28th Annual SLAPT Physics Contest

Washington University in St. Louis

April 27, 2013

Mechanics Test

$g = 9.8\ \frac{\text{m}}{\text{s}^2}$ $\qquad$ $1\text{cm}^3 = \text{millimeter}$

Please answer the following questions on the supplied answer sheet. You may write on this test booklet and keep it for your records. Only the answer sheets will be scored.

Your answer sheets must have your name, your school, and MECHANICS on them

The cash prizes for this exam will be:
First Prize of $100, Second Prize of $50, and Third Prize of $25.

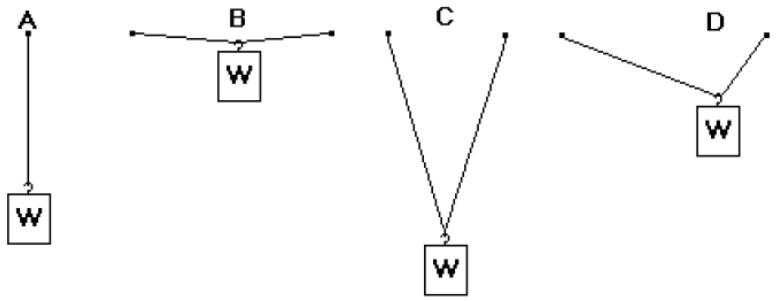
Newton Awards will be presented to the next highest scoring twenty percent of the contestants, and certificates to the top three scoring schools.

Award Ceremony at approximately 12:30 in this room

1. A tractor-trailer truck is traveling down the road. The trailer's mass is 4 times the mass of the tractor. If the tractor accelerates forward, the force that the trailer applies on the tractor is
   A. 4 times greater than the force of the tractor on the trailer.
   B. 2 times greater than the force of the tractor on the trailer.
   C. equal to the force of the tractor on the trailer.
   D. 1/4 the force of the tractor on the trailer.
   E. zero since the tractor is pulling the trailer forward.

2. An airplane with air speed 120 km/h is heading due north in a wind blowing due east at 50 km/h. What is the ground speed of the plane?
   [A] 60 km/h [B] 120 km/h [C] 130 km/h [D] 140 km/h [E] None of these

3. A weight can be hung in any of the following four ways. In which case is the string most likely to break?

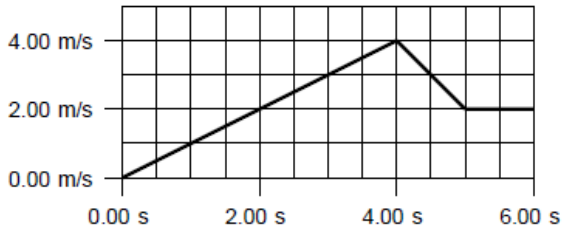


   A. A B. B C. C D. D E. all the same

4. If air resistance can be neglected, what happens to the horizontal velocity component of a basketball as it is thrown to the basket from the free-throw line?
   A. increases
   B. decreases
   C. decreases until the ball reaches the top then increases as the ball comes down
   D. increases until the ball reaches the top then decreases as the ball comes down
   E. remains constant

5. Which is a dimensionally correct set of units for power?
   A. $kg \cdot s$
   B. $kg \cdot m/s$
   C. $kg \cdot m^2/s$
   D. $kg \cdot m^2/s^2$
   E. $kg \cdot m^2/s^3$

6. A graph of velocity as a function of time is shown for the rectilinear motion of an object. What is the magnitude of the displacement of the object during the 6.0 s interval shown in the graph?

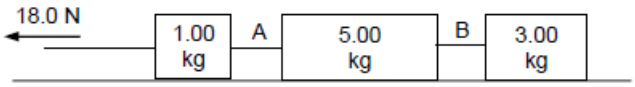


A. 9.0 m
B. 12.0 m
C. 13.0 m
D. 17.0 m
E. 20.0 m

7. In the situation described in problem 6, what is the magnitude of the average acceleration during the 6.0 s time interval shown in the graph?

A. 0.33 m/s^2
B. 0.67 m/s^2
C. 1.00 m/s^2
D. 2.00 m/s^2
E. 3.00 m/s^2

8. Three masses are on a level, frictionless surface. They are attached as shown by unstretchable strings A and B of negligible mass. A horizontal 18.0 N force pulls on the 1.00 kg mass. What is the magnitude of the acceleration of the 5.00 kg mass?



A. 2.00 m/s^2
B. 3.60 m/s^2
C. 6.00 m/s^2
D. 18.0 m/s^2
E. 36.0 m/s^2

9. In the situation described in problem 8, what is the tension in string B?

A. 3.00 N
B. 6.00 N
C. 12.0 N
D. 18.0 N
E. 54.0 N

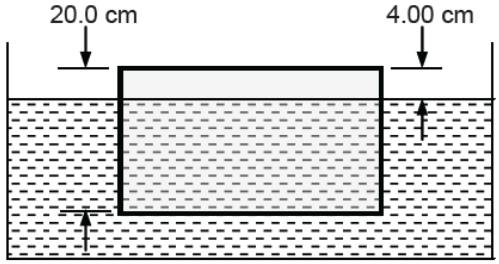
10. A binary star system consists of star A with a mass 4.00×10^{30} kg and star B with a mass 8.00×10^{30} kg orbiting each other in elliptical orbits. When the two stars are 5.00×10^{9} m apart, their total kinetic energy is 2.00×10^{41} J. How far apart are the two stars when their total kinetic energy is 3.00×10^{41} J?
    A. 2.22×10^{9} m
    B. 3.33×10^{9} m
    C. 4.05×10^{9} m
    D. 7.50×10^{9} m
    E. 1.13×10^{10} m

11. A tire rolls without slipping along a straight line on a flat surface. The center of the wheel moves 200 m as the tire rotates 50.0 revolutions. What is the diameter of the tire?
    A. 0.250 m
    B. 0.637 m
    C. 0.785 m
    D. 1.27 m
    E. 4.00 m

12. A diver leaves the diving board rotating at 1.20 rad/s with her body configured in such a manner that the moment of inertia about the axis of rotation is 30.0 kg·m^2. As the dive progresses, the diver reconfigures her body so her rate of rotation increases to 2.00 rad/s. What is the diver's moment of inertia about the axis of rotation in the new configuration?
    A. 10.8 kg·m^2
    B. 18.0 kg·m^2
    C. 30.0 kg·m^2
    D. 72.0 kg·m^2
    E. 83.3 kg·m^2

13. In the situation described in problem 12, what is the rotational kinetic energy of the diver in the initial configuration?
    A. 10.4 J
    B. 21.6 J
    C. 25.0 J
    D. 36.0 J
    E. 540 J

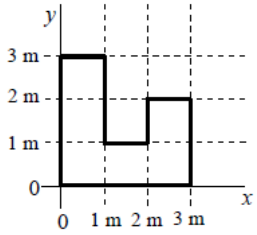
14. A 12.0 kg rectangular block of material is 20.0 cm by 30.0 cm by 40.0 cm. The block floats in a liquid so that the 20.0 cm edge is vertical and 4.00 cm of that edge is above the surface of the liquid. What is the density of the liquid?



A. 300 kg/m^3
B. 375 kg/m^3
C. 500 kg/m^3
D. 625 kg/m^3
E. 2500 kg/m^3

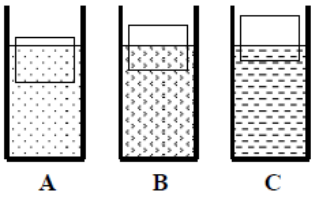
15. A uniform sheet of material is outlined by the bold lines in the diagram. What is the *x*-component of the center of mass of the sheet of material? For significant figure purposes, all of the boundaries of the material are within 0.01 m of an integer coordinate.

A. 1.17 m
B. 1.33 m
C. 1.50 m
D. 1.67 m
E. 1.83 m



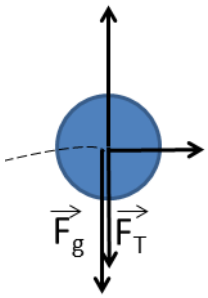
16. Three identical objects are floating in equilibrium in containers of fluid as shown. Container A holds a fluid with a density 1000 kg/m^3. Container B holds a fluid with a density 2000 kg/m^3. Container C holds a fluid with a density 3000 kg/m^3. What is the ratio of the buoyant force acting on the object in container A, F_A, to the buoyant force acting on the object in container B, F_B, to the buoyant force acting on the object in container C, F_C (F_A: F_B : F_C)?

A. 1:2:3
B. 3:2:1
C. 1:4:9
D. 9:4:1
E. 1:1:1



17. A hypothetical planet orbits a star with mass one-half the mass of our sun. The planet's orbital radius is the same as the Earth's. Approximately how many Earth years does it take for the planet to complete one orbit?
    A. 1/2
    B. $1/\sqrt{2}$
    C. 1
    D. $\sqrt{2}$
    E. 2

18. The free-body diagram to the right is supposed to represent a rock at the end of a string which is being whirled clockwise in a vertical circle. The rock is at the top of its circular path at the instant shown. How should we label the rightward force?

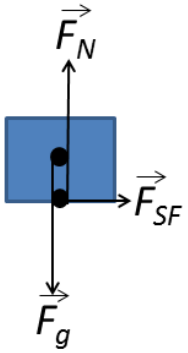


    A. F_M (force of motion)
    B. F_I (force of inertia)
    C. F_D
    D. The diagram is wrong: the right force should not be there at all.
    E. The diagram is wrong: there should be a leftward force instead of a rightward force.

19. Consider again the free-body diagram in problem 18. How should we label the upward force?
    A. F_C (centrifugal force)
    B. F_C (centripetal force)
    C. ma
    D. F_I (force of inertia)
    E. The diagram is wrong: there is no upward force.

20. An object falling vertically at a speed of 20 m/s lands in a snowbank and comes to rest 0.5 s later. What is the object's average acceleration during this interval?
    A. 10 m/s^2 up
    B. 10 m/s^2 down
    C. 40 m/s^2 up
    D. 40 m/s^2 down
    E. 5 m/s^2 up

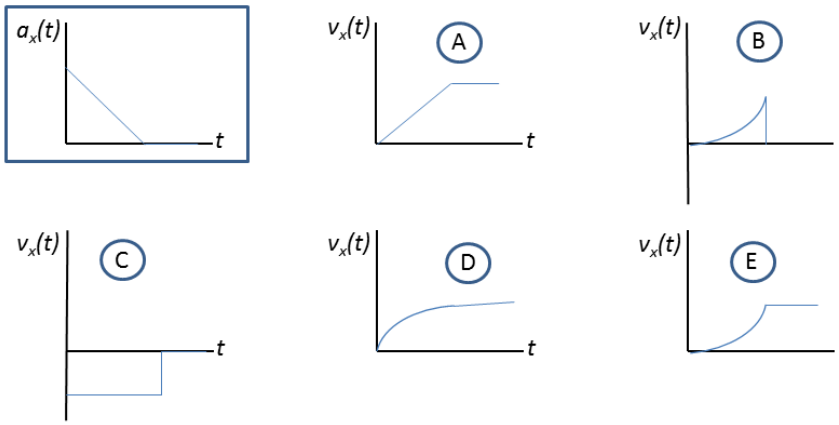
21. The drawing to the right is supposed to be a free-body diagram of a box that sits without slipping on the back of a truck that is moving to the right but is slowing down. Is the diagram correct?



    A. Yes
    B. No: F_{SF} should point leftward
    C. No: the F_{SF} label should be F_{KF}
    D. No: there should be a leftward drag force
    E. No: F_N should not be equal to F_g

22. In the 1920 astronomer Fritz Zwicky found the first evidence of "Dark Matter". What did Zwicky observe?
    A. The stars within a particular galaxy are moving faster than expected implying there is some extra, unseen, matter.
    B. The stars within a particular galaxy are moving slower than expected implying there is some extra, unseen, matter.
    C. Distant supernova seem to be rushing away from us at increasing speeds.
    D. Distant supernova seem to be rushing toward us at increasing speeds.

23. An object's x-acceleration $a_x(t)$ is shown in the boxed graph at the top left. Which of the other graphs in the set most correctly describes its x-velocity?

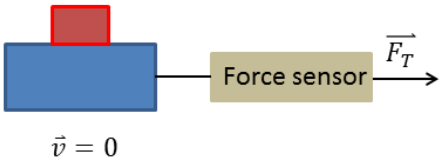


24. If a car's x-position at time t=0 is $x(0)$=0 and it has an x-velocity of $v_x(t)=b(t-T)^2$, where b and T are constants, which function below best describes $x(t)$?
    A. $x(t) = 2\ b(t-T)$
    B. $x(t) = 3\ b(t-T)^3$
    C. $x(t) = (1/3)\ b(t-T)^3$
    D. $x(t) = (1/2)\ b(t-T)$
    E. $x(t) = (1/3)\ b[(t-T)^3 + T^3]$

25. A 1-kg rock is suspended by a massless string from one end of a 1-m measuring stick. What is the mass of the measuring stick if it is balance by a support force at the 0.25-m mark?
    A. 0.25 kg
    B. 0.5 kg
    C. 1kg
    D. 2kg
    E. 4 kg

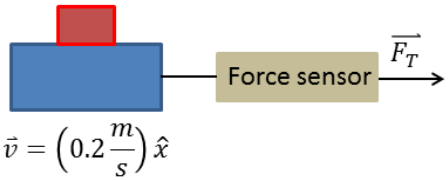
26. In which of the following experiments does the output of the force sensor also equal the magnitude of the kinetic frictional force between the bottom mass and the horizontal surface?

(A)



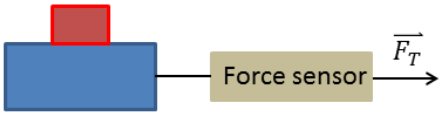
$\vec{v} = 0$

(B)



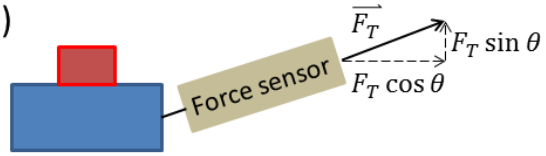
$\vec{v} = \left(0.2\frac{m}{s}\right)\hat{x}$

(C)



$\vec{a} = \left(0.1\frac{m}{s^2}\right)\hat{x}$

(D)



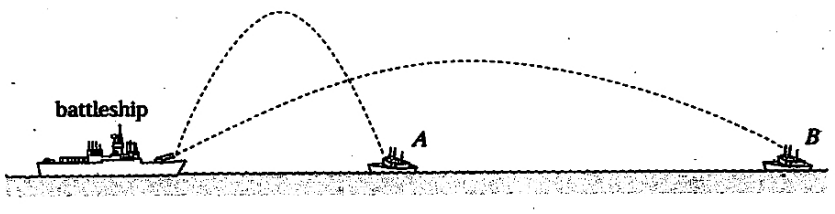
$\vec{v} = \left(0.2\frac{m}{s}\right)\hat{x}$

27. For the scenario illustrated in problem 26, does it take more force to start motion or to sustain it once it begins?
    A. Start the motion
    B. Sustain the motion

28. Imagine that a satellite orbits the earth so closely that it experiences some drag due to the earth's upper atmosphere. This will drain away some of the orbital energy of this system, converting it to thermal energy. If this happens fairly slowly, the satellite's orbit will remain nearly circular. What happens to the radius of this satellite's orbit as time passes in this case?
    A. It slowly decreases.
    B. It remains the same: just the satellite's speed decreases.
    C. It slowly increases

29. In the situation described in the previous problem, what do you think will happen to the satellite's speed as time passes?
    A. It slowly decreases.
    B. It remains roughly the same.
    C. It slowly increases.

30. A battleship simultaneously fires two shells at enemy ships. If the shells follow the parabolic trajectories shown, which ship gets hit first?



A. A
B. B
C. Both are hit at the same time.
D. Need more information

31. Imagine that we throw a baseball with an initial speed of 12 m/s in a direction 60^o upward from the horizontal. What is the baseball's speed at the peak of its trajectory?
A. 12 m/s
B. 10.4 m/s
C. 6 m/s
D. 3 m/s
E. 0 m/s

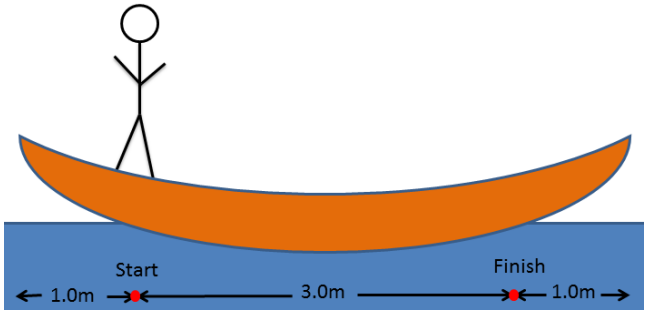
32. Imagine that a certain engine can cause the road to exert a certain maximum forward force F_{SF} on a certain car. If we change the car's design to reduce its drag coefficient by a factor of 2, by what factor will the car's maximum speed increase (other things being equal)?
A. No increase
B. 1.41
C. 2
D. 4

33. A bicyclist rounds a curve at a constant speed. Their velocity is also constant, T or F?
A. True
B. False

34. A person is sitting at rest on a stool that is free to rotate about a vertical axis while holding in one hand a bicycle wheel that is rapidly spinning counterclockwise when viewed from above. The person then stops the wheel with the other hand. What happens to the person as a result?
A. The person must rotate counterclockwise
B. The person must rotate clockwise
C. The person will rotate in a direction that depends on which hand does the stopping.
D. Nothing; the wheel's angular momentum is carried away by external interactions.
E. Nothing; the wheel's angular momentum is simply dissipated by the friction interaction.

35. Two hockey pucks are initially at rest on a horizontal plane of frictionless ice. Puck *A* has twice the mass of puck *B.* Imagine that we apply the same constant force to each puck for the same interval of time *dt*. How do the pucks' kinetic energies compare at the end of this interval?
    A. $K_A=4K_B$
    B. $K_A=2K_B$
    C. $K_A=K_B$
    D. $K_B=2K_A$
    E. $K_B=4K_A$

36. A 45.0kg woman stands up in a 60.0kg canoe which is 5.00m long. She walks from a point 1.00m from one end to a point 1.00m from the other end. If you ignore resistance to motion of the canoe in the water, approximately how far does the canoe move?



    A. 1.0 m
    B. 1.25 m
    C. 1.75 m
    D. 3 m

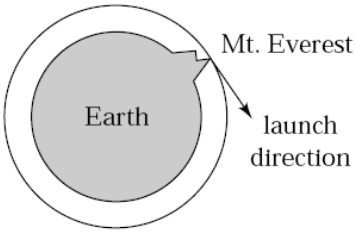
37. An object moving with a velocity whose components are [4 m/s, -1 m/s, 3 m/s] is acted on by a force whose components are [-5 N, 0, +5 N]. What is the power of the energy transfer involved in this interaction?
    A. – 35 W
    B. – 5 W
    C. 0
    D. +5 W
    E. + 35 W

38. Two identical balls leave point A at the same time with the same initial speed. Which ball will arrive at the point B first?

A. The ball following path #1
B. The ball following path #2
C. Both balls will arrive at the same time
D. It's impossible to tell from the information provided

39. Which has the larger kinetic energy, a 50-kg person running at a speed of 2 m/s or a 5-g nickel falling at a speed of 200 m/s?
A. The running person.
B. The falling nickel.
C. Both have the same kinetic energy.

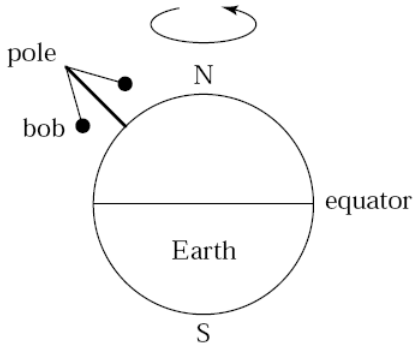
40. Suppose Earth had no atmosphere and a ball were fired from the top of Mt. Everest in a direction tangent to the ground. If the initial speed were high enough to cause the ball to travel in a circular trajectory around Earth, the ball's acceleration would



A. be much less than *g* (because the ball doesn't fall to the ground).
B. be approximately *g*.
C. depend on the ball's speed.

41. The Moon does not fall to Earth because
A. It is in Earth's gravitational field.
B. The net force on it is zero.
C. It is beyond the main pull of Earth's gravity.
D. It is being pulled by the Sun and planets as well as by Earth.
E. none of the above

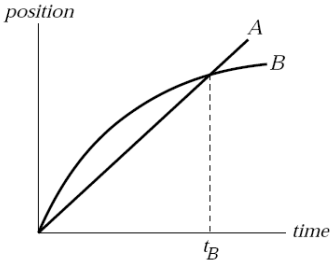
42. A pendulum bob is suspended from a long pole somewhere on the northern hemisphere. When the pendulum is at rest, the combined action of gravitation and Earth's rotation makes the bob



A. point straight down toward the center of Earth.
B. deviate toward the east.
C. deviate toward the west.
D. deviate toward the north.
E. deviate toward the south.

43. A person standing at the edge of a cliff throws one ball straight up and another ball straight down at the same initial speed. Neglecting air resistance, the ball to hit the ground below the cliff with the greater speed is the one initially thrown
A. upward.
B. downward.
C. neither—they both hit at the same speed.

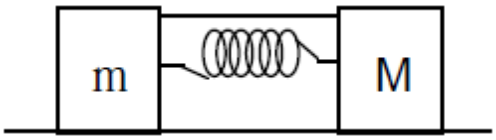
44. The graph shows position as a function of time for two trains running on parallel tracks. Which is true?



A. At time t_B, both trains have the same velocity.
B. Both trains speed up all the time.
C. Both trains have the same velocity at some time before t_B.
D. Somewhere on the graph, both trains have the same acceleration.

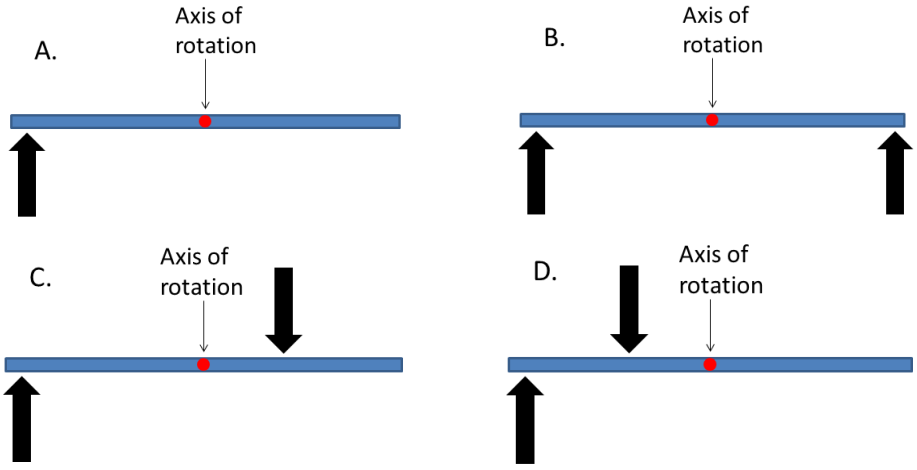
45. A rocket near the surface of the earth is accelerating vertically upward at 10 m/s^2. The rocket releases an instrument package. Immediately after release the acceleration of the instrument package is:
A. 20 m/s^2 up
B. 10 m/s^2 up
C. 0
D. 10 m/s^2 down
E. 20 m/s^2 down

46. A spring is compressed between two objects with unequal masses, *m* and *M*, held together by a string as shown in the figure below. The objects are initially at rest on a horizontal frictionless surface. The string is then cut. Which statement is true?



A. Kinetic energy is the same as before the string was cut.
B. The total final kinetic energy is zero.
C. The two objects have equal kinetic energy.
D. The speed of one object is equal to the speed of the other.
E. The total final momentum of the two objects is zero.

47. Which configuration below will exert the largest net torque on the rod? Assume that each force (indicated by the block arrows) has the same magnitude.



48. Two blocks, one of mass *m* and one of mass 2*m*, are at rest on a compressed spring. A moment after the spring is released the blocks are ejected from the spring. Which block goes higher?
A. The block of mass 2*m*.
B. The block of mass *m*.
C. The go the same height.

49. A person, located at the equator, of mass *m* weighs themself on a scale. A person, located at the North Pole, of mass *m* weighs themselves on a scale. If the scales are identical, which scale will display a higher number implying a greater weight?
A. The scale at the North Pole.
B. The scale at the equator.
C. Both scales will read the same thing.

50. A projectile is launched from ground level at an angle of 50.0° above the horizontal, reaching a maximum height of 30.0 m above the level ground. Assuming negligible air friction, what was the launch speed of the projectile?

    A. 18.7 m/s
    B. 24.2 m/s
    C. 31.7 m/s
    D. 37.7 m/s
    E. 42.6 m/s