$$w(\varepsilon) = \Phi_{S'} + \Phi_V(\varkappa^2 - (1-\varepsilon)^2) + \Phi_T[\mu_0^2(\varkappa^2 + 2(1-\varepsilon)) + (1-\varepsilon_0^2)(1-\varepsilon)^2] + \Phi_{SV}\mu_0(1-\varepsilon)$$
$$+ \Phi_{ST}[\mu_0^2 + (1-\varepsilon_0^2)(1-\varepsilon)] + \Phi_{VT}\mu_0(1+\varkappa^2-\varepsilon), \qquad (3)$$

where the coefficients Φ do not depend on E_μ; the first three are positive. With conservation of temporal (combined) parity we have $\Phi_{ST} = \Phi_{VT} = 0$. In this case it is possible, in general, to have interference between S- and V-variants ($\Phi_{S'}$ and Φ_{SV}). In contradistinction to the K_{e3} case, it is impossible here to say that the presence of symmetry relative to the point $\epsilon = 1$ means that the interfering terms are zero (in the T-variant we have the term with $1 - \epsilon$).

Integrating over ϵ, which can be done without any assumptions about strong interactions, does not give anything so clear as in the K_{e3} case, and we will not give the result here.

We note that, as in the K_{e3} case, the $K_{\mu 3}$ spectrum of π-mesons can, in principle, give information for determining the form of the functions Φ.

I should like to use this opportunity to express my gratitude to L. B. Okun' for sending the manuscript of his work before publication.

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153

MEASUREMENTS OF MOLECULAR ATTRACTION BETWEEN DISSIMILAR SOLIDS

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THE present report is a continuation of the article[1] in which the basic theory of this problem was given, the method of measurement was described in detail, and the results of measurement of molecular attraction between fused quartz plates and lenses was given.

We chose fused quartz as basic material for preparation of specimens in the first experiments for the following reasons: its transparency allows the use of the most accurate optical method for determining the size of the gap between the surfaces; its surfaces can easily be given a high polish; and, lastly, quartz surfaces are not damaged by the various cleaning methods. All the above qualities of quartz surfaces make it possible to obtain and measure small gaps between the surfaces.

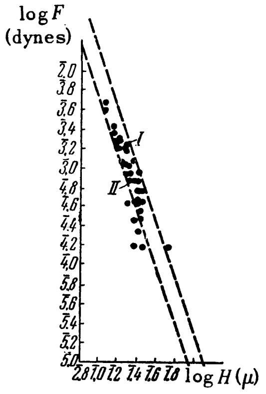

FIG. 1

The smallness of the forces of attraction between macroscopic objects makes it desirable to choose materials which, other things being equal, are characterized by large interaction forces. According to the theory of E. M. Lifshitz[2,3] the magnitude of the interaction force depends only on the electrostatic value of the dielectric constant ϵ_0 for sufficiently large distances between the bodies. The energy of attraction U, per cm^2, of two parallel plates may be written in the form

$$U = -\frac{K}{H^3}, \quad K = \frac{\hbar c}{3}\frac{\pi^2}{240}\left(\frac{\varepsilon_0 - 1}{\varepsilon_0 + 1}\right)^2 \varphi(\varepsilon_0) \qquad (1)$$

(H is the magnitude of the gap between the surfaces, $\hbar$ is Planck's constant, c is the velocity of light, and $\varphi(\epsilon_0)$ is a function tabulated in Ref. 2). For the majority of solid dielectrics the values of ϵ_0 fall in a narrow range. From among the dielectrics with a large value of ϵ_0 we found tallium halogens most convenient for our measurements.

A series of measurements was carried out on the interaction between a plate and a lens made of a mixed TlBr and TlI crystal (42.5 and 57.5% respectively). In Fig. 1 we have plotted on a log-log scale the dependence of the force of attraction F on the separation H for these samples, using a lens with a radius of 12.5 cm. In Fig. 2, where we give the dependence of the specific energy U on the separation H, the points and crosses refer to experiments with a lens of radius R = 12.5 cm and R = 5.2 cm respectively. The dashed lines in Figs. 1 and 2 are the corresponding curves obtained from formulae of Lifshitz in the limit of large separations. The theoretical curve I corresponds to assuming for the mixed tallium halogen crystal a static dielectric constant $\epsilon_0 \approx 50$ and curve II corresponds to $\epsilon = n^2 \approx 6$ (n is the index of refraction in the optical region). Here, as for quartz, the curve II is probably a more accurate approximation (see Refs. 1 and 3). The molecular attraction of these samples is approximately five times that of quartz.

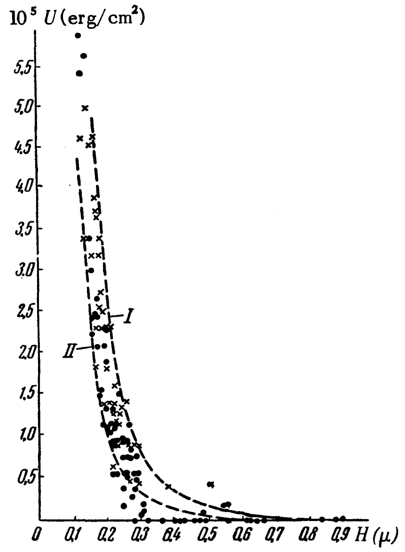

FIG. 2

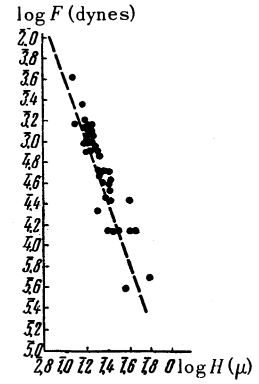

FIG. 3

The large forces of interaction and the simplicity of calculation make metals an interesting object for study; however, we must necessarily use a substantially more complicated method for measuring the gap. We had measured the gap H from the diameters of the Newton's rings seen through the upper of the studied objects. The case of a metal-transparent dielectric pair is simpler, from the point of view of procedure, since the optical method for measuring the gap can be retained. In contrast to the case of two dielectrics, it is necessary in the calculation of the gap H between the quartz and metal surfaces (from the diameters of Newton's rings) to take into account the phase shift on the reflection from the metal. In the corresponding experiments we have used a quartz-glass lens and a quartz plate coated with chromium by evaporating in vacuum. The choice of chromium was dictated by its comparatively small coefficient of reflection of light. This makes possible the observation of sufficiently contrasty interference rings in the gap between the metal and quartz surfaces. Figs. 3 and 4 give graphically the measurements for chromium.

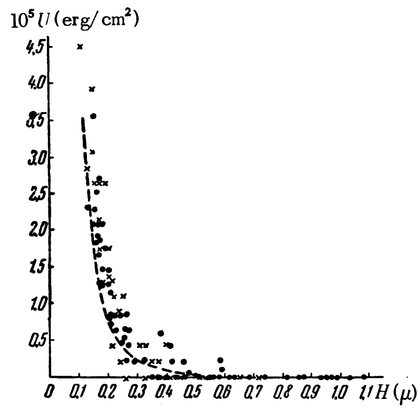

FIG. 4

According to the Lifshitz theory, the estimated interaction force f between a metal and a dielectric at sufficiently large separations is

$$f = \frac{\hbar c}{H^4}\frac{\pi^2}{240}\frac{\varepsilon_0 - 1}{\varepsilon_0 + 1}\varphi_1(\varepsilon_0), \qquad (2)$$

where $\varphi_1(\epsilon_0)$ is the function tabulated in Ref. 3 and the remaining symbols are the same as in Eq. (1). Considering, as in the past, the transparency of quartz for wavelengths of the order of H, we have used for our calculations, the results of which are shown dashed in Figs. 3 and 4, the values ϵ_0 which also equal the squre of the index of refraction in the optical region. In the present case the measured attraction is approximately four times the interaction of quartz surfaces.

We find the agreement between experiment and theory fully satisfactory, considering the inaccuracy of the theoretical estimates and the experimental errors.

It is interesting to note that in the experiments of Prosser and Kitchener[4] precisely the same results were obtained using a method different from ours.

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154

DISPERSION RELATIONS FOR S AND P WAVES FOR MESON PHOTOPRODUCTION IN FIRST ORDER OF 1/m

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THE matrix element of the R-matrix for the transition corresponding to the photoproduction of a meson on a nucleon can be written in the form[1]

$$\langle\pi\,|\,R\,|\,\gamma\rangle=\frac{i\,(2\pi)^4}{\sqrt{4k^0q^0}}\,\delta\,(p_1+q-p-k)\sum_{i=1}^{4}\left(\delta_{\rho 3}A_i^{(1)}+\tau_\rho A_i^{(2)}+\frac{1}{2}\,[\tau_\rho,\,\tau_3]\,A_i^{(3)}\right)\eta_i. \tag{1}$$

Here k, q, p, and p_1 are the momenta of the photon, meson, and nucleon in the initial and final state respectively; η_i are the spin operators which in the center of mass system have the form (e — polarization vector of the photon)

$$\eta_1=i\,(\sigma\mathbf{e});\quad \eta_2=k^{-1}q^{-1}\,(\sigma\mathbf{q})\,(\sigma[\mathbf{k}\times\mathbf{e}]);\ \eta_3=ik^{-1}q^{-1}\,(\sigma\mathbf{k})\,(\mathbf{qe});\quad \eta_4=iq^{-2}\,(\sigma\mathbf{q})\,(\mathbf{qe})$$

and $A_i^{(\lambda)}=A_i^{(\lambda)}(W,x)$, where W is the total energy of the system, $x=\cos\theta$ (θ — scattering angle). The quantities $A_i^{(\lambda)}$ as functions of W obey the dispersion relations[1]

$$\mathrm{Re}\,A_i^{(\lambda)}(W,\,x)=\overset{0}{A}{}_i^{(\lambda)}(W,\,x)+\frac{1}{\pi}\,\mathrm{P}\int_{m+\mu}^{\infty}dW'\sum_{i'=1}^{4}f_{ii'}^{(\lambda)}(W,\,W',\,x)\,\mathrm{Im}\,A_{i'}^{(\lambda)}(W',x'), \tag{2}$$

where $\overset{0}{A}{}_i^{(\lambda)}$ and $f_{ii'}^{(\lambda)}$ are known functions, and x', the cosine of the primed angle, is connected with x, W, and W' by the relation

$$k\,(\omega-qx)=k'\,(\omega'-q'x').$$

It follows from this expression that in the c.m.s., i.e., where $\mathbf{p}+\mathbf{p}_1=0$, the unobservable energy range corresponds to the unobservable range of the primed angles, i.e., the range where $-\infty<x'<-1$. One therefore has to know the analytical properties of $A_i^{(\lambda)}$ as a function of x.

By means of a phase-shift analysis one can obtain expressions for the A_i in terms of Legendre polynomials; for example

$$A_1=\sum_{l=0}^{\infty}\{[lM_{l+}+E_{l+}]P'_{l+1}(x)+[(l+1)\,M_{l-}+E_{l-}]P'_{l-1}(x)\}\ \text{etc.}$$

(ℓ — angular momentum of the meson; the subscript ± refers to the total angular momentum $\ell\pm 1/2$ respectively; $M_{\ell\pm}$ corresponds to magnetic and $E_{\ell\pm}$ to electric multipoles). Let us assume that these infinite series can be terminated [for this to be true the integrals in (2) have to be sufficiently strongly convergent]. Then the $A_i^{(\lambda)}$ will be analytic functions of x. Further one can in (2) eliminate the angles and write down dispersion relations for $M_{\ell\pm}^{(\lambda)}$, $E_{\ell\pm}^{(\lambda)}$. We shall give these limiting ourselves to S and P waves and including recoil corrections up to the order 1/m. Introducing new variables $\epsilon=W-m$; $\epsilon'=W'-m$ we have