This is not due for a grade. It is provided for you to review for your test. Assigned on Monday, October 28, 2024

Review: Unit 2b – Gravity, Friction, and Circles...Oh My!

Not for grade

Part 1: College Board AP Physics 1 Topics Covered on Test

Topic 2.6: Gravitational Force

Learning Objective: Describe the gravitational interaction between two objects or systems with mass.

Essential Knowledge:

- Newton's law of universal gravitation describes the gravitational force between two objects or systems as directly proportional to each of their masses and inversely proportional to the square of the distance between the systems' centers of mass.

  Relevant equation:

  $$|\vec{F}_g| = G\frac{m_1 m_2}{r^2}$$

  - The gravitational force is attractive.
  - The gravitational force is always exerted along the line connecting the centers of mass of the two interacting systems.
  - The gravitational force on a system can be considered to be exerted on the system's center of mass.
- A field models the effects of a noncontact force exerted on an object at various positions in space.
  - The magnitude of the gravitational field created by a system of mass M at a point in space is equal to the ratio of the gravitational force exerted by the system on a test object of mass m to the mass of the test object.

    Derived equation:

    $$|\vec{g}| = \frac{|\vec{F}_g|}{m} = G\frac{M}{r^2}$$

  - If the gravitational force is the only force exerted on an object, the observed acceleration of the object (in m/s^2) is numerically equal to the magnitude of the gravitational field strength (in N/Kg) at that location.

    Derived Equation:

    $$\text{Weight} = F_g = mg$$

Learning Objective: Describe situations in which the gravitational force can be considered constant.

Essential Knowledge:

- If the gravitational force between two systems' centers of mass has a negligible change as the relative position of the two systems changes, the gravitational force can be considered constant at all points between the initial and final positions of the systems.
- Near the surface of Earth, the strength of the gravitational field is g = 10 N/kg.

Learning Objective: Describe the conditions under which the magnitude of a system's apparent weight is different from the magnitude of the gravitational force exerted on that system.

Essential Knowledge:

- The magnitude of the apparent weight of a system is the magnitude of the normal force exerted on the system.
- If the system is accelerating, the apparent weight of the system is not equal to the magnitude of the gravitational force exerted on the system.
- A system appears weightless when there are no forces exerted on the system or when the force of gravity is the only force exerted on the system.
- The equivalence principle states that an observer in a noninertial reference frame is unable to distinguish between an object's apparent weight and the gravitational force exerted on the object by a gravitational field.

Learning Objective: Describe inertial and gravitational mass.

Essential Knowledge:

- Objects have inertial mass, or inertia, a property that determines how much an object's motion resists changes when interacting with another object.
- Gravitational mass is related to the force of attraction between two systems with mass
- Inertial mass and gravitational mass have been experimentally verified to be equivalent.

Topic 2.7: Kinetic and Static Friction

Learning Objective: Describe kinetic friction between two surfaces.

Essential Knowledge:

- Kinetic friction occurs when two surfaces in contact move relative to each other
    - The kinetic friction force is exerted in a direction opposite to the motion of each surface relative to the other surface.
    - The force of friction between two surfaces does not depend on the size of the surface area of contact.
- The magnitude of the kinetic friction force exerted on an object is the product of the normal force the surface exerts on the object and the coefficient of kinetic friction.
  Relevant equation:
  $$|\vec{F}_{f,k}| = |\mu_k \vec{F}_n|$$
    - The coefficient of kinetic friction depends on the material properties of the surfaces that are in contact.
    - Normal force is the perpendicular component of the force exerted on an object by the surface with which it is in contact; it is directed away from the surface.

Learning Objective: Describe static friction between two surfaces.

Essential Knowledge:

- Static friction may occur between the contacting surfaces of two objects that are not moving relative to each other.
- Static friction adopts the value and direction required to prevent an object from slipping or sliding on a surface.
  Relevant equation:
  $$|\vec{F}_{f,s}| \leq |\mu_s \vec{F}_n|$$
    - Slipping and sliding refer to situations in which two surfaces are moving relative to each other.
    - There exists a maximum value for which static friction will prevent an object from slipping on a given surface.
      Derived equation:
      $$F_{f,s,\max} = \mu_s F_n$$
- The coefficient of static friction is typically greater than the coefficient of kinetic friction for a given pair of surfaces.

Topic 2.9: Circular Motion

Learning Objective: Describe the motion of an object traveling in a circular path.

Essential Knowledge:

- Centripetal acceleration is the component of an object's acceleration directed toward the center of the object's circular path.
    - The magnitude of centripetal acceleration for an object moving in a circular path is the ratio of the object's tangential speed squared to the radius of the circular path.
      Relevant equation:
      $$a_c = \frac{v^2}{r}$$
    - Centripetal acceleration is directed toward the center of an object's circular path.
- Centripetal acceleration can result from a single force, more than one force, or components of forces exerted on an object in circular motion.
    - At the top of a vertical, circular loop, an object requires a minimum speed to maintain circular motion. At this point, and with this minimum speed, the gravitational force is the only force that causes the centripetal acceleration.
      Derived equation:
      $$v = \sqrt{gr}$$
    - Components of the static friction force and the normal force can contribute to the net force producing centripetal acceleration of an object traveling in a circle on a banked surface.
    - A component of tension contributes to the net force producing centripetal acceleration experienced by a conical pendulum.
- Tangential acceleration is the rate at which an object's speed changes and is directed tangent to the object's circular path.
- The net acceleration of an object moving in a circle is the vector sum of the centripetal acceleration and tangential acceleration.
- The revolution of an object traveling in a circular path at a constant speed (uniform circular motion) can be described using period and frequency.
    - The time to complete one full circular path, one full rotation, or a full cycle of oscillatory motion is defined as period, T.
    - The rate at which an object is completing revolutions is defined as frequency, f.

Relevant equation:

$T = \frac{1}{f}$

- For an object traveling at a constant speed in a circular path, the period is given by the derived equation $T = \frac{2\pi r}{v}$.

Learning Objective: Describe circular orbits using Kepler's third law.

Essential Knowledge:

- For a satellite in circular orbit around a central body, the satellite's centripetal acceleration is caused only by gravitational attraction. The period and radius of the circular orbit are related to the mass of the central body. Derived equation:

$T^2 = \frac{4\pi^2}{GM} R^3$

Part 2: Practice Problems (Be sure to look at all assignments done in class, also!)

Multiple Choice Practice

1. Which of the following statements about Newton's Law of Gravitation is true?
   A) The gravitational field between two objects depends only on their masses.
   B) The gravitational field between two objects depends only on the distance between them.
   C) The gravitational force between two objects is proportional to the product of their masses and inversely proportional to the square of the distance between them.
   D) The gravitational force between two objects is always attractive and constant.

2. Which of the following best describes the gravitational field at a distance *r* from the center of a planet of mass *M*?
   A) The field is directly proportional the product of the mass of the object in the field and M.
   B) The field is directly proportional to *M* and inversely proportional to r^2.
   C) The field is directly proportional to r and inversely proportional to *M*.
   D) The field is constant, regardless of r and *M*.

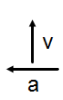
3. A block sits on a horizontal surface. A horizontal force is gradually applied to the block until it just begins to move. Which of the following statements is true about the forces acting on the block at the moment it starts to move?
   A) The applied force is less than the maximum static friction force.
   B) The applied force is equal to the maximum static friction force.
   C) The applied force is greater than the maximum static friction force.
   D) The applied force equals the kinetic friction force.

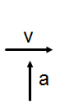
4. A book is sliding across a table and gradually slows down and stops. Which force is primarily responsible for the book coming to a stop?
   A) Gravity B) Normal force C) Kinetic friction D) Static friction

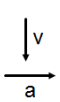
5. A box is placed on an inclined plane. As the angle of the incline gradually increases, which of the following correctly describes the behavior of static friction before the box starts to slide?
   A) Static friction remains constant.
   B) Static friction decreases as the incline angle increases.
   C) Static friction increases to balance the component of gravity parallel to the incline, until it reaches a maximum.
   D) Static friction becomes zero just before the box starts to slide.

6. A motorcyclist moves at a constant speed down one hill and up another hill along the smooth curved surface. When the motorcyclist reaches the lowest point of the curve its velocity and acceleration directions are:

A) 

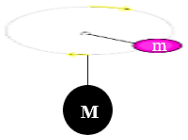
B) 

C) 

D) 

7. A centripetal force F is applied to an eraser moving at a constant speed v in a horizontal circle of radius r. If the same force is applied, but the radius is halved, what happens to the speed of the eraser?
   A) Increased by a factor of 2 B) decreased by a factor of 2 C) increased by a factor of $\sqrt{2}$ D) decreased by a factor of $\sqrt{2}$

8. An object m is tied to one end of a string and moves in a circle with a constant speed v on a horizontal frictionless table. The second end of the string is connected to a big mass M and goes through a small hole in the table. What is the value of M if it stays in equilibrium?
   (A) mv^2/rg (B) v^2/rmg (C) rg/mv^2 (D) mv^2r/g



9. Is it possible for an object moving with a constant speed to accelerate? Explain.
   (A) No, if the speed is constant then the acceleration is equal to zero.
   (B) No, an object can accelerate only if there is a net force acting on it.
   (C) Yes, if the direction of the object can be changing.
   (D) Yes, if an object is moving it can experience acceleration

10. Two objects attract each other gravitationally. If the distance between their centers is cut in half, the gravitational force
   A) is cut to one fourth. B) is cut in half. C) doubles. D) quadruples

11. A planet is discovered to orbit around a star in the galaxy Andromeda, with the same orbital diameter as the Earth around our Sun. If that star has 4 times the mass of our Sun, what will the period of revolution of that new planet be, compared to the Earth's orbital period?
   A) one-fourth as much B) one-half as much C) twice as much D) four times as much

12. An astronaut goes out for a "space walk" at a distance above Earth's surface equal to the radius of Earth. What is her acceleration due to gravity?
   A) zero B) g C) g/2 D) g/4

13. Spacecraft X has twice the mass of Spacecraft Y. They orbit Earth at the same radius. Which of these must be true?
   A) X feels a greater gravitational force than Y
   B) X travels twice as fast as Y
   C) X takes twice as long to complete an orbit
   D) The orbital period of X is half of the orbital period of Y

14. A student who weighs 500 N on Earth travels to a planet whose mass and radius are twice that of Earth. His weight on that planet is about
   A) 1000 N B) 500 / $\sqrt{2}$ N C) 500 N D) 250 N

Free Response Question Practice

1. Two objects, each with a mass of 5 kg, are placed 2 meters apart. What is the gravitational force between them?
2. Suppose the distance between two planets doubles, but their masses remain constant. By what factor does the gravitational force between them change?
3. A 2,000 kg satellite orbits Earth at a distance of 8600 km from the surface of the earth. Calculate the gravitational force exerted by Earth on the satellite. (The mass of the earth is 5.972×10^{24} kg and the radius of the earth is 6400 km.)
4. Mars has a mass of $6.42\text{x}10^{23}$ kg and a radius of $3.38\text{x}10^{6}$ m. What gravitational field strength would an astronaut experience on its surface? What percent of Earth's surface field strength is this?
5. If the gravitational field strength on the surface of Planet X is 5 N/kg, what is the gravitational force acting on a 10 kg object on its surface?
6. Bill Ding has a mass *m* and is standing on a scale in an elevator accelerating downward with acceleration *a*. What is Bill's apparent weight in terms of *m*, *a*, and *g*?
7. A block with a mass of 5.0 kg is pushed across a horizontal surface with a constant force of 20.0 N applied at an angle of 30˚ above the horizontal. The coefficient of kinetic friction between the block and the surface is 0.20. Draw a diagram of the scenario and calculate the acceleration of the block.

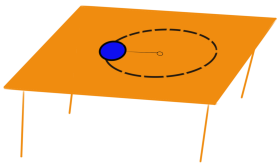
8. A block of mass *m* is placed on an inclined plane that makes an angle θ with the horizontal. The coefficient of static friction between the block and the plane is μ_s. Find the expression for the maximum angle θ_{max} at which the block will just begin to slide down the incline.

9. In each of the following situations, what effect will the change have on the amount of friction? Use the following choices:

a) increase b) decrease c)no change

_____ The normal force (force pushing surfaces together) increases
_____ The roughness of only one surface is increased
_____ The surface area in contact increases
_____ A lubricant is added between the surfaces
_____ Static friction changes to kinetic friction

10. On Earth, a scale shows that you weigh 585 N when you are not moving. What would your weight be on the Moon (g = 1.6 m/s^2)

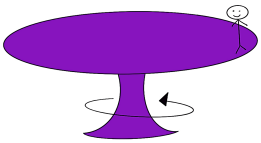


11. A 0.013kg rubber ball is attached to a 0.93m string. The ball is swung in a horizontal circle on a frictionless table with a period of 1.18 seconds.

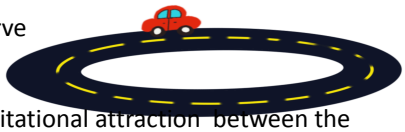
a) With what speed is the ball traveling?
b) Find the tension force exerted by the string on the ball

12. While driving along a country lane with a speed of 17 m/s, you encounter a dip in the road. You coast down the dip that has a radius of 65m. If the passenger is 80-kg what normal force will the person experience?

13. A Carnival clown rides a motorcycle down a ramp and around a vertical loop. If the loop has a radius of 18 m, what is the slowest speed the rider can have at the top of the loop to avoid falling?



14. A child sits on a rotating merry-go-round, 2.1 m from its center. If the speed of the child is 1.9 m/s, what is the minimum coefficient of friction between the child and the merry-go-round that will prevent the child from slipping?

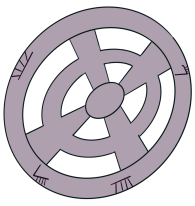


15. A car racing on a flat track at 22 m/s around a curve with a 56 meter radius. What minimum coefficient of static friction between the tires and road is necessary for the car to round the curve without slipping?

16. A physics student is flying on an airplane 11,887m above ground. a) Determine the force of gravitational attraction between the earth (5.98 x 10^{24} kg) and the 70 kg physics student if the distance of earths radius is 6.38 x 10^6 m. b) Find the acceleration of gravity the physics student experiences.

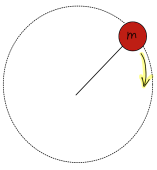
17. Mars travels at an average speed of 2.41×10^4 m/s around the Sun, and takes 5.94×10^7 s to complete one revolution. How far is the center of Mars from the center of the Sun?

18. The design for a rotating spacecraft below consists of two rings. The outer ring with a radius of 30 m holds the living quarters and mimics the surface gravity of Earth, approximately 9.80 m/s^2. The inner ring is designed to help the astronauts become accustom to the surface gravity of a new planet: 5.35 m/s^2.



a) Calculate the linear speed of the outer ring.
b) Calculate the spacecraft's period of rotation.
c) Calculate the radius of the inner ring.

19. A 1.13-kg ball is swung vertically from a 0.5m cord in uniform circular motion at a speed of 2.4 m/s.



a) What is the tension in the cord at the bottom of the ball's motion
b) What is the tension in the cord at the top of the ball's motion?
c) What is the tension in the cord when the ball is horizontal on the right side?

20. Find the period of revolution for the planet Mercury, whose average distance from the sun is 5.79 x 10^{10} m. (Mass of the sun is 2 x 10^{30}kg)

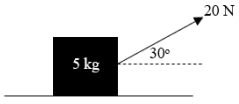
21. Find the altitude above the surface of the Moon where a "lunasynchronous" satellite would orbit (meaning the satellite would travel at the same speed that the moon rotates). The period of a lunar day is 27.332 days. (R_{moon} = 1,736,482 m, M_{moon} = 7.34767309 × 10^{22} kg)

Answers

Multiple Choice Practice

1. C
2. B
3. B
4. C
5. C
6. C
7. D
8. A
9. C
10. D
11. B
12. D
13. A
14. D

Free Response Questions

1. 4.17×10^{-11}N
2. Decreases by factor of 4
3. 3.55×10^{3}N
4. a) 3.8 N/Kg (3.8 m/s^2); b) 38%
5. 50 N
6. $m(g-a)$
7. 

1.90 m/s^2
8. $\theta_{max}=\tan^{-1}(\mu_s)$
9. a, a, c, b, b
10. 95.5 N
11. a) 4.95 m/s; b) 0.343 N
12. 1140 N
13. 13.3 m/s
14. 0.175
15. >=0.88
16. a) 684 N; b) 9.77 m/s^2
17. 1.43 × 10^{12} m
18. a) 17.2 m/s; b) 11.0 s; c) 16.4 m
19. a) 21.1 N; b) 1.9 N; c) 13.0 N
20. 7.58 × 10^{6} s (88 days)
21. 8.67x10^{7} m