = 10$^{-5}$ N)

Reducing the Lmin to 50 [nm] will provide a thrust force ~ 870 [dyn].

If the Lmin can be brought up to 10 [nm], it will allow to get $\mathbf{F}_{thrust}$ ~ 110 000 [dyn].

Evaluating acceleration unloaded panel have the following values (if the mass of the panel ~ 700g, the size of 1 m x 1 m x 0.5 mm, the coefficient of the hollow= 0.5, the material - **Al**):

- Lmin = 200 [nm]: acceleration a~ 0.02 [cm/s$^2$],

- Lmin = 50 [nm]: acceleration a~ 1.24 [cm/s$^2$],

- Lmin = 10 [nm]: acceleration a~ 160 [cm/s$^2$]= 0.16 [g].

**9.** Qualitative confirmation of the considered effect in the **experiment** can be obtained quite easily and quickly in the result of measurements thrust " angle bar "fixed in a different orientation on the torsion balance.

**10**. The Casimir effect is a macroscopic effect of the existence of virtual photons. The same status of existence have and all other virtual particles - both mass and massless.

In this regard, is of considerable interest experimental study of analogues of the Casimir effect for other fields and particles. Especially interesting assessment of the possibility of obtaining thrust and technologically achievable.

This interest is explained by the obvious assumption that the thrust generated by the massive particles can be significantly greater than the thrust created by a massless virtual photons.

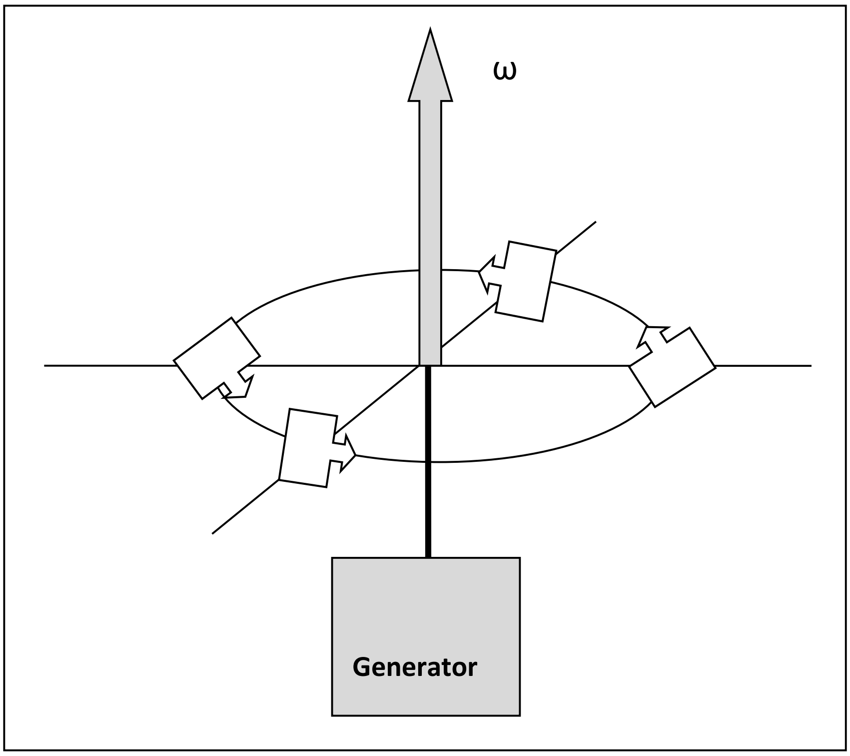



Fig. 10

The use of panels on the basis of " angle bar " to the shaft of the generator.

**11.** Practical application of propulsion based panels with "angle bar" is obvious: from energy generation (when placing them on the shaft conventional generator) (Fig. 10), to create traction engines for moving constructions and vehicles (aircraft, missiles, flying platform, space ships, ocean surface and underwater vessels, vehicles, including a miniature personal).

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