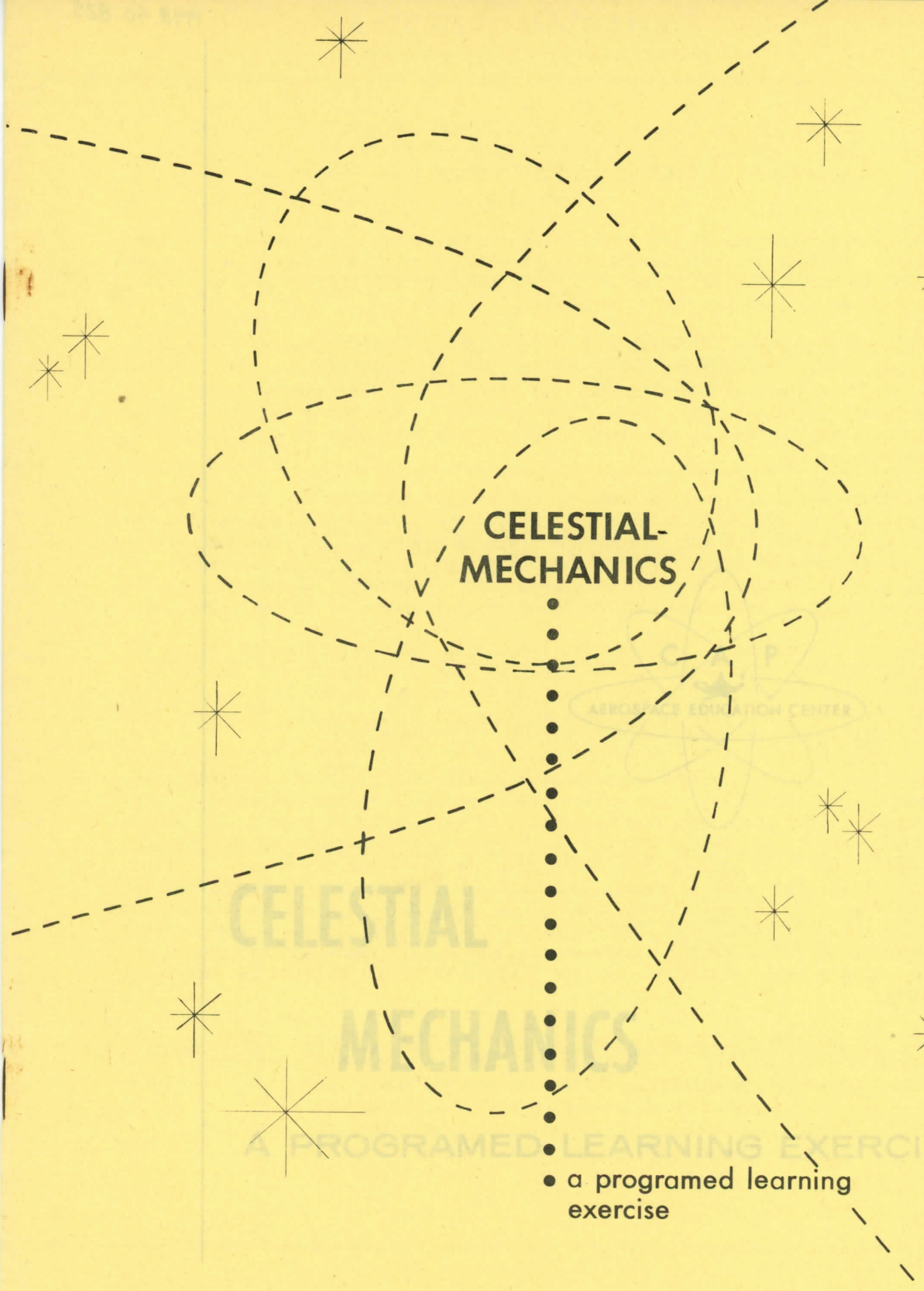
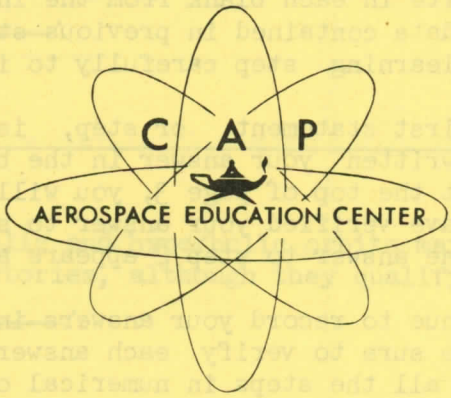


CELESTIAL-MECHANICS

- a programed learning exercise



CELESTIAL MECHANICS

A PROGRAMED LEARNING EXERCISE

HOW TO USE THIS BOOKLET

Celestial mechanics is the study of motion in space, both natural and man-made. It includes consideration of gravity, orbits, orbital velocity, escape velocity, celestial motion, and other factors that govern the behavior of satellites and space vehicles.

This is a new type of textbooklet. It consists of 107 numbered statements. These steps of learning present information in a new manner, yet they employ principles of learning that are very old. The learning experiences provided by this booklet are self-supporting. Reference to other sources of information is not required, and previous knowledge of the subject is unnecessary.

Each statement or learning step in the booklet includes one or more blanks that must be filled in to complete the statement. Read each statement carefully, then fill in the appropriate blank or blanks. You should know what to write in each blank from the information provided in each statement, or from data contained in previous statements. However, you should consider each learning step carefully to insure that your answer is the right one.

The first statement, or step, is located at the top of page 1. When you have written your answer in the blank in step 1, immediately turn to page 3. At the top of page 3, you will find the correct answer to step 1. When you have verified your answer to step 1, go on to step 2 at the top of page 3. The answer to step 2 appears at the top of page 5.

Continue to record your answers in the blanks that occur in each statement, and be sure to verify each answer before going on to the next step. Complete all the steps in numerical order; i. e., begin on page 1 with step 1 and progress completely through the right-hand, odd-numbered pages at one level, then turn back to page 1 and complete the steps at the next level on all of the odd-numbered pages, then turn again to page 1 and go through the statements at the next level, and so on until all the steps on these pages have been completed, one level at a time. Then turn to page 2 and progress through all the learning steps on the left-hand, even-numbered pages one level at a time until the remaining steps have been completed in numerical order.

If you read carefully, you should make few, if any, errors. When you have completed the booklet, you should have learned the answers to many of your questions about satellites, orbits, and space travel.

CELESTIAL MECHANICS
A PROGRAMED LEARNING EXERCISE

	The term trajectory is used to describe the path or route a projectile or body follows in space. The path of a bullet fired from a rifle is an example of a _____. 1
trajectory 9	In contrast, a circular or oval path followed by a satellite revolving about the sun, moon, or planets is known not as a trajectory but as an _____. 10
closed 18	Unlike the path of a body in a circular orbit, the closed path of a body in an elliptical orbit is longer than it is _____. 19
open 27	For this reason, parabolic and hyperbolic orbits may be considered as trajectories, although they qualify technically as _____. 28
speed 36	The exact precision required in launching makes circular and _____ orbits extremely difficult to achieve. 37
closest (or synonym) 45	The speed of a satellite in an elliptical, parabolic, or hyperbolic orbit decreases as it recedes from and increases as it approaches its parent body. At the point it comes closest to its parent body, the satellite achieves its _____ speed. 46

speed (or velocity) gravity 54	A satellite in an orbit around the earth is freely following the attraction of the earth's _____. 55
greatest (or synonym) 63	As a satellite reaches points in its orbit which are increasingly remote from its parent body, its speed becomes progressively _____. 64
speed 72	At the point of its orbit that is nearest its parent body, the velocity or speed of a satellite is _____. 73
force 81	As a satellite's speed and centrifugal force is reduced by air resistance, its ability to compete with the pull of the parent body's gravity becomes _____. 82
escape 90	A satellite or space vehicle may counterbalance gravity and achieve an elliptical orbit at a lower speed known as orbital velocity. When a satellite or space vehicle counterbalances gravity, it has been accelerated to _____ velocity. 91
wide 99	At the present time, the orbits of most manmade satellites are _____ in shape. 100

trajectory 1	The word orbit is another term used to describe the path or route of a body traveling in space. We refer to the path followed by the earth around the sun as the earth's _____. 2
orbit 10	Technically, there are four basic types of orbits: circular, elliptical, parabolic, and hyperbolic. We have already mentioned the oval, or elliptical, orbit and the _____ orbit. 11
wide 19	Since the path of the elliptical orbit is longer than it is wide, the distance of the orbiting body from the center of its source of gravity changes and does not remain _____. 20
orbits 28	The term orbit is generally applied to a body in space that follows a closed path. Paths that are closed are characteristic of the _____ orbit and the _____ orbit. 29
parabolic 37	Circular and parabolic orbits are more difficult to achieve than hyperbolic orbits or _____ orbits. 38
greatest (or synonym) 46	As a body in an elliptical, parabolic, or hyperbolic orbit recedes from its parent body, its speed becomes progressively _____. 47

orbit 2	The terms trajectory and orbit both refer to the _____ or route followed by a body traveling in space. 3
circular 11	A satellite moving in a circular orbit follows a closed path around its source of gravity. A basic characteristic of the circular orbit is its _____ path. 12
equal (or synonym) 20	A body that maintains an equal distance from the center of its source of gravity is said to be in a _____ orbit. 21
circular elliptical 29	Launching a satellite into a circular orbit is extremely difficult and requires exact precision. The precision required in launching makes it particularly difficult to achieve a _____ orbit. 30
elliptical 38	Because of the exact precision required to achieve circular and parabolic orbits, manmade objects sent into space are most likely to move in elliptical orbits or _____ orbits. 39
less (or synonym) 47	A principal factor in determining the type of path or orbit a satellite or space vehicle will follow is its velocity or _____. 48

gravity 55	A satellite in an orbit around the earth does not fly off into space because it is attracted to the earth by the pull of the earth's _____. 56
less (or synonym) 64	Orbital velocity is the speed or velocity necessary to produce a centrifugal or _____ force that counterbalances the downward pull of the earth's _____. 65
greatest (or synonym) 73	The point in an orbit that is nearest to a satellite's parent body is known as the perigee. The perigee is the point in the orbit that is _____ to the satellite's parent body. 74
less (or synonym) 82	As resistance to the air in an atmosphere continues to reduce the speed and centrifugal force of a satellite, it gradually loses its ability to compete with the pull of the parent body's _____. 83
orbital 91	At or near the earth's surface, the speed required to overcome gravity is slightly more than 25,000 miles per hour. A space vehicle accelerated to this speed would have achieved _____ velocity. 92
elliptical 100	Circular and elliptical orbits have _____ paths, but parabolic and hyperbolic orbits have _____ paths. 101

gravity 56	The orbiting satellite does not fall back to earth because it has a sustaining outward or centrifugal force generated by its _____ or velocity. 57
outward (or synonym) gravity 65	To achieve an elliptical orbit about the earth, a satellite must be accelerated to a speed of 18,000 to 25,000 miles per hour. This speed is known as orbital _____. 66
nearest (or closest) 74	A satellite is moving at its maximum speed when it reaches the point in its orbit known as the _____. 75
gravity 83	Eventually, the heat generated by friction between a satellite and the _____ will destroy the satellite. 84
escape 92	Velocities greater than escape velocities result in parabolic or open-ended orbits. To leave the earth on a space exploration mission, a space vehicle must be accelerated to _____ velocity necessary to achieve an _____-ended orbit. 93
closed open 101	Because they have open paths, parabolic and hyperbolic orbits may be considered as trajectories, but they qualify technically as _____. 102

path 3	The word trajectory is generally used to describe a path over a limited course, which has both a beginning and an ending. A missile traveling from its launch site to its target follows a course that begins at the launch site and _____ at the target. 4
closed 12	A body in a circular orbit also travels at a constant speed. A body traveling in a circular orbit not only follows a closed path, it maintains a _____ speed. 13
circular 21	A satellite following an elliptical orbit revolves about the center of its source of gravity on a path that is _____ than it is wide. 22
circular 30	To achieve a circular orbit, the body from which the satellite is launched must be considered to be a perfect sphere. Achievement of a circular orbit requires exact _____ in the launching process. 31
hyperbolic 39	Gravity is a primary factor in launching a satellite. Every satellite follows some type of curved path related to its source of _____. 40
speed 48	The curved path of a satellite in a parabolic orbit may be changed to a hyperbola or to an ellipse by slight deviations in the satellite's _____. 49

gravity 56	The orbiting satellite does not fall back to earth because it has a sustaining outward or centrifugal force generated by its _____ or velocity. 57
outward (or synonym) gravity 65	To achieve an elliptical orbit about the earth, a satellite must be accelerated to a speed of 18,000 to 25,000 miles per hour. This speed is known as orbital _____. 66
nearest (or closest) 74	A satellite is moving at its maximum speed when it reaches the point in its orbit known as the _____. 75
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closed open 101	Because they have open paths, parabolic and hyperbolic orbits may be considered as trajectories, but they qualify technically as _____. 102

speed 57	The satellite remains in orbit because there is a balance between the centrifugal or outward force generated by its _____ and the downward pull of the earth's _____. 58
velocity 66	The point in an orbit that is farthest away from a satellite's parent body is known as the apogee of the orbit. The apogee of an orbit is the point in the orbit that is _____ away from the parent body. 67
perigee 75	As it reaches the perigee of its orbit, the satellite's centrifugal or outward force generated by its velocity exceeds the pull of the parent body's _____. 76
air (or atmosphere) 84	The earth rotates from west to east. Satellites are usually launched in an easterly direction to take advantage of the natural velocity generated by the earth's west to east _____. 85
escape open 93	A satellite or space vehicle accelerated to a speed below escape velocity achieves an elliptical orbit. An elliptical orbit ties a satellite or space vehicle to its parent body because its path is not open but _____. 94
orbits 102	The velocity or speed of a satellite in an elliptical orbit changes as the satellite approaches and withdraws from its source of _____. 103

ends 4	The missile follows a limited course. Its path _____ at the launch site and _____ at the target. 5
constant 13	A body traveling in a circular orbit also remains an equal distance from the center of its source of gravity. The distance of a satellite in a circular orbit from the center of its gravitational attraction does not change. It remains _____. 14
longer 22	The orbits of most manmade satellites are elliptical in shape. A manmade satellite usually follows not an open but a _____ path around the center of its source of _____. 23
precision (or synonym) 31	The earth is not perfectly spherical. It is about 13 miles flatter at the poles than at the equator. Exact precision in launching is necessary to achieve a _____ orbit. 32
gravity 40	The paths followed by bodies in circular, elliptical, hyperbolic, and parabolic orbits are not straight lines; they are _____. 41
speed (or velocity) 49	The gravitational attraction of its parent body is a second factor in determining the type of path or _____ a satellite will follow. 50

speed (or velocity) gravity 58	When there is a balance between the outward force generated by its speed and the downward pull of the earth's gravity, a satellite remains in orbit. Only when a satellite is in a circular orbit is this ideal state of _____ achieved and maintained over a prolonged period. 59
farthest 67	The speed of a satellite becomes progressively less as it approaches the _____ of its orbit. 68
gravity 76	The satellite then begins another outward journey into space as the pull of the parent body's gravity is exceeded by the satellite's centrifugal or _____ force. 77
rotation 85	To leave the earth on a space exploration mission, a space vehicle must first overcome the pull of the earth's _____. 86
closed 94	The terms trajectory and orbit both refer to the path or route followed by a body traveling in _____. 95
gravity 103	Rockets are used to accelerate satellites to the _____ necessary for them to overcome the pull of the earth's _____. 104

begins ends 5	A trajectory is a path over a _____ course, which has both a _____ and an _____. 6
equal (or synonym) 14	A body is said to be in a circular orbit when its distance from the center of its source of gravity remains _____, when it travels at a _____ speed, and when it follows a _____ path. 15
closed gravity 23	A body accelerated to such a high rate of speed that it escapes into space follows a path known either as a parabolic orbit or as a hyperbolic orbit. We have already studied the _____ orbit and the _____ orbit. 24
circular 32	Because the earth is not a perfect sphere, it is less difficult to launch a body into an elliptical orbit than into a _____ orbit. 33
curved (or curves) 41	The velocity or speed of a satellite traveling in an elliptical, parabolic, or hyperbolic orbit changes as the satellite approaches or withdraws from its source of _____. 42
orbit 50	Two important factors in determining the type of orbit are the _____ of the satellite and the _____ of its parent body. 51

balance (or synonym) 59	The exact precision necessary in achieving circular orbits makes it likely that most manmade objects sent into space will follow _____ or _____ orbits. 60
apogee 68	A satellite nearing the apogee of its orbit loses its initial velocity because it is traveling away from its parent body and against the pull of the parent body's _____. 69
outward 77	Unless it is routed through an atmosphere where air slows it down, a satellite will continue revolving about its source of _____ indefinitely without additional power. 78
gravity 86	To overcome the earth's gravity and achieve a parabolic orbit, or open-ended path, necessary to leave the earth, a space vehicle must be accelerated to a required _____. 87
space 95	The term trajectory is generally used to describe the path or route followed by a body in space over a limited course, which has both a beginning and an _____. 96
speed (or velocity) gravity 104	Changes in a satellite's speed at different points in its orbit are the result of the changing influence of the earth's _____ and the satellite's _____ force. 10

limited beginning ending 6	The path of a missile traveling from its launch site to its target is known as the missile's _____. 7
equal (or synonym) constant closed 15	A majority of the planets in our solar system revolve around the sun in this type of orbit, one that is nearly _____ in shape. 16
circular elliptical 24	A body following a parabolic orbit or a hyperbolic orbit has been accelerated to a high rate of _____. 25
circular 33	Like the circular orbit, the parabolic orbit, which is an open-ended path followed by a body in space, requires exact precision in the launching process. Circular and elliptical orbits follow closed paths, but the path of a parabolic orbit is _____-ended. 34
gravity 42	The speed of a satellite in an elliptical, parabolic, or hyperbolic orbit is greatest when the satellite is closest to its parent body. The speed or velocity of a satellite in a circular orbit does not change; it remains _____. 43
speed gravity 51	To leave the earth and achieve an orbit, a satellite must first overcome the pull of the earth's _____. 52

elliptical hyperbolic 60	Since most manmade satellites follow elliptical or egg-shaped paths, the dominant force that influences these satellites constantly shifts from the downward pull of the earth's _____ to the satellite's centrifugal or _____ force.
gravity 69	When a satellite reaches the apogee of its orbit, the pull of its parent body's gravity becomes greater than the centrifugal or outward force generated by the satellite's _____.
gravity 78	It will remain in orbit because of the interaction between the parent body's _____ and the satellite's centrifugal or outward _____.
speed (or velocity) 87	Circular and elliptical orbits tie satellites and space vehicles to their parent bodies because the paths of these orbits are _____ rather than open-ended.
ending 96	The term orbit is generally used to describe the circular path followed by a body in space as it revolves about its source of _____.
gravity centrifugal (or outward) 105	A satellite does not fly off into space because it is attracted to its parent body by the pull of _____.

trajectory 7	The word orbit is generally used to describe the circular or oval path followed by a body in space around its source of gravity. The path followed by the moon in its revolution about the earth is known as the moon's _____. 8
circular 16	The orbits of Mars, Mercury, and Pluto deviate from the circular, and their paths tend to be oval, or elliptical, in shape. The oval paths followed by these planets are not circular; they are _____. 17
speed 25	The path of the body becomes open rather than remaining closed as this speed allows the body to _____ into space. 26
open 34	A body following a parabolic orbit must have been accelerated to a high rate of speed. One factor in the achievement of a parabolic orbit is a high rate of _____. 35
constant 43	A satellite in a circular orbit does not approach or withdraw from its parent body. It maintains an _____ distance from its source of _____. 44
gravity 52	This may be accomplished by accelerating the satellite to a required _____ or velocity. 53

gravity outward 61	Changes in a satellite's speed at different points in its orbit are the result of the changing influence of the earth's _____ and the satellite's _____ force. 62
speed (or velocity) 70	As the pull of the parent body's gravity exceeds the centrifugal or outward force generated by a satellite's speed, the satellite is attracted back toward its parent _____. 71
gravity force 79	When a satellite enters an atmosphere, resistance to the air reduces the satellite's _____. 80
closed 88	Satellites and space vehicles following parabolic or hyperbolic orbits escape into space because their paths are not closed, but _____-ended. 89
gravity 97	A satellite in a circular orbit follows a _____ path, maintains a _____ speed, and remains and _____ distance from its source of gravity. 98
gravity 106	A satellite remains in orbit because there is a balance between the centrifugal or outward force generated by its _____ and the downward pull of the earth's _____. 107

orbit 8	Routes from the earth to the moon or to the planets extend over limited courses, and each route has a beginning and an ending. Such a path or route is known not as an orbit but as a _____. (Continue with step 10 on page 1.) 9
elliptical 17	An elliptical orbit is a closed path which is longer than it is wide. A body traveling in an elliptical orbit revolves around the center of its source of gravity on a path that is not open but _____. (Continue with step 19 on page 1.) 18
escape 26	Circular and elliptical orbits have closed paths, but the paths of parabolic and hyperbolic orbits are _____. (Continue with step 28 on page 1.) 27
speed 35	The curved path of a satellite in a parabolic orbit may be changed to a hyperbola or to an ellipse by even slight deviations in the satellite's rate of _____. (Continue with step 37 on page 1.) 36
equal (or synonym) gravity 44	The speed of a satellite in an elliptical, parabolic, or hyperbolic orbit is greatest when the satellite is _____ to its parent body. As the satellite recedes from its parent body, its speed becomes progressively less. (Continue with step 46 on page 1.) 45
speed 53	Rockets are used to accelerate satellites to the _____ necessary for them to overcome the pull of the earth's _____. (Continue with step 55 on page 2.) 54

gravity centrifugal (or outward) 62	At the point it is nearest to its parent body, a satellite's speed is _____. (Continue with step 64 on page 2.) 63
body 71	As the satellite approaches its parent body, it gradually regains the velocity or _____ it lost during its outward journey. (Continue with step 73 on page 2.) 72
speed (or velocity) 80	A reduction in speed or velocity also reduces a satellite's centrifugal or outward _____. (Continue with step 82 on page 2.) 81
open 89	The minimum speed at which an object overcomes gravity is known as escape velocity. A space vehicle accelerated to the minimum speed necessary to overcome the pull of the earth's gravity would have achieved _____ velocity. (Continue with step 91 on page 2.) 90
closed constant equal (or synonym) 98	An elliptical orbit is longer than it is _____. (Continue with step 100 on page 2.) 99
speed (or velocity) gravity 107	(End)

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