N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
PHYSICO-MATHEMATICAL SERIES
ISSN 1991-346X
Volume 5, Number 315 (2017), 13 – 21

UDC 53, 532.133, 621.3.018.72.025.1

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ORGANIZATION OF COMPUTER LAB WORK "CALCULATION AND VISUALIZATION OF FORCED OSCILLATIONS IN THE PRESENCE OF AN EXTERNAL FORCE" WITH THE USE OF THE SOFTWARE PACKAGE MATLAB

Abstract. The organization of computer lab work "Calculation and visualization of forced oscillations in the presence of an external force" is proposed with the use of the Matlab software package: a) external force - constant; b) external force - F = F0 e; c) external force - F = F0e cosβt; d) F = 0 for t <0; F = F0 t / T for 0 <t <T;, F = F0 for t> T. For each of these cases, solutions, calculation programs and visualizations are presented. The results are presented in the form of graphs of the dependence of the acting external force on time and the displacement of the particle from the equilibrium position from time.

Key words: external force, damped oscillation, calculation, visualization, graph.

The capabilities of the Matlab system are huge, and in terms of the speed of tasks, it is ahead of many other similar systems. All these features make the MATLAB system very attractive for use in the educational process in higher education institutions [1].

One of the difficult tasks of introducing the results of the use of information technologies in educational institutions is the insufficient practical ability of teachers to use computer models of physical phenomena to organize computer lab work.

Revitalization, motivation and, ultimately, the effectiveness of training largely depend on the organization of computer laboratory works. We have previously written about the creation and use of models of the organization for the performance of computer laboratory work on the study of various physical phenomena in the educational process [2-20].

This article gives an example of the use of the Matlab system in organizing the computer lab work "Calculation and visualization of forced oscillations in the presence of an external force" for the performance by the students.

Theme of laboratory work No. 1: Calculation and visualization of forced oscillations in the presence of an external force: Determine the forced oscillations of the system under the influence of the external force F (t), if at the initial instant t = 0 the system is at rest in the equilibrium position (x = 0, x = 0) For the following cases:

a) F = const = F0. The system oscillates according to the law

$$x = \frac{a}{m\omega^2}(\omega t - \sin \omega t).$$

Calculation and visualization program

```
>> w=1;
>> a=2;
>> m=0.1;
>> t=0:0.1:30;
```

```
>> x=a./(m*w.^2).*(w.*t-sin(w.*t));
>> plot(t,x,'k-')
>> grid on
```

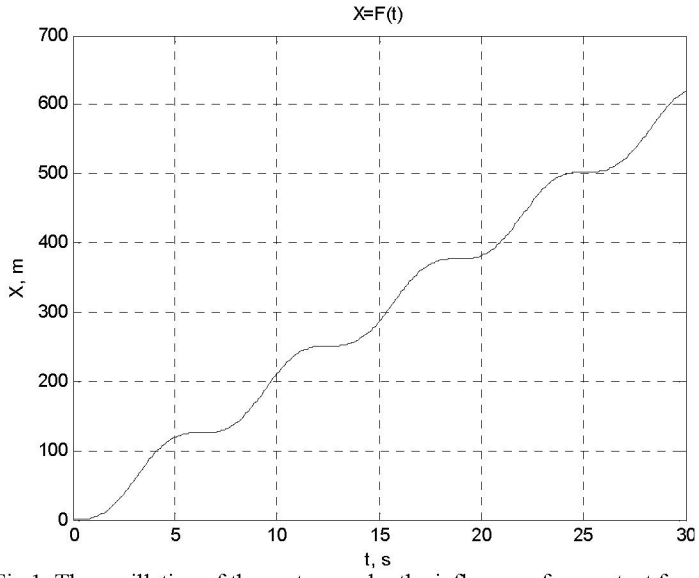

Fig.1. The oscillation of the system under the influence of a constant force

The action of a constant force leads to a shift in the equilibrium position around which oscillations occur.

b) $F=F_0 e^{-at}$.

The system oscillates according to the law

$$x = \frac{F_0}{m\left(\omega^2 + a^2\right)}\left(e^{-at} - \cos\omega t + \frac{\alpha}{\omega}\sin\omega t\right)$$

Calculation and visualization program

```
>> f0=2; w0=1;
>> m=0.1;
>>f0=2; w0=1;
>>m=0.1;
>> t=0:0.1:4;
```

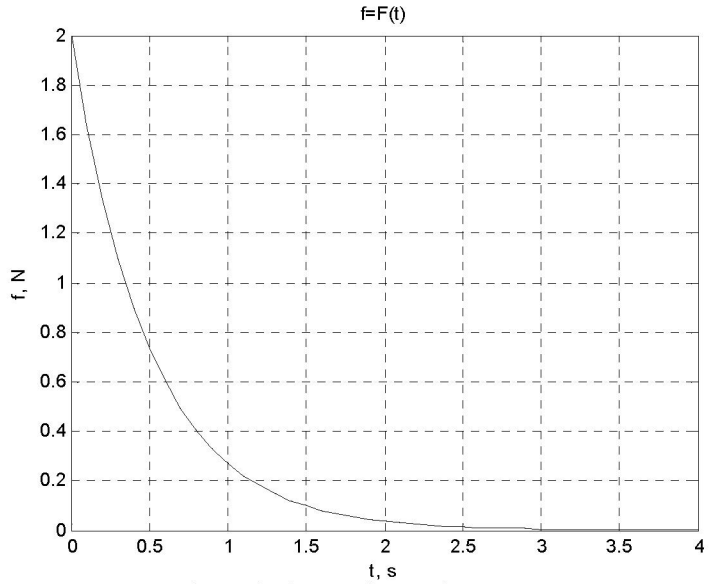

Fig.2. The force acting on the system

```
>> t=0:0.1:30;
>> a=2;
>> x=(f0./(m*(w0.^2+a.^2))).*(exp(-a.*t)-cos(w.*t)+a.*sin(w.*t)./w);
>> plot(t,x,'k-')
>> grid on
>> xlabel('t, s')
>> ylabel('X, m')
>> title('X=F(t)')
```

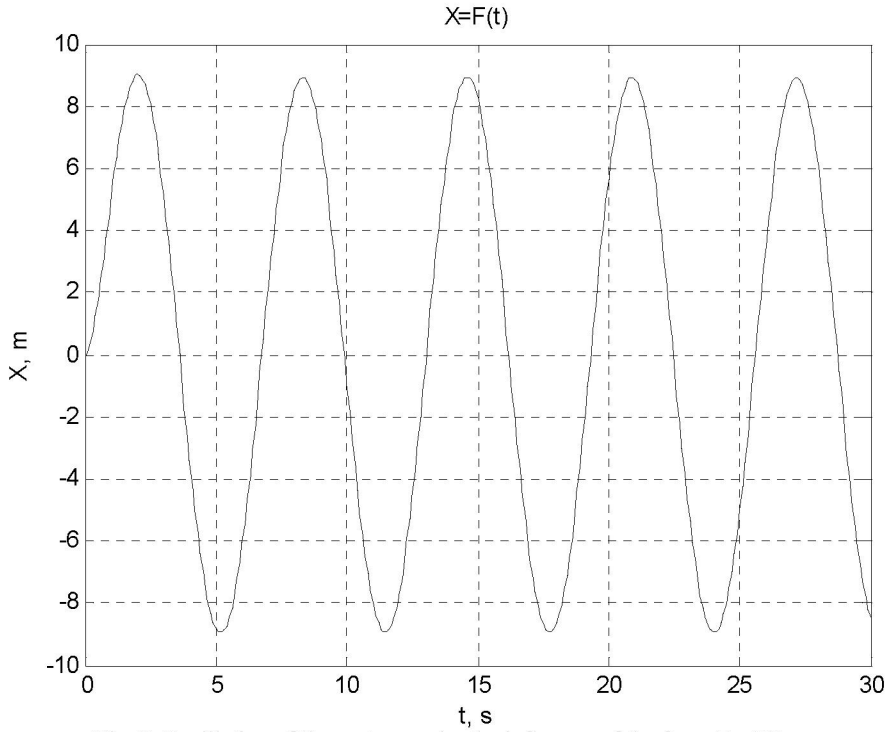

Fig. 3. Oscillation of the system under the influence of the force F = F0e.

c) $F=F_0e^{-at}\cos\beta t$. The oscillation of the system under the action of such a force occurs according to the law

$$x=\frac{F_0}{m\left[\left(\omega^2+\alpha^2-\beta^2\right)^2+4\alpha\beta^2\right]}\left\{-\left(\omega^2+\alpha^2-\beta^2\right)\cos\omega t+\right.$$

$$\left.+\frac{\alpha}{\omega}\left(\omega+\alpha^2+\beta^2\right)\sin\omega t+e^{-at}\left[\left(\omega^2+\alpha^2-\beta^2\right)\cos\beta t-2\alpha\beta\sin\beta t\right]\right\}$$

Calculation and visualization program

```
>> f0=2; w0=1;
>>m=0.1;
>> t=0:0.1:4;
>> a=2;
>>b=0.1;
>> f=f0.*exp(-a.*t).*cos(b.*t);
>> plot(t,f,'k-')
>> grid
```

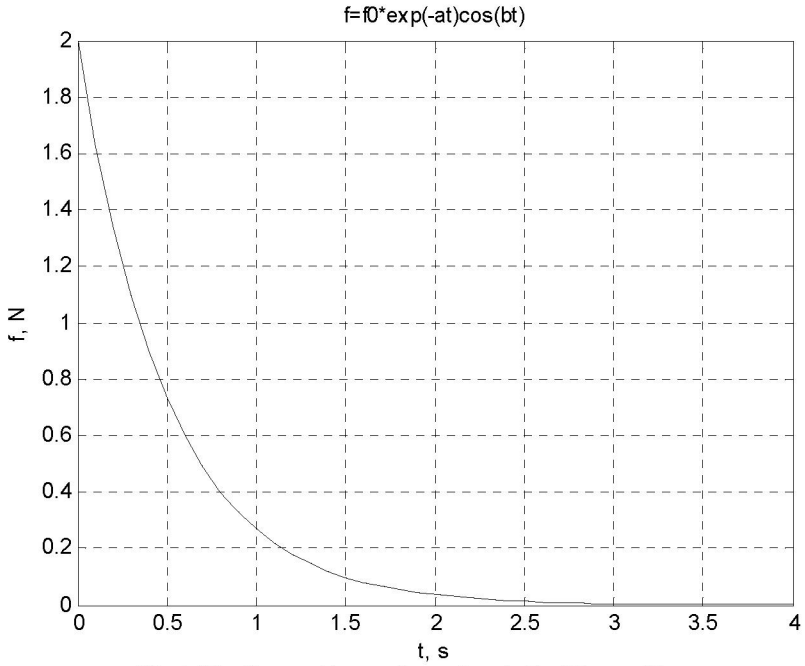

Fig.4. The force acting on the system is F = F0e cos βt.

```
>> t=0:0.1:30;
>> a=2;
>> b=0.1;
>> A=f0./(m.*((w.^2+a.^2-b.^2).^2+4.*a.*b));
>> B=(w.^2+a.^2-b.^2).^2;
>> C=a.*(w.^2+a.^2-+-b.^2).^2;
>> x=A.*(-B).*cos(w.*t)+C./w.*(sin(w.*t)+exp(-a.*t)).*(B.*cos(w.*t)-2.*b.*a.*sin(w.*t));
>> plot(t,x,'k-')
>> grid on
```

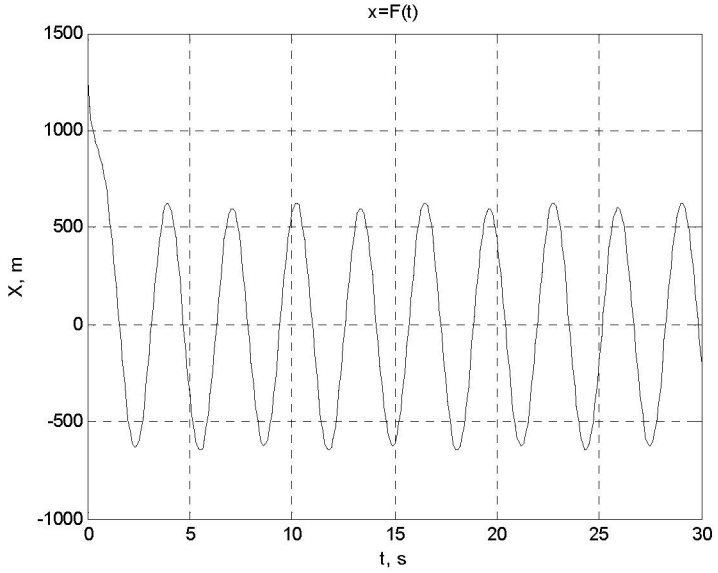

Fig.5. The oscillation of the system under the influence of force F = F0e cos βt.

d) Determine the oscillation of the system after the action of an external force varying according to the law F = 0 for t <0, F = F0 t / T for 0 <t <T, F = F0 for t> T (Fig. 6); Up to the instant t = 0 the system is at rest in the equilibrium position.

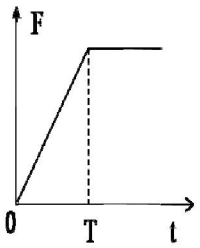

Fig. 6. The force acting on the system

Solution: for 0 <t <T

$$x = \frac{F_0}{mT\omega^3}(\omega t - \sin \omega t)$$

For t <T, we seek the solution in the form

$$x = c_1 \cos \omega(t - T) + c_2 \sin \omega(t - T) + \frac{F_0}{m\omega^2}$$

For t = T, from the continuity of x and $\dot{x}$ *we find*:

$$c_1 = -\frac{F_0}{mT\omega^3} \sin \omega T, c_2 = \frac{F_0}{mT\omega^3}(1 - \cos \omega T).$$

The amplitude of the oscillations

$$a = \sqrt{c_1^2 + c_2^2} = \frac{2F_0}{mT\omega^3} \sin \frac{\omega T}{2}.$$

Note that the smaller the slower the "power" F0 is turned on (ie, the larger T).
Calculation and visualization program

```
>> w=1;
>>T=10;
>>t=0:0.1:30;
>>f0=2; m=0.1;
>> x1=f0./(m.*T.*w.^3);
>> x=x1.*(w.*t-sin(w.*t));
>> plot(t,x,'k-')
>> grid on
```

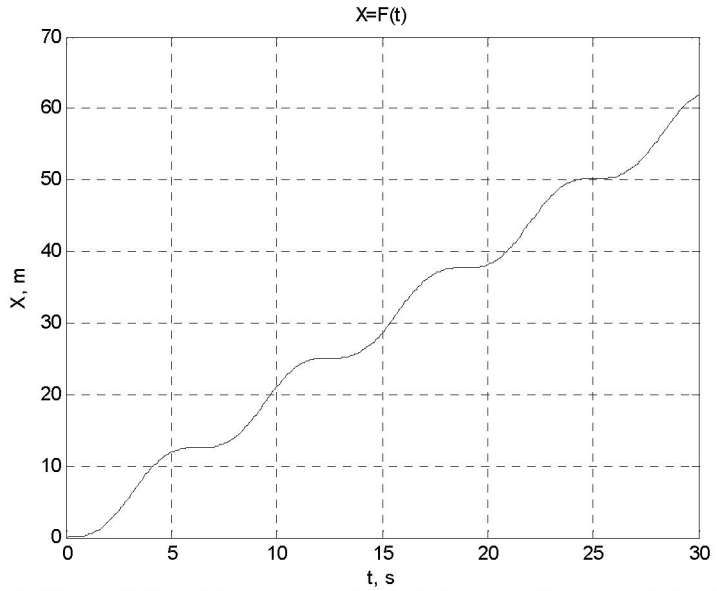

Fig.7. The oscillation of the system under the influence of force at t> T, F = F0

```
>> w=1;
>> T=10;
>> t=0:0.1:30;
>> f0=2; m=0.1;
>> x1=f0./(m.*T.*w.^3);
>> x=x1.*(w.*t-sin(w.*t));
>> plot(t,x,'k-')
>> grid on
>> c1=-x1.*sin(w.*T);
>> c2=x1.*(1-cos(w.*t));
>> X=c1.*cos(w.*(t-T))+c2.*sin(w.*(t-T))+f0./(m.*w.^2);
>> plot(t,X,'k-')
>> grid on
```

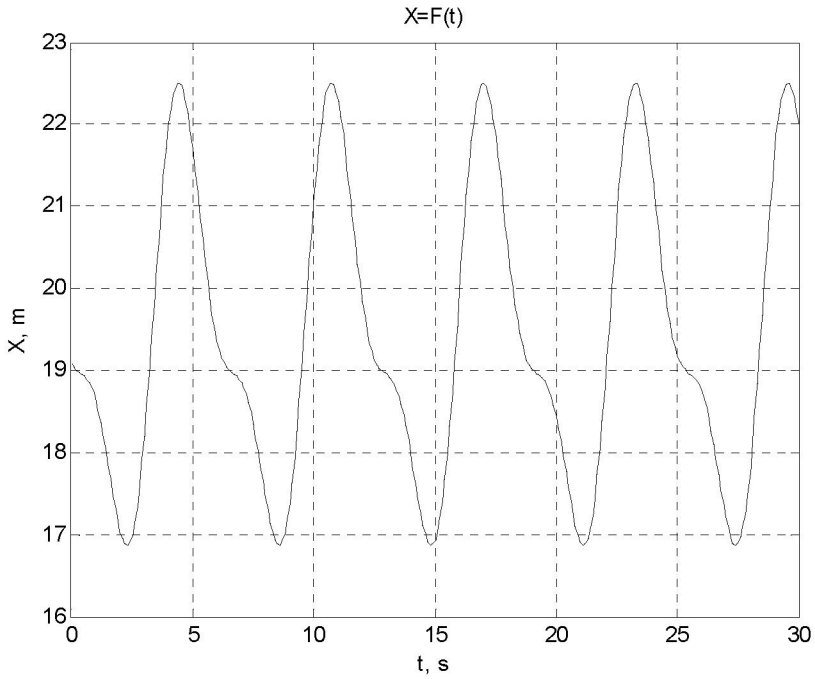

Fig.8. The oscillation of the system under the influence of force at 0 <t <T

e) Find the trajectory of the motion of the particle in the central field U = k r ^ 2/2, the so-called spatial oscillator.
The calculated formulas w = √ (k / m) is the eigenvector frequency, x = acos (wt + α), y = bcos (wt + β) - where a is the amplitude of the oscillation.

Calculation and visualization program

```
>> a=1; b=2; w=1;
>> t=0:0.1:30;
>> alfa=pi./3; beta=pi./6;
>> fi=w.*t-alfa; delta=beta-alfa;
>> x=a.*cos(fi);
>> y=b.*cos(delta).*cos(fi)-b.*sin(delta).*sin(fi);
>> plot(x,y,'k-')
>> grid on
>> xlabel('X')
>> ylabel('Y')
>> title('Y=F(X)')
```

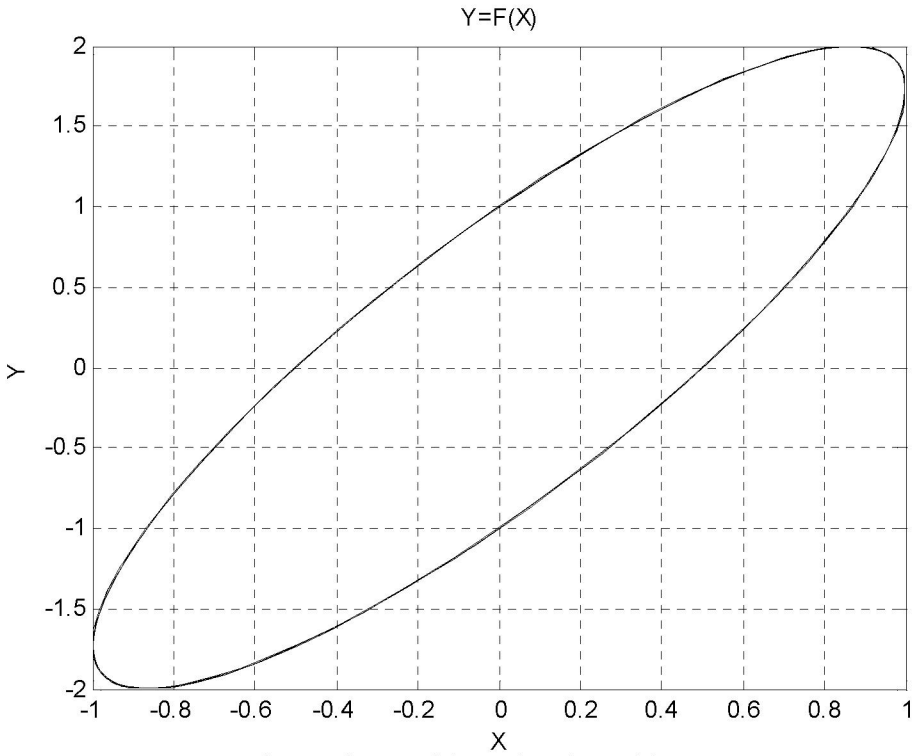

Fig.9. Trajectory of the motion of a particle

Presented laboratory works were performed by third-year students of our university, who are studying in the specialty 5B060400-physics, while conducting laboratory classes on the discipline "Computer simulation of physical phenomena." Especially I want to note that visualization of calculations in the form of graphs allows you to better understand the essence of physical processes and students with great desire perform this part of the task.

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УДК 53, 532.133, 621.3.018.72.025.1

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MATLAB БАҒДАРЛАМАЛАР ПАКЕТІН ҚОЛДАНЫП «СЫРТҚЫ КҮШ ӘСЕР ЕТКЕНДЕ МӘЖБҮРЛІ ТЕРБЕЛІСТЕРДІ ЕСЕПТЕУ ЖӘНЕ ВИЗУАЛИЗАЦИЯЛАУ» КОМПЬЮТЕРЛІК ЗЕРТХАНАЛЫҚ ЖҰМЫСТЫ ОРЫНДАУДЫ ҰЙЫМДАСТЫРУ

Аннотация. Matlab бағдарламалар пакетін қолданып «Сыртқы күш әсер еткенде мәжбүрлі тербелістерді есептеу және визуализациялау» компьютерлік зертханалық жұмысты орындауды ұйымдастыру ұсынылады: а) сыртқы күш– тұрақты; в) сыртқы күш - $F=F_0 e^{-at}$;

с) сыртқы күш - $F=F_0 e^{-at} \cos \beta t$; д) $t < 0$ кезінде $F = 0$; $0 < t < T$ кезінде

$F = F_0 t/T$; $t>T$ кезінде $F = F_0$. Осы әр жағдай үшін шешу жолдары, есептеу және визуализация бағдарламалары келтірілген. Нәтижелер уақыттан әсер етуші сыртқы күштің және уақыттан тепе-теңдік қалпынан бөлшектің ығысуының тәуелділік графиктері түрінде келтірілген.

Тірек сөздер: сыртқы күш, өшетін тербеліс, есептеу, визуализация, график.

УДК 53, 532.133, 621.3.018.72.025.1

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ОРГАНИЗАЦИЯ ВЫПОЛНЕНИЯ КОМПЬЮТЕРНОЙ ЛАБОРАТОРНОЙ РАБОТЫ «РАСЧЕТ И ВИЗУАЛИЗАЦИЯ ВЫНУЖДЕННЫХ КОЛЕБАНИЙ ПРИ НАЛИЧИИ ВНЕШНЕЙ СИЛЫ» С ПРИМЕНЕНИЕМ ПАКЕТА ПРОГРАММ MATLAB

Аннотация. Предлагается организация компьютерной лабораторной работы «Расчет и визуализация вынужденных колебаний при наличии внешней силы» с применением пакета программ Matlab: а) внешняя сила – постоянная; в) внешняя сила - $F=F_0 e^{-at}$;

с) внешняя сила - $F=F_0 e^{-at} \cos \beta t$; д) $F = 0$ при $t < 0$; $F = F_0 t/T$ при $0 < t < T$;, $F = F_0$ при $t>T$. Для каждого из этих случаев приведены решения, программы расчетов и визувализации. Результаты представлены в виде графиков зависимостей действующей внешней силы от времени и смещения частицы от положения равновесия от времени.

Ключевые слова: внешняя сила, затухающее колебание, расчет, визуализация, график.

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