Московский государственный технический университет
имени Н.Э. Баумана

Методические указания

И.С. Дедушенко

Обучение чтению и устной речи на английском языке по специальности «Физика»

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В каждом из трех уроков содержатся словарь, три текста и задания, позволяющие контролировать понимание текстов. Грамматические упражнения направлены на повторение наиболее сложных конструкций английского языка.

Для студентов старших курсов, обучающихся по специальности «Физика» (кафедра ФН-4).

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ПРЕДИСЛОВИЕ

Данные методические указания предназначены для обучения студентов-физиков старших курсов чтению, переводу научно-технической литературы на английском языке, навыкам реферирования и аннотирования, а также умению дискутировать на профессиональные темы.

Перед чтением основного текста урока рекомендуется ознакомиться с предваряющим текст вокабуляром. Усвоение терминов облегчает дальнейшее беспереводное понимание текстов. Любая работа с текстом должна начинаться с просмотрового чтения, а не с дословного перевода.

В разделе Discussion даны задания на понимание текста и применение материалов урока при обсуждении проблем по физике. Этот раздел очень важен для обучения студентов навыкам устной речи, умению анализировать материал и логически строить ответ. Эти навыки и умения позволят студенту подготовиться к презентации доклада на конференции, а также с легкостью вести беседу на профессиональную тему и обсуждать научные проблемы.

Грамматические упражнения составлены таким образом, что обеспечивают повторение наиболее сложных конструкций английского языка, таких, как образование множественного числа существительных латинского и греческого происхождения, неличные формы глагола. Предложенный грамматический материал необходим для правильного перевода статей по физике, а также для ведения научной беседы.

Методические указания помогут будущим специалистам в области физики лучше ориентироваться в огромном потоке публикаций на английском языке, определять их ценность и постоянно повышать свой профессиональный уровень.

Unit 1. THREE NEWTON'S LAWS

Memorize the following vocabulary to text 1A.

center-of-mass acceleration — центр инерционной массы
conversion *n* — превращение, преобразование, переход
converse *v* — преобразовывать
exert *v* — прилагать усилия, напрягать силы
downward force — сила, направленная вниз
total force — результирующая (полная, суммарная) сила
upward force — подъемная сила; сила, направленная вверх
let down *v* — опускать, спускать; ослаблять, замедлять, снижать
negligible *adj* — ничтожный, не принимаемый в расчет
on the order of — порядка …
pull up *v* — натягивать
side-effect — побочный эффект
speed up *v* — ускорять
stick, stuck *v* — задерживать, останавливать
streamlined *adj* — обтекаемый, четкий
taper off *v* — сужаться, убывать по конусу
terminal velocity — конечная скорость
vanquish *v* — преодолевать, побеждать
velocity *n* — 1. скорость; 2. вектор скорости
weigh *v* — взвешивать
weight *n* — вес

Text 1A. Newton's First Law

Read and translate the text. Study the examples given in the text.

If the total force on an object is zero, its center of mass continues in the same state of motion.

In other words, an object initially at rest is predicted to remain at rest if the total force on it is zero, and an object in motion remains in motion with the same velocity in the same direction. The converse of Newton's first law is also true: if we observe an object moving with constant velocity along a straight line, then the total force on it must be zero.

What happens if the total force on an object is not zero? It accelerates.

For example: An elevator has a weight of 5000 N. Compare the forces that the cable must exert to raise it at constant velocity, lower it at constant velocity, and just keep it hanging.

Answer: In all three cases the cable must pull up with a force of exactly 5000 N. Most people think you'd need at least a little more than 5000 N to make it go up, and a little less than 5000 N to let it down, but that's incorrect. Extra force from the cable is only necessary for speeding the car up when it starts going up or slowing it down when it finishes going down. Decreased force is needed to speed the car up when it gets going down and to slow it down when it finishes going up. But when the elevator is cruising at constant velocity, Newton's first law says that you just need to cancel the force of the earth's gravity. It seems that the statement in the example that the cable's upward force "cancels" the earth's downward gravitational force implies that there has been a contest, and the cable's force has won, vanquishing the earth's gravitational force and making it disappear. We know that both forces continue to exist because they both have side-effects other than their effects on the car's centre-of-mass motion. That is incorrect. Both forces continue to exist, but because they add up numerically to zero, the elevator has no center-of-mass acceleration. The force acting between the cable and the car continues to produce tension in the cable and keep the cable taut. The earth's gravitational force continues to keep the passengers (whom we are considering as part of the elevator-object) stuck to the floor and to produce internal stresses in the walls of the car, which must hold up the floor.

Example 2 (terminal velocity for falling objects): An object like a feather that is not dense or streamlined does not fall with constant acceleration, because air resistance is nonnegligible. In fact, its acceleration tapers off to nearly zero within a fraction of a second, and the feather finishes dropping at constant speed (known as its terminal velocity). Why does this happen?

Newton's first law tells us that the total force on the feather must have been reduced to nearly zero after a short time. There are two forces acting on the feather: a downward gravitational force from the planet earth, and an upward frictional force from the air. As the feather speeds up, the air friction becomes stronger and stronger, and eventually it cancels out the earth's gravitational force, so the feather just continues with constant velocity without speeding up any more.

The situation for a skydiver is exactly analogous. It's just that the skydiver experiences perhaps a million times more gravitational force than the feather, and it is not until she is falling very fast that the force of air friction becomes as strong as the gravitational force. It takes her several seconds to reach terminal velocity, which is on the order of a hundred miles per hour.

(*2885*)

Tasks to text 1A

1. Give the definition of the First Newton's Law.
2. What forces act on a falling object?
3. What fields of physics can the First Newton's Law be applied to?
4. Give your own examples of the First Newton's Law application.

Text 1B. Newton's Second Law

Read the text and state what acceleration is.

What about cases where the total force on an object is not zero, so that Newton's first law doesn't apply? The object will have acceleration. The way positive and negative signs of force and acceleration are defined guarantees that positive forces produce positive accelerations, and likewise for negative values. How much acceleration will it have? It will clearly depend on both the object's mass and on the amount of force.

Experiments with any particular object show that its acceleration is directly proportional to the total force applied to it. This may seem wrong, since we know of many cases where small amounts of force fail to move an object at all, and larger forces get it going.

This apparent failure of proportionality actually results from forgetting that there is a frictional force in addition to the force we apply to move the object. The object's acceleration is exactly proportional to the total force on it, not to any individual force on it. In the absence of friction, even a very tiny force can slowly change the velocity of a very massive object. Experiments also show that the acceleration is inversely proportional to the object's mass, and combining these two proportionalities gives the following way of predicting the acceleration of any object:

$$\textit{Newton's second law: } a = F_{total} / m,$$

where m is an object's mass, F_{total} is the sum of the forces acting on it, and a is the acceleration of the object's center of mass. The case is presently restricted to where the forces of interest are parallel to the direction of motion.

For example: A bus with a mass of 2000 kg accelerates from 0 to 25 m/s (freeway speed) in 34 s. Assuming the acceleration is constant, what is the total force on the bus?

We solve Newton's second law for $F_{total} = ma$, and substitute $a = v/t$ for a, giving

$$F_{total} = mv/t = (2000\ \text{kg})(25\ \text{m/s} - 0\ \text{m/s})/(34\ \text{s}) = 1.5\ \text{kN}.$$

As with the first law, the second law can be easily generalized to include a much larger class of interesting situations: suppose an object is being acted on by two sets of forces, one set lying along the object's initial direction of motion and another set acting along a perpendicular line. If the forces perpendicular to the initial direction of motion cancel out, then the object accelerates along its original line of motion according to $a = F_{total} / m$.

(*1916*)

Text 1C. Newton's Third Law

Read, translate the text and answer the question: Was Newton's Third ***Law ever violated?***

Newton created the modern concept of force starting from his insight that all the effects that govern motion are interactions between two objects: unlike the Aristotelian theory, Newtonian physics has no phenomena in which an object changes its own motion. Is one object always the "order-giver" and the other the "order-follower"?

As an example, consider a batter hitting a baseball. The bat definitely exerts a large force on the ball, because the ball accelerates drastically. But it is known that the ball also makes a force on the bat.

How does the ball's force on the bat compare with the bat's force on the ball? The bat's acceleration is not as spectacular as the ball's, since the bat's mass is much greater. In fact, careful measurements of both objects' masses and accelerations would show that *mballaball* is very nearly equal to *mbatabat,* which suggests that the ball's force on the bat is of the same magnitude as the bat's force on the ball, but in the opposite direction.

Let's discuss two examples:

a) Two magnets exert forces on each other;

b) Two people's hands exert forces on each other.

In the first experiment, a large magnet and a small magnet are weighed separately, and then one magnet is hung from the pan of the top balance so that it is directly above the other magnet. There is an attraction between the two magnets, causing the reading on the top scale to increase and the reading on the bottom scale to decrease. The large magnet is more "powerful" in the sense that it can pick up a heavier paperclip from the same distance, so many people have a strong expectation that one scale's reading will change by a far different amount than the other. Instead, the two changes are found to be equal in magnitude but opposite in direction: the force of the bottom magnet pulling down on the top one has the same strength as the force of the top one pulling up on the bottom one.

In the second experiment, two people pull on two spring scales. Regardless of who tries to pull harder, the two forces as measured on the spring scales are equal. Interposing the two spring scales is necessary in order to measure the forces, but the outcome is not some artificial result of the scales' interactions with each other. If one person slaps another hard on the hand, the slapper's hand hurts just as much as the slappee's, and it doesn't matter if the recipient of the slap tries to be inactive. (Punching someone in the mouth causes just as much force on the fist as on the lips. It's just that the lips are more delicate. The forces are equal, but not the levels of pain and injury.)

Newton, after observing a series of results such as these, decided that there must be a fundamental law of nature at work:

Newton's third law: Forces occur in equal and opposite pairs: whenever object A exerts a force on object B, object B must also be exerting a force on object A. The two forces are equal in magnitude and opposite in direction.

In one-dimensional situations, we can use plus and minus signs to indicate the directions of forces, and Newton's third law can be written succinctly as *FA on B = –FB on A.*

There is no cause and effect relationship between the two forces. There is no "original" force, and neither one is a response to the other. The pair of forces is a relationship. Newton came up with the third law as a generalization about all the types of forces with which he was familiar, such as frictional and gravitational forces. When later physicists discovered a new type force, such as the force that holds atomic nuclei together, they had to check whether it obeyed Newton's third law. So far, no violation of the third law has ever been discovered, whereas the first and second laws were shown to have limitations by Einstein and the pioneers of atomic physics.

Newton's third law does not mean that forces always cancel out so that nothing can ever move. If the two figure skaters, initially at rest, push against each other, they will both move.

It often sounds as though Newton's third law implies nothing could ever change its motion, since the two equal and opposite forces would always cancel. The two forces, however, are always on two different objects, so it doesn't make sense to add them in the first place — we only add forces that are acting on the same object. If two objects are interacting via a force and no other forces are involved, then both objects will accelerate — in opposite directions!

It doesn't make sense to refer to the equal and opposite forces of Newton's third law as canceling. It only makes sense to add up forces that are acting on the same object, whereas two forces related to each other by Newton's third law are always acting on two different objects.

Newton's third law is completely symmetric in the sense that neither force constitutes a delayed response to the other. Newton's third law does not even mention time, and the forces are supposed to agree at any given instant. This creates an interesting situation when it comes to non contact forces. Suppose two people are holding magnets, and when one person waves or wiggles her magnet, the other person feels an effect on his. In this way they can send signals to each other from opposite sides of a wall, and if Newton's third law is correct, it would seem that the signals are transmitted instantly, with no time lag. The signals are indeed transmitted quite quickly, but experiments with electronically controlled magnets show that the signals do not leap the gap instantly: they travel at the same speed as light, which is an extremely high speed but not an infinite one.

Is this a contradiction to Newton's third law? Not really. According to current theories, there are no true non contact forces. Action at a distance does not exist. Although it appears that the wiggling of one magnet affects the other with no need for anything to be in contact with anything, what really happens is that wiggling a magnet unleashes a shower of tiny particles called photons. The magnet shoves the photons out with a kick, and receives a kick in return, in strict obedience to Newton's third law. The photons fly out in all directions, and the ones that hit the other magnet then interact with it, again obeying Newton's third law.

Light is made of photons, but our eyes receive such huge numbers of photons that we do not perceive them individually. The photons you would make by wiggling a magnet with your hand would be of a "color" that you cannot see, far off the red end of the rainbow.

(*5366*)

Discussion

1. Show that the Newton can be reexpressed in terms of the three basic mks units as the combination $kg \cdot m/s^2$.

2. What is wrong with the following statements?

(1) "*g* is the force of gravity."

(2) "Mass is a measure of how much space something takes up."

3. Criticize the following incorrect statement:

"If an object is at rest and the total force on it is zero, it stays at rest. There can also be cases where an object is moving and keeps on moving without having any total force on it, but that can only happen when there's no friction, like in outer space."

4. Newton said that objects continue moving if no forces are acting on them, but his predecessor Aristotle said that a force was necessary to keep an object moving. Why does Aristotle's theory

seem more plausible, even though we now believe it to be wrong? What insight was Aristotle missing about the reason why things seem to slow down naturally?

5. Interpret the equation $v_{terminal} = 0$.

6. How would the terminal velocity of a 4-cm steel ball compare to that of a 1-cm ball?

7. Criticize the following incorrect statement: "If you shove a book across a table, friction takes away more and more of its force, until finally it stops".

8. You hit a tennis ball against a wall. Explain any and all incorrect ideas in the following description of the physics involved: "The ball gets some force from you when you hit it, and when it hits the wall, it loses part of that force, so it doesn't bounce back as fast. The muscles in your arm are the only things that a force can come from".

Grammar revision

Ex. 1. ***Express the idea using the verbs in brackets.***

Model: This value increases. (assume) — The value is assumed to increase.

1. These data are in good agreement with the experimental ones. (consider).
2. Density changes with temperature. (know)
3. The distance is shown indirectly. (expect)
4. The altitude is uniform during this period of time. (seem)
5. The value is derived from the above equation. (suppose)
6. The path is reduced twice. (appear)
7. The photons fly out in all directions. (believe)
8. The first and second laws have limitations. (show)

Ex. 2. ***Translate into Russian paying attention to Complex Subject with the Infinitive.***

1. An object initially at rest is predicted to remain at rest if the total force on it is zero.

2. Both forces are known to continue to exist because they both have side-effects.

3. Pressure is known to act equally in all directions.

4. When the car gets going down decreased force is needed to speed it up.

5. The predicted precision was found to be difficult to obtain in practice.

6. Everyone seems to realize the potential dangers of some scientific discoveries.

7. An object initially at rest is predicted to remain at rest if the total force on it is zero.

8. The property appears to have been mentioned frequently in the past.

9. The information is assumed to provide an appropriate solution to the problem.

Ex. 3. ***Translate into Russian, paying attention to the function of the infinitive in the sentence.***

1. Acceleration of an object is shown to be directly proportional to the total force applied to it.

2. To introduce numerical methods and their use in physics is the purpose of this paper.

3. Acceleration is said to be inversely proportional to the objects mass.

4. The methods to be introduced are extremely useful for solving many practical problems.

5. To come to this conclusion we have exerted much in this field.

6. We have nonnegligible evidence to predict this result.

7. The set of laws to be involved in these calculations must be studied in detail.

8. To interpret these results in terms of your concept is rather difficult.

9. Two forces to act on the feather are a downward gravitational force from the planet earth, and an upward frictional force from the air.

10. In that case air force was said to be negligible.

Ex. 4. ***Translate into English, using different forms of the infinitive.***

1. Вот движение тела, которое нужно объяснить.
2. Для того чтобы объяснить движение тела, мы вовлекаем понятие инерции.
3. Уравнение, которое необходимо решить в данном случае, требует длительных вычислений.
4. Для того чтобы облегчить наши вычисления, мы воспользуемся компьютером.
5. Для того чтобы предсказать конечный результат, мы вовлекаем знакомые нам понятия.
6. Применить эти понятия к данным явлениям — цель нашей работы.

Unit 2. CONSERVATION OF ENERGY

Memorize the following vocabulary to text 2A.

collide *v* — сталкиваться
collision *n* — столкновение
fail *v* — не суметь, не быть в состоянии, оказаться неспособным
turn smth into smth — превращать что-то во что-то
substance *n* — вещество
perpetual motion — постоянное движение
exert *v* — напрягать силы, прилагать усилия
encounter *v* — сталкиваться, встретиться
lay odds — давать преимущество

Text 2A. The Search for a Perpetual Motion Machine

Read, translate and render the text.

Don't underestimate greed and laziness as forces for progress. Modern chemistry was born from the collision of lust for gold with distaste for the hard work of finding it and digging it up. Failed efforts by generations of alchemists to turn lead into gold led finally to the conclusion that it could not be done: certain substances, the chemical elements, are fundamental, and chemical reactions can neither increase nor decrease the amount of an element such as gold.

Now flash forward to the early industrial age. Greed and laziness have created the factory, the train, and the ocean liner, but in each of these is a boiler room where someone gets sweaty shoveling the coal to fuel the steam engine. Generations of inventors have tried to create a machine, called a perpetual motion machine that would run forever without fuel. Such a machine is not forbidden by Newton's laws of motion, which are built around the concepts of force and inertia. Force is free, and can be multiplied indefinitely with pulleys, gears, or levers. The principle of inertia seems even to encourage the belief that a cleverly constructed machine might not ever run down.

Here is an example: The magnet draws the ball to the top of the ramp, where it falls through the hole and rolls back to the bottom. The example shows one of the innumerable perpetual motion machines that have been proposed. The reason this example doesn't work is not much different from the reason all the others have failed. Consider the machine. Even if we assume that a properly shaped ramp would keep the ball rolling smoothly through each cycle, friction would always be at work. The designer imagined that the machine would repeat the same motion over and over again, so that every time it reached a given point its speed would be exactly the same as the last time. But because of friction, the speed would actually be reduced a little with each cycle, until finally the ball would no longer be able to make it over the top.

Friction has a way of creeping into all moving systems. The rotating earth might seem like a perfect perpetual motion machine, since it is isolated in the vacuum of outer space with nothing to exert frictional forces on it. But in fact our planet's rotation has slowed drastically since it first formed, and the earth continues to slow its rotation, making today just a little longer than yesterday. The very subtle source of friction is the tides. The moon's gravity raises bulges in the earth's oceans, and as the earth rotates the bulges progress around the planet. Where the bulges encounter land, there is friction, which slows the earth's rotation very gradually.

(*2197*)

Additional vocabulary

Memorize the terminology and use it while discussing the tasks.

Energy (E) — a numerical scale used to measure heat, motion, or other properties that would require fuel or physical effort to put into an object; a scalar quantity with units of joules (J).

Power (P) — the rate of transferring energy; a scalar quantity with units of watts (W).

Kinetic energy (KE) — the energy an object possesses because of its motion.

Heat — the energy that an object has because of its temperature. Heat is different from temperature because an object with twice as much mass requires twice as much heat to increase its temperature by the same amount.

Temperature — what a thermometer measures. Objects left in contact with each other tend to reach the same temperature. Temperature is essentially a measure of the average kinetic energy per molecule.

W — watts, the SI unit of power; equivalent to J/s.

Q — the amount of heat transferred into or out of an object.

Text 2B. Energy

Read and translate the text with a dictionary.

The analysis based on friction is somewhat superficial, however. One could understand friction perfectly well and yet imagine the following situation.

Astronauts bring back a piece of magnetic ore from the moon which does not behave like ordinary magnets. A normal bar magnet attracts a piece of iron essentially directly toward it, and has no left- or righthandedness. The moon rock, however, exerts forces that form a whirlpool pattern around it. NASA goes to a machine shop and has the moon rock put in a lathe and machined down to a smooth cylinder. If we now release a ball bearing on the surface of the cylinder, the magnetic force whips it around and around at ever higher speeds. Of course there is some friction, but there is a net gain in speed with each revolution.

Physicists would lay long odds against the discovery of such a moon rock, not just because it breaks the rules that magnets normally obey but because, like the alchemists, they have discovered a very deep and fundamental principle of nature which forbids certain things from happening.

The first alchemist who deserved to be called a chemist was the one who realized one day: "In all these attempts to create gold where there was none before, all I've been doing is sending the same atoms back and forth among different test tubes. The only way to increase the amount of gold in my laboratory is to bring some in through the door."

We say that the number of grams of gold is a conserved quantity. In this context, the word "conserve" does not have its usual meaning of trying not to waste something. In physics, a conserved quantity is something that you wouldn't be able to get rid of even if you wanted to. Conservation laws in physics always refer to a closed system, meaning a region of space with boundaries through which the quantity in question is not passing. In our example, the alchemist's laboratory is a closed system because no gold is coming in or out through the doors.

A similar light bulb eventually lit up in the heads of the people who had been frustrated trying to build a perpetual motion machine. In perpetual motion machine a, consider the motion of one of the balls. It performs a cycle of rising and falling. On the way down it gains speed, and coming up it slows back down. Having a greater speed is like having more money in your checking account, and being high up is like having more in your savings account. The device is simply sending funds back and forth between the two. Having more balls doesn't change anything fundamentally.

Not only that, but friction is always draining off money into a third "bank account" heat. The reason we rub our hands together when we're cold is that kinetic friction heats things up. The continual buildup in the "heat account" leaves less and less for the "motion account" and "height account," causing the machine eventually to run down.

These insights can be distilled into the following basic principle of physics: the law of conservation of energy. It is possible to give a numerical rating, called energy, to the state of a physical system. The total energy is found by adding up contributions from characteristics of the system such as motion of objects in it, heating of the objects, and the relative positions of objects that interact via forces. The total energy of a closed system always remains constant. Energy cannot be created or destroyed, but only transferred from one system to another.

The moon rock story violates conservation of energy because the rock cylinder and the ball together constitute a closed system. Once the ball has made one revolution around the cylinder, its position relative to the cylinder is exactly the same as before, so the numerical energy rating associated with its position is the same as before. Since the total amount of energy must remain constant, it is impossible for the ball to have a greater speed after one revolution. If it had picked up speed, it would have more energy associated with motion, the same amount of energy associated with position, and a little more energy associated with heating through friction. There cannot be a net increase in energy.

(*3436*)

Text 2C. Momentum

Read and render the text. Write a short summary.

It should also be noted that conservation of momentum is not a consequence of Newton's laws, as is often asserted in textbooks. Newton's laws do not apply to light, and therefore could not possibly be used to prove anything about a concept as general as the conservation of momentum in its modern form.

Einstein played a role in two major changes in the momentum concept in the 1900's. First Einstein showed that the equation $p = mv$ would not work for a system containing objects moving at very high speeds relative to one another. He came up with a new equation, to which mv is only the low-velocity approximation.

The second change, and a far stranger one, was the realization that at the atomic level, motion is inescapably random. The electron in a hydrogen atom doesn't really orbit the nucleus, it forms a vague cloud around it. It might seem that this would prove nonconservation of momentum, but in fact the random wanderings of the proton are exactly coordinated with those of the electron so that the total momentum stays exactly constant. In an atom of lead, there are 82 electrons plus the nucleus, all changing their momenta randomly from moment to moment, but all coordinating mysteriously with each other to keep the vector sum constant. In the 1930s, Einstein pointed out that the theories of the atom then being developed would require this kind of spooky coordination, and used this as an argument that there was something physically unreasonable in the new ideas. Experiments, however, have shown that the spooky effects do happen, and Einstein's objections are remembered today only as a historical curiosity.

Example 1: The rifle and bullet have zero momentum and zero kinetic energy to start with. When the trigger is pulled, the bullet gains some momentum in the forward direction, but this is canceled by the rifle's backward momentum, so the total momentum is still zero. The kinetic energies of the gun and bullet are both positive scalars, however, and do not cancel.

The total kinetic energy is allowed to increase, because kinetic energy is being traded for other forms of energy. Initially there is chemical energy in the gunpowder. This chemical energy is converted into heat, sound, and kinetic energy. The gun's "backward" kinetic energy does not refrigerate the shooter's shoulder!

Example 2: As the moon completes half a circle around the earth, its motion reverses direction. This does not involve any change in kinetic energy, and the earth's gravitational force does not do any work on the moon. The reversed velocity vector does, however, imply a reversed momentum vector, so conservation of momentum in the closed earth-moon system tells us that the earth must also change its momentum. In fact, the earth wobbles in a little "orbit" about a point below its surface on the line connecting it and the moon. The two bodies' momentum vectors always point in opposite directions and cancel each other out.

(*2451*)

Additional vocabulary

Memorize the terminology and use it while discussing the tasks.

Periodic motion — motion that repeats itself over and over.

Period — the time required for one cycle of a periodic motion.

Frequency — the number of cycles per second, the inverse of the period.

Amplitude — the amount of vibration, often measured from the center to one side; may have different units depending on the nature of the vibration.

Simple harmonic motion — motion whose x–t graph is a sine wave.

T — period;

f — frequency;

A — amplitude.

Discussion

1. If all the air molecules in the room settled down in a thin film on the floor, would that violate conservation of momentum as well as conservation of energy?

2. Derive a formula expressing the kinetic energy of an object in terms of its momentum and mass.

3 Two people in a rowboat wish to move around without causing the boat to move. What should be true about their total momentum? Explain.

4. You are driving your car, and you hit a brick wall head on, at full speed. The car has a mass of 1500 kg. The kinetic energy released is a measure of how much destruction will be done to the car and to your body. Calculate the energy released if you are traveling at (a) 40 km/hr, and again (b) if you're going 80 km/hr. What is counterintuitive about this, and what implication does this have for driving at high speeds?

5. All stars, including our sun, show variations in their light output to some degree. Some stars vary their brightness by a factor of two or even more, but our sun has remained relatively steady during the hundred years or so that accurate data have been collected. Nevertheless, it is possible that climate variations such as ice ages are related to long-term irregularities in the sun's light output. If the sun was to increase its light output even slightly, it could melt enough Antarctic ice to flood all the world's coastal cities. The total sunlight that falls on Antarctica amounts to about 1 × 1016 watts.

Grammar and vocabulary revision

Ex. 1. ***Study the meanings of due, be due to and due to and translate the sentences.***

Due (to) *adj* — соответствующий, надлежащий, вызванный, обусловленный.

Be due to — быть обусловленным, являться следствием, быть разработанным, предложенным.

Due to *prep* — благодаря, из-за, вследствие (syn. because of, on account of, owing to, in view of, thanks to, by/in virtue of, consequent on).

1. Due consideration must be given to missile performance requirements.

2. No difference due to n–p scattering in the target was found.

3. Coincidences arise due to second-order effect.

4. A due explanation of the phenomenon of radioactivity was first given by the Curies.

5. This phenomenon was found to be due to the lowering of the temperature down to –200 °C.

6. An up-to-date apparatus, due to Frankenburg, is shown in Fig. 10.

Ex. 2. ***Insert "due to" or "to be due to".***

1. The errors … careless analysis.

2. We shall discuss the errors … the scattering of rays.

3. The physical properties of metals … relatively free mobile electrons.

4. The problem could be solved … very careful investigations.

5. High yields were obtained … extremely pure starting products.

6. Part of the filtering action … mechanical properties of crystals.

7. … its motion around the Sun the Earth will represent different systems of inertia.

8. The quantum theory … Planck.

9. The discovery of radioactivity … pure accident.

10. Some misunderstanding … the complexity of the problem.

Ex. 3. ***Make up singular-rplural pairs.***

Foci, quanta, maximum, analyses, vacua, axis, maxima, radius, genii, radii, locus, nuclei, analysis, focus, hypothesis, criteria, nucleus, quantum, crisis, theses, momenta, axes, synthesis, criterion, phenomena, genius, species, loci, hypothesis, thesis, momentum, syntheses, phenomenon, vacuum, species.

Ex. 4. ***Translate the following sentences into Russian, paying attention to the form and function of the Participle.***

1. Electrons forming an atom are in motion.
2. Having considered the problem involved they arrived at a definite conclusion.
3. Following the method involved we found it to be effective.
4. The results obtained agree with those predicted by the theory.
5. Having been separated from a mixture the substance was investigated under the microscope.
6. When heated to a high temperature in a vacuum a metal gives off free electrons.

Ex. 5. ***Translate the following sentences into Russian, paying attention to the Absolute Participial Construction*.**

1. An electron leaving the surface, the metal becomes positively charged.
2. With the experiments carried out, they started new investigations.
3. A magnet is broken into two parts, each piece becoming a magnet with its own pair of poles.
4. All the liberated electrons having reached the anode, saturation occurs.
5. The temperature of the conductor being raised, the motion of electrons also increases.
6. Hydrogen is the simplex substance, atoms of all other elements having a more complex structure.
7. The nucleus of an ordinary hydrogen atom consists of one proton, with one electron moving around it.
8. All these elements radioactive, their atoms being unstable and undergoing spontaneous disintegration.
9. The pressure being reduced within the tube, certain remarkable phenomena occur.
10. Having applied a positive pulse of voltage to the control electrode, we made the valve conducting.

Ex. 6. ***Translate the following sentences into English, paying attention to the Participle and the Absolute Participial Constructions.***

1. Двигаясь по кругу с одинаковой скоростью, тело непрерывно изменяет свое направление.
2. После того как прибор прошел тщательное испытание, его ввели в эксплуатацию.
3. Луч лазера имеет почти неограниченные возможности применения в промышленности.
4. Нейрон — частица, имеющая одинаковую массу с протоном, но не несущая электрического заряда.
5. Так как измерения производились неточными приборами, данные были ненадежными.
6. Испытываемое оборудование требует дальнейшего усовершенствования.
7. Когда атом возбужден, он испускает квант излучения.
8. Получив необходимую энергию, электроны ионизируют атомы.
9. После того как информация обработана, выходное устройство передает окончательный результат.

Unit 3. VIBRATIONS

Memorize the following vocabulary to text 3A.

conjure *v* — 1. показывать фокусы; 2. вызывать в воображении (— up)
link *v* — соединять, связывать
to be linked to — быть привязанным к чему-либо
pitch *n* — высота тона, звука
repetition *n* — повторение
repetitive *adj* — повторяющийся
seam *n* — шов
seamless *adj* — бесшовный
random *adj* — произвольный, случайный
randomly — произвольно
at random — наугад, наобум
prevail *v* — преобладать, господствовать
prevail over — одолевать, торжествовать над кем-либо
prevail on — убедить кого-либо
prevalent *adj* — распространенный, преобладающий

Text 3A. Vibrations

Read and translate the text.

Dandelion. Cello. Read those two words, and your brain instantly conjures a stream of associations, the most prominent of which have to do with vibrations. Our mental category of “dandelion-ness” is strongly linked to the color of light waves that vibrate about half a million billion times a second: yellow.

The velvety throb of a cello has as its most obvious characteristic a relatively low musical pitch — the note you are spontaneously imagining right now might be one whose sound vibrations repeat at a rate of a hundred times a second.

Evolution has designed our two most important senses around the assumption that not only will our environment be drenched with information-bearing vibrations, but in addition those vibrations will often be repetitive, so that we can judge colors and pitches by the rate of repetition.

Granting that we do sometimes encounter nonrepeating waves such as the consonant “sh,” which has no recognizable pitch, why was Nature’s assumption of repetition nevertheless so right in general?

Repeating phenomena occur throughout nature, from the orbits of electrons in atoms to the reappearance of Halley’s Comet every 75 years. Ancient cultures tended to attribute repetitious phenomena like the seasons to the cyclical nature of time itself, but we now have a less mystical explanation. Suppose that instead of Halley’s Comet’s true, repeating elliptical orbit that closes seamlessly upon itself with each revolution, we decide to take a pen and draw a whimsical alternative path that never repeats. We will not be able to draw for very long without having the path cross itself. But at such a crossing point, the comet has returned to a place it visited once before, and since its potential energy is the same as it was on the last visit, conservation of energy proves that it must again have the same kinetic energy and therefore the same speed. Not only that. The comet’s direction of motion cannot be randomly chosen, because angular momentum must be conserved as well. Although this falls short of being an ironclad proof that the comet’s orbit must repeat, it no longer seems surprising that it does.

Conservation laws, then, provide us with a good reason why repetitive motion is so prevalent in the universe. But it goes deeper than that. Up to this point in your study of physics, I have been indoctrinating you with a mechanistic vision of the universe as a giant piece of clockwork. Breaking the clockwork down into smaller and smaller bits, we end up at the atomic level, where the electrons circling the nucleus resemble — well, little clocks!

From this point of view, particles of matter are the fundamental building blocks of everything, and vibrations and waves are just a couple of the tricks that groups of particles can do. A chain of discoveries initiated by Albert Einstein at the beginning of the 20th century led to the realization that the so-called subatomic "particles" were in fact waves. In this new world-view, it is vibrations and waves that are fundamental, and the formation of matter is just one of the tricks that waves can do.

(*2608*)

Text 3B. Period, Frequency, and Amplitude

Read the text and render it.

A spring is our most basic example of a vibration. With no forces on it, the spring assumes its equilibrium length. It can be stretched, or compressed. Imagine that the spring is attached to a wall on the left and to a mass on the right. If now the mass is hit with a hammer, it oscillates. If we assume that the mass slides back and forth without friction and that the motion is one-dimensional, then conservation of energy proves that the motion must be repetitive.

When the block comes back to its initial position again, its potential energy is the same again, so it must have the same kinetic energy again. The motion is in the opposite direction, however. Finally, it returns to its initial position with the same kinetic energy and the same direction of motion. The motion has gone through one complete cycle, and will now repeat forever in the absence of friction. The usual physics terminology for motion that repeats itself over and over is periodic motion, and the time required for one repetition is called the period, T. (The symbol P

is not used because of the possible confusion with momentum.) One complete repetition of the motion is called a cycle.

We are used to referring to short-period sound vibrations as “high” in pitch, and it sounds odd to have to say that high pitches have low periods. It is therefore more common to discuss the rapidity of a vibration in terms of the number of vibrations per second, a quantity called the frequency, f.

Since the period is the number of seconds per cycle and the frequency is the number of cycles per second, they are reciprocals of each other, $f = 1/T$.

(*1328*)

Text 3C. Simple Harmonic Motion

Read the text and give a short summary.

Why are sine-wave vibrations so common? If we actually construct the mass-on-a-spring system and measure its motion accurately, we will find that its x–t graph is nearly a perfect sine-wave shape. (We call it a “sine wave” or “sinusoidal” even if it is a cosine, or a sine or cosine shifted by some arbitrary horizontal amount.) It may not be surprising that it is a wiggle of this general sort, but why is it a specific mathematically perfect shape? Why is it not a sawtooth shape or some other shape?

The mystery deepens as we find that a vast number of apparently unrelated vibrating systems show the same mathematical feature. A tuning fork, a sapling pulled to one side and released, a car bouncing on its shock absorbers, all these systems will exhibit sine-wave motion under one condition: the amplitude of the motion must be small.

It is not hard to see intuitively why extremes of amplitude would act differently. For example, a car that is bouncing lightly on its shock absorbers may behave smoothly, but if we try to double the amplitude of the vibrations the bottom of the car may begin hitting the ground. (Although we are assuming for simplicity that energy is never dissipated, this is clearly not a very realistic assumption in this example. Each time the car hits the ground it will convert quite a bit of its potential and kinetic energy into heat and sound, so the vibrations would actually die out quite quickly, rather than repeating for many cycles as shown in the figure.)

The key to understanding how an object vibrates is to know how the force on the object depends on the object's position. If an object is vibrating to the right and left, then it must have a leftward force on it when it is on the right side and a rightward force when it is on the left side.

(*1467*)

Tasks to perform

1. Find an equation for the frequency of simple harmonic motion in terms of k and m.

2. Many single-celled organisms propel themselves through water with long tails, which they wiggle back and forth. (The most obvious example is the sperm cell.) The frequency of the tail's vibration is typically about 10–15 Hz. To what range of periods does this range of frequencies correspond?

3. (a) Pendulum 2 has a string twice as long as pendulum 1. If we define x as the distance traveled by the bob along a circle away from the bottom, how does the k of pendulum 2 compare with the k of pendulum 1? Give a numerical ratio. (Hint: the total force on the bob is the same if the angles away from the bottom are the same, but equal angles do not correspond to equal values of x.)

(b) Based on your answer from part (a), how does the period of pendulum 2 compare with the period of pendulum 1? Give a numerical ratio.

Grammar and vocabulary revision

Ex. 1. ***Translate the following sentences into Russian, paying attention to "following" and "followed".***

1. The calculations following the experiment gave accurate results.
2. The lecture followed by the demonstration of experiments was a success.
3. The practical studies following the theoretical ones were of great use.
4. Following this new method they achieved good results.
5. 10^8 is a number expressed by one followed by eight zeroes.
6. Experiments of many other scientists following Rutherford's research proved his predictions.

Ex. 2. ***Insert the right preposition: "at", "under".***

1. This assumption holds true … certain conditions.
2. The experiment has been carried our … normal pressure.
3. The rate … which the speed of an object changes is called acceleration.
4. The body is kept … normal pressure.
5. A state of equilibrium is achieved … certain circumstances.
6. The collision of molecules become violent … high temperatures.
7. The Hall electric current increases … the action of a magnetic field.
8. Gases … normal conditions are poor conductors of electricity.

Ex. 3. ***Translate these sentences into Russian paying attention to the Gerund forms and functions.***

1. Solving physical problems is a difficult job.
2. They spoke of the results having been achieved.
3. Their having obtained the data is very important.

4. His knowing physics well did not surprise us.
5. On measuring the current they put down the results.
6. Besides putting forward a new theory he succeeded in proving it experimentally.

Ex. 4. ***Translate these sentences into English paying attention to the Gerund forms and functions.***

1. Стоит обсудить проблему субатомных частиц подробно.
2. Мы не можем не попытаться дать определение этим понятиям.
3. Не стоит повторять эти измерения без высокочувствительного прибора.
4. Нельзя не признать ценность этих исследований.
5. Не имеет смысла перечислять достоинства этой работы.
6. Стоит учесть все недостатки этой работы.

SUPPLEMENTARY READING TO UNIT 1

Read the following texts with a dictionary and answer the questions.

Text 1. Forces Have No Perpendicular Effects

Suppose you could shoot a rifle and arrange for a second bullet to be dropped from the same height at the exact moment when the first left the barrel. Which would hit the ground first? Nearly everyone expects that the dropped bullet will reach the dirt first, and Aristotle would have agreed. Aristotle would have described it like this. The shot bullet receives some forced motion from the gun. It travels forward for a split second, slowing down rapidly because there is no longer any force to make it continue in motion. Once it is done with its forced motion, it changes to natural motion, i.e. falling straight down. While the shot bullet is slowing down, the dropped bullet gets on with the business of falling, so according to Aristotle it will hit the ground first.

A bullet is shot from a gun, and another bullet is simultaneously dropped from the same height. 1. Aristotelian physics says that the horizontal motion of the shot bullet delays the onset of falling, so the dropped bullet hits the ground first. 2. Newtonian physics says the two bullets have the same vertical motion, regardless of their different horizontal motions.

Luckily, nature isn't as complicated as Aristotle thought! To convince yourself that Aristotle's ideas were wrong and needlessly complex, stand up now and try this experiment. Take your keys out of your pocket, and begin walking briskly forward.

Without speeding up or slowing down, release your keys and let them fall while you continue walking at the same pace. You have found that your keys hit the ground right next to your feet. Their horizontal motion never slowed down at all, and the whole time they were dropping, they were right next to you. The horizontal motion and the vertical motion happen at the same time, and they are independent of each other. Your experiment proves that the horizontal motion is unaffected by the vertical motion, but it's also true that the vertical motion is not changed in any way by the horizontal motion. The keys take exactly the same amount of time to get to the ground as they would have if you simply dropped them, and the same is true of the bullets: both bullets hit the ground simultaneously.

These have been our first examples of motion in more than one dimension, and they illustrate the most important new idea that is required to understand the three-dimensional generalization of Newtonian physics: Forces have no perpendicular effects. When a force acts on an object, it has no effect on the part of the object's motion that is perpendicular to the force.

In the examples above, the vertical force of gravity had no effect on the horizontal motions of the objects. These were examples of projectile motion, which interested people like Galileo because of its military applications. The principle is more general than that, however. For instance, if a rolling ball is initially heading straight for a wall, but a steady wind begins blowing from the side, the ball does not take any longer to get to the wall. In the case of projectile motion, the force involved is gravity, so we can say more specifically that the vertical acceleration is 9.8 m/s^2, regardless of the horizontal motion.

(*2641*)

Text 2. Relationship to Relative Motion

These concepts are directly related to the idea that motion is relative. Galileo's opponents argued that the earth could not possibly be rotating as he claimed, because then if you jumped straight up in the air you wouldn't be able to come down in the same place. Their argument was based on their incorrect Aristotelian assumption that once the force of gravity began to act on you and bring you back down, your horizontal motion would stop. In the correct Newtonian theory, the earth's downward gravitational force is acting before, during, and after your jump, but has no effect on your motion in the perpendicular (horizontal) direction. If Aristotle had been correct, then we would have a handy way to determine absolute motion and absolute rest: jump straight up in the air, and if you land back where you started, the surface from which you jumped must have been in a state of rest. In reality, this test gives the same result as long as the surface under you is an inertial frame. If you try this in a jet plane, you land back on the same spot on the deck from which you started, regardless of whether the plane is flying at 500 miles per hour or parked on the runway. The method would in fact only be good for detecting whether the plane was accelerating.

(*1038*)

Text 3. Newton's Laws in Three Dimensions

It is now fairly straightforward to extend Newton's laws to three dimensions: Newton's first law: If all three components of the total force on an object are zero, then it will continue in the same state of motion.

Newton's second law: The components of an object's acceleration are predicted by the equations $a_x = F_{x,total}/m$, $a_y = F_{y,total}/m$, and $a_z = F_{z,total}/m$.

Newton's third law: If two objects A and B interact via forces, then the components of their forces on each other are equal and opposite.

For example: An object is initially at rest. Two constant forces begin acting on it, and continue acting on it for a while. As suggested by the two arrows, the forces are perpendicular, and the rightward force is stronger. What happens?

Aristotle believed, and many students still do, that only one force can "give orders" to an object at one time. They therefore think that the object will begin speeding up and moving in the direction of the stronger force. In fact the object will move along a diagonal. In the example the object will respond to the large rightward force with a large acceleration component to the right, and the small upward force will give it a small acceleration component upward. The stronger force does not overwhelm the weaker force, or have any effect on the upward motion at all. The force components simply add together: $F_{x,total} = F_{1,x} + F_{2,x}$ where $F_{1,x} = 0$, $F_{2,x} = 0$.

Let's summarize it in this way.

A force does not produce any effect on the motion of an object in a perpendicular direction. The most important application of this principle is that the horizontal motion of a projectile has zero acceleration, while the vertical motion has acceleration equal to g. That is, an object's horizontal and vertical motions are independent.

(*1464*)

Discussion questions to Unit 1

1. When you stand still, there are two forces acting on you, the force of gravity (your weight) and the normal force of the floor pushing up on your feet. Are these forces equal and opposite? Does Newton's third law relate them to each other? Explain.

2. A tugboat of mass m pulls a ship of mass M, accelerating it. The speeds are low enough that you can ignore fluid friction acting on their hulls, although there will of course need to be fluid friction acting on the tug's propellers.

(a) Analyze the forces in which the tugboat participates. Don't worry about vertical forces.

(b) Do the same for the ship.

(c) Assume now that water friction on the two vessels' hulls is negligible. If the force acting on the tug's propeller is F, what is the tension, T, in the cable connecting the two ships?

3. Ginny has a plan. She is going to ride her sled while her dog pulls her. However, Ginny hasn't taken physics, so there may be a problem: she may slide right off the sled when the dog starts pulling.

(a) Analyze all the forces in which Ginny participates.

(b) Analyze all the forces in which the sled participates.

(c) The sled has mass m, and Ginny has mass M. The coefficient of static friction between the sled and the snow is μ_1, and μ_2 is the corresponding quantity for static friction between the sled and her snow pants. Ginny must have a certain minimum mass so that she will not slip off the sled. Find this in terms of the other three variables.

(d) Under what conditions will there be no solution for *M*?

4. When you fire a gun, the exploding gases push outward in all directions, causing the bullet to accelerate down the barrel. What third law pairs are involved? [Hint: Remember that the gases themselves are an object.]

5. Tom grabs Sarah by the hand and tries to pull her. She tries to remain standing without moving. A student analyzes the situation as follows. "If Tom's force on Sarah is greater than her force on him, he can get her to move. Otherwise, she'll be able to stay where she is." What's wrong with this analysis?

6. Kinetic friction is usually more or less independent of velocity. However, inexperienced drivers tend to produce a jerk at the last moment of deceleration when they stop at a stop light. What does this tell you about the kinetic friction between the brake shoes and the brake drums?

7. You hit a tennis ball against a wall. Explain any and all incorrect ideas in the following description of the physics involved: "According to Newton's third law, there has to be a force opposite to your force on the ball. The opposite force is the ball's mass, which resists acceleration, and also air resistance."

8. A student states that when he tries to push his refrigerator, the reason it won't move is because Newton's third law says there's an equal and opposite frictional force pushing back. After all, the static friction force is equal and opposite to the applied force. How would you convince him he is wrong?

9. The earth is attracted to an object with a force equal and opposite to the force of the earth on the object. If this is true, why is it that when you drop an object, the earth does not have an acceleration equal and opposite to that of the object?

SUPPLEMENTARY READING TO UNIT 2

Read the texts and discuss the problems given below.

Text 1A. Numerical Scale of Energy

Energy comes in a variety of forms, and physicists didn't discover all of them right away. They had to start somewhere, so they picked one form of energy to use as a standard for creating a numerical energy scale.

One practical approach is to define an energy unit based on heating water. The SI unit of energy is the joule, J, (rhymes with "cool"), named after the British physicist James Joule. One Joule is the amount of energy required in order to heat 0.24 *g* of water by 1 °C. Note that heat, which is a form of energy, is completely different from temperature, which is not. Twice as much heat energy is required to prepare two cups of coffee as it takes to make one, but two cups of coffee mixed together don't have double the temperature. In other words, the temperature of an object tells us how hot it is, but the heat energy contained in an object also takes into account the object's mass and what it is made of.

Once a numerical scale of energy has been established for some form of energy such as heat, it can easily be extended to other types of energy. Here are some examples of other types of energy that can be measured using the same units of joules: chemical energy, nuclear energy. New types of energy are kept getting added to the list.

To establish the existence of a new form of energy, a physicist has to (1) show that it could be converted to and from other forms of energy; and (2) show that it related to some definite measurable property of the object, for example its temperature, motion, position relative to another object, or being in a solid or liquid state.

For example, energy is released when a piece of iron is soaked in water, so apparently there is some form of energy already stored in the iron. The release of this energy can also be related to a definite measurable property of the chunk of metal: it turns reddish-orange. There has been a chemical change in its physical state, which we call rusting.

It might seem that if the principle of conservation of energy ever appeared to be violated, we could fix it up simply by inventing some new type of energy to compensate for the discrepancy. In the 20th there were experiments that suggested energy was not conserved in radioactive processes. Precise measurements of the energy released in the radioactive decay of a given type of atom showed inconsistent results. One atom might decay and release, say, 1.1×10^{-10} J of energy, which had presumably been stored in some mysterious form in the nucleus. But in a later measurement, an atom of exactly the same type might release 1.2×10^{-10} J. Atoms of the same type are supposed to be identical, so both atoms were thought to have started out with the same energy. If the amount released was random, then apparently the total amount of energy was not the same after the decay as before, i.e., energy was not conserved. Only later was it found that a previously unknown particle, which is very hard to detect, was being spewed out in the decay.

The particle, now called a neutrino, was carrying off some energy, and if this previously unsuspected form of energy was added in, energy was found to be conserved after all. The discovery of the energy discrepancies is seen with hindsight as being a step in the establishment of a new form of energy, and the discovery of the neutrino was that step.

(*2726*)

Text 2. Energy and Relative Motion

Although Einstein's theory of relativity was mentioned above, it's more relevant right now to consider how conservation of energy relates to the simpler Galilean idea that motion is relative. Galileo's Aristotelian enemies would probably have objected to conservation of energy. After all, the Galilean idea that an object in motion will continue in motion indefinitely in the absence of a force is not so different from the idea that an object's kinetic energy stays the same unless there is a mechanism like frictional heating for converting that energy into some other form.

More subtly, however, it's not immediately obvious that what has been learnt so far about energy is strictly mathematically consistent with the principle that motion is relative. Suppose we verify that a certain process, say the collision of two pool balls, conserves energy as measured in a certain frame of reference: the sum of the balls' kinetic energies before the collision is equal to their sum after the collision. (In reality it is necessary to add in other forms of energy, like heat and sound, which are liberated by the collision.) But what if we were to measure everything in a frame of reference that was in a different state of motion? A particular pool ball might have less kinetic energy in this new frame; for example, if the new frame of reference was moving right along with it, its kinetic energy in that frame would be zero. On the other hand, some other balls might have a greater kinetic energy in the new frame. It's not immediately obvious that the total energy before the collision will still equal the total energy after the collision. After all, the equation for kinetic energy is fairly complicated, since it involves the square of the velocity, so it would be surprising if everything still worked out in the new frame of reference. It does still work out.

(*1570*)

Text 3. Mass into Energy

Einstein showed that mass itself could be converted to and from energy, according to his celebrated equation $E = mc^2$, in which c is the speed of light. So mass is spoken of as simply another form of energy, and it is valid to measure it in units of joules. The mass of a 15-gram pencil corresponds to about 1.3 × × 1015 J. The issue is largely academic in the case of the pencil, because very violent processes such as nuclear reactions are required in order to convert any significant fraction of an object's mass into energy. Cosmic rays, however, are continually striking you and your surroundings and converting part of their energy of motion into the mass of newly created particles. A single high-energy cosmic ray can create a "shower" of millions of previously nonexistent particles when it strikes the atmosphere.

Even today, when the energy concept is relatively mature and stable, a new form of energy has been proposed based on observations of distant galaxies whose light began its voyage to us billions of years ago. Astronomers have found that the universe's continuing expansion, resulting from the Big Bang, has not been decelerating as rapidly in the last few billion years as would have been expected from gravitational forces. They suggest that a new form of energy may be at work.

(*1077*)

Text 4. Conservation of Momentum

In many subfields of physics these days, it is possible to read an entire issue of a journal without ever encountering an equation involving force or a reference to Newton's laws of motion. In the last hundred and fifty years, an entirely different framework has been developed for physics, based on conservation laws.

The new approach is not just preferred because it is in fashion. It applies inside an atom or near a black hole, where Newton's laws do not.

Even in everyday situations the new approach can be superior. We have already seen how perpetual motion machines could be designed that were too complex to be easily debunked by Newton's laws. The beauty of conservation laws is that they tell us something must remain the same, regardless of the complexity of the process.

So far we have discussed only two conservation laws, the laws of conservation of mass and energy. Is there any reason to believe that further conservation laws are needed in order to replace Newton's laws as a complete description of nature? Yes. Conservation of mass and energy do not relate in any way to the three dimensions of space, because both are scalars. Conservation of energy, for instance, does not prevent the planet earth from abruptly making a 90-degree turn and heading straight into the sun, because kinetic energy does not depend on direction. A new conserved quantity, called momentum, which is a vector, is developed.

(*1208*)

Discussion to the texts

1. Cosmic rays are particles from outer space, mostly protons and atomic nuclei, which are continually bombarding the earth. Most of them, although they are moving extremely fast, have no discernible effect even if they hit your body, because their masses are so small. Their energies vary, however, and a very small minority of them has extremely large energies. In some cases the energy is as much as several Joules, which is comparable to the KE of a well thrown rock! If you are in a plane at a high altitude and are so incredibly unlucky as to be hit by one of these rare ultra-high-energy cosmic rays, what would you notice, the momentum imparted to your body, the energy dissipated in your body as heat, or both? Base your conclusions on numerical estimates, not just random speculation. (At these high speeds, one should really take into account the deviations

from Newtonian physics described by Einstein's special theory of relativity.)

2. Show that for a body made up of many equal masses, the equation for the center of mass becomes a simple average of all the positions of the masses.

3. A refrigerator has coils in back that get hot, and heat is molecular motion. These moving molecules have both energy and momentum. Why doesn't the refrigerator need to be tied to the wall to keep it from recoiling from the momentum it loses out the back?

4. Good pool players learn to make the cue ball spin, which can cause it not to stop dead in a head-on collision with a stationary ball. If this does not violate the laws of physics, what hidden assumption was there in the example above?

5. A jet plane traveling due east at 300 km/hr collides with a jumbo jet which was heading southwest at 150 km/hr. The jumbo jet's mass is 5.0 times greater than that of the jet plane. When they collide, the jet plane sticks into the fuselage of the jumbo jet, and they fall to earth together. Their engines stop functioning immediately after the collision. On a map, what will be the direction from the location of the collision to the place where the wreckage hits the ground? (Give an angle.)

6. Suppose that you were trying out different equations for kinetic energy to see if they agreed with the experimental data. Based on the meaning of positive and negative signs of velocity, why would you suspect that proportionality to mv would be less likely than mv^2?

7. If a pendulum is released at A and caught by a peg as it passes through the vertical, B. To what height will the bob rise on the right?

8. Can kinetic energy ever be less than zero? Explain.

SUPPLEMENTARY READING TO UNIT 3

Read, translate and render the texts. Discuss the questions given below.

Text 1. Period, Frequency, and Amplitude

We have discussed how to measure how fast something vibrates, but not how big the vibrations are. The general term for this is amplitude, A. The definition of amplitude depends on the system being discussed, and two people discussing the same system may not even use the same definition. In the example of the block on the end of the spring, the amplitude will be measured in distance units such as cm. One could work in terms of the distance traveled by the block from the extreme left to the extreme right, but it would be somewhat more common in physics to use the distance from the center to one extreme. The former is usually referred to as the peak-to-peak amplitude, since the extremes of the motion look like mountain peaks or upside-down mountain peaks on a graph of position versus time.

In other situations we would not even use the same units for amplitude. The amplitude of a child on a swing would most conveniently be measured as an angle, not a distance, since her feet will move a greater distance than her head. The electrical vibrations in a radio receiver would be measured in electrical units such as volts or amperes.

(*937*)

Text 2. Energy in Vibrations

One way of describing the collapse of the bridge is that the bridge kept taking energy from the steadily blowing wind and building up more and more energetic vibrations. In this section, we discuss the energy contained in a vibration, and in the subsequent sections we will move on to the loss of energy and the adding of energy to a vibrating system, all with the goal of understanding the important phenomenon of resonance.

Going back to our standard example of a mass on a spring, we find that there are two forms of energy involved: the potential energy stored in the spring and the kinetic energy of the moving mass. We may start the system in motion either by hitting the mass to put in kinetic energy by pulling it to one side to put in potential energy. Either way, the subsequent behavior of the system is identical. It trades energy back and forth between kinetic and potential energy. (We are still assuming there is no friction, so that no energy is converted to heat, and the system never runs down.)

The most important thing to understand about the energy content of vibrations is that the total energy is proportional to the square of the amplitude.

(*958*)

Discussion to Unit 3

1. Consider the same pneumatic piston described in the previous problem, but now imagine that the oscillations are not small. Sketch a graph of the total force on the piston as it would appear over this wider range of motion. For a wider range of motion, explain why the vibration of the piston about equilibrium is not simple harmonic motion, and sketch a graph of x vs t, showing roughly how the curve is different from a sine wave. (Hint: Acceleration corresponds to the curvature of the x–t graph, so if the force is greater, the graph should curve around more quickly.)

2. 3 Archimedes' principle states that an object partly or wholly immersed in fluid experiences a buoyant force equal to the weight of the fluid it displaces. For instance, if a boat is floating in water, the upward pressure of the water (vector sum of all the forces of the water pressing inward and upward on every square inch of its hull) must be equal to the weight of the water displaced, because if the boat was instantly removed and the hole in the water filled back in, the force of the surrounding water would be just the right amount to hold up this new "chunk" of water. (a) Show that a cube of mass m with edges of length b floating upright (not tilted) in a fluid of density ρ. Will have a draft (depth to which it sinks below the waterline) h given at equilibrium by $h_0 = m / b\ 2\rho$. (b) Find the total force on the cube when its draft is h, and verify that plugging in $h = h_0$ gives a total force of zero. (c) Find the cube's period of oscillation as it bobs up and down in the water, and show that it can be expressed in terms of h_0 and g only.

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