

# ***UNIT 2 TEST REVIEW***

## **Force, Circular Motion, and Gravity**

### **Chapters 4 - 5**

**\* In studying for your test, make sure to study this review sheet along with your quizzes and homework assignments.**

**Multiple Choice Review:** On this portion of the test, you will not be allowed to use your calculator or AP formula sheet. (You may, however, use your AP table of information.) Approximate  $g=10\text{m/s}^2$  for simplicity of calculations. No partial credit will be given.

1. A rope of negligible mass supports a block that weighs 30N. The breaking strength of the rope is 50N. The largest acceleration that can be given to the block by pulling up on it with the rope without breaking the rope is most nearly...  
a.  $6\text{m/s}^2$     b.  $6.7\text{m/s}^2$     c.  $10\text{m/s}^2$     d.  $15\text{m/s}^2$     e.  $16.7\text{m/s}^2$
  
2. A new planet is discovered that has twice the Earth's mass and twice the Earth's radius. On the surface of this new planet, a person who weighs 500N on Earth would experience a gravitational force of...  
a. 125N    b. 250N    c. 500N    d. 1000N    e. 2000N
  
3. Three forces act on an object. If the object is in translational equilibrium, which of the following must be true?  
I. The vector sum of the three forces must equal zero.  
II. The magnitudes of the three forces must all be equal.  
III. All three forces must be parallel.  
a. I only  
b. II only  
c. I and III only  
d. II and III only  
e. I, II, and III

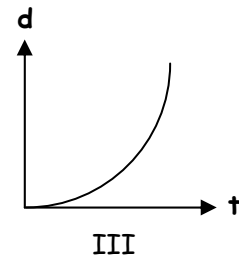
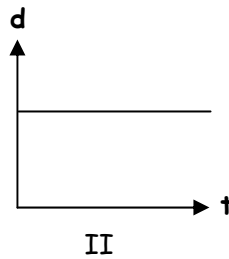
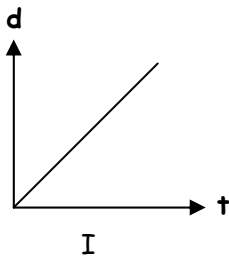
4. What is the orbital speed of a satellite of mass  $m$  orbiting the earth at a distance  $r$  from the center of the Earth? (Assume that  $G$  stands for the gravitational constant and  $M$  stands for the Earth's mass.)

- a.  $\frac{GM}{r}$     b.  $\sqrt{\frac{2GM}{r}}$     c.  $\frac{2Gm}{r}$     d.  $\sqrt{\frac{2Gm}{r}}$     e.  $\sqrt{\frac{GM}{r}}$

5. A child has a toy tied to the end of a string and whirls the toy above his head at a constant speed in a horizontal circular path of radius  $R$ . The toy completes each revolution of its motion in a time period  $T$ . What is the magnitude of the acceleration of the toy?

- a. Zero    b.  $\frac{4\pi^2 R}{T^2}$     c.  $\frac{\pi R}{T^2}$     d.  $g$     e.  $2\pi g$

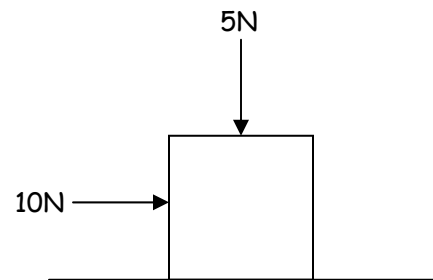
6. Three objects can only move along a straight, level path. The graphs below show the position  $d$  of the objects plotted as a function of time  $t$ . The sum of the forces on the object is zero in which of the cases?



- a. II only  
 b. III only  
 c. I and II only  
 d. I and III only  
 e. I, II, and III

7. A 2kg block slides with constant velocity along a horizontal tabletop. A horizontal applied force of 10N and a downward applied force of 5N act on the block, as shown. The coefficient of friction between the block and tabletop is most nearly...

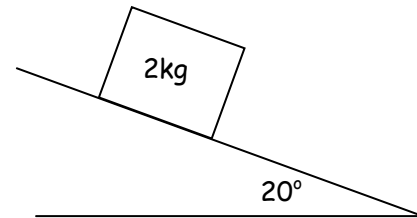
- a. 0.3    b. 0.4    c. 0.5    d. 0.75



- e. 1

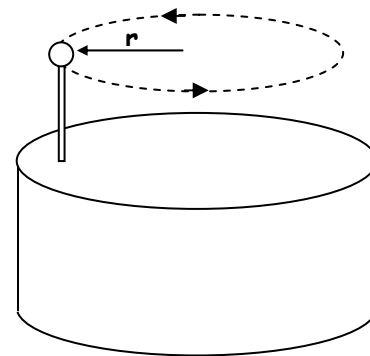
8. A 2kg object is released to slide down a  $20^\circ$  incline. If the coefficient of kinetic friction between the object and incline is 0.4, the object will accelerate down the incline at a rate of...

- $(0.4)(2g)$
- $\frac{(0.4)(2g)}{2}$
- $\frac{(0.4)(2g)(\cos 20^\circ)}{2}$
- $\frac{(2g)(\sin 20^\circ) - (0.4)(2g)(\cos 20^\circ)}{2}$
- $\frac{(0.4)(2g)(\cos 20^\circ) - (2g)(\sin 20^\circ)}{2}$



**Questions 9 and 10:**

A steel ball supported by a stick is attached to a rotating cylinder, and itself rotates in a circle of radius  $r$ , as shown.



9. The direction of the net force acting on the ball when it is in the position shown is indicated by which of the following?

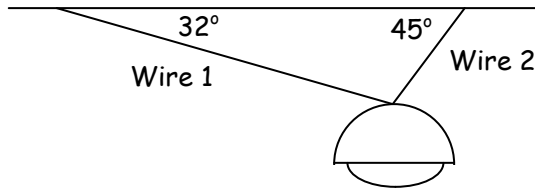
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10. If the ball becomes disconnected from its supporting stick at the position shown in the diagram above, it will become a projectile with an initial velocity in which direction?

- straight upward
- straight downward
- out of the plane of the page
- to the right
- to the left

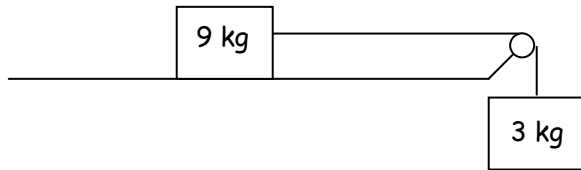
**Problem Review:** On this portion of the test, you may use your calculator, AP formula sheet, and AP table of information. Partial credit will be given on these problems.

11. The 100N light fixture in the figure is at rest. Find the tension in the two wires that support the fixture



12. The coefficient of static friction between a 3kg crate and the  $35^\circ$  incline it sits upon is 0.200. This friction is not enough to keep the box from sliding down the incline. What is the minimum 'squeezing' force that must be applied to the box, perpendicular to the incline, to keep the crate from sliding?
13. An airplane accelerates uniformly from rest. A physicist passenger holds up a thin string of negligible mass to which she has tied her ring and notices that the string makes an angle with the vertical. If the plane reaches a takeoff speed of 65m/s after accelerating for a total of 30s, determine the angle  $\theta$  that the string makes with the vertical during the acceleration of the plane before it leaves the ground.

14. The two blocks in the picture are being held in place, and are then released from rest. Use force ideas and kinematics to find the following, assuming the table and pulleys are frictionless: the tension in the cord connecting the blocks, the acceleration of the 3kg block as it descends, and the speed of the 3kg block as it strikes the floor, 1.2m below where it started.



15. A 15cm-radius Beatles album spins at 78 rev/min. What are the magnitude and direction of the acceleration of a dust particle sitting at the album's outer edge?
16. A 2000kg car rounds a circular turn of radius 30m. If the road is flat and the coefficient of static friction between the tires and road is 0.67, what is the fastest velocity the car can have as it rounds the corner without skidding?

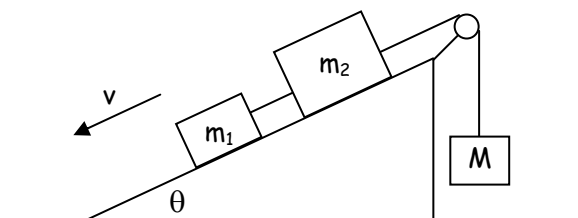
17. A roller-coaster car has a mass of 600kg when fully loaded with passengers. The vehicle is approaching the top of a hill that is shaped like part of a circle of radius 20m. What is the maximum speed the car can have when it is at the top of the hill, in order for gravity to keep the car on the track?

Body	Mass (kg)	Mean Radius (m)	Distance from Sun (m)
Earth	$5.98 \times 10^{24}$	$6.37 \times 10^6$	$1.496 \times 10^{11}$
Sun	$1.991 \times 10^{30}$	$6.96 \times 10^8$	--
Moon	$7.36 \times 10^{22}$	$1.74 \times 10^6$	--

\* Distance from the Earth to the Moon = 384,000 km

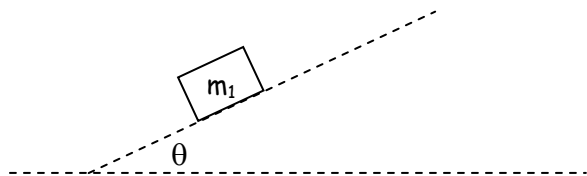
18. Use the given information in the table to determine the orbital speed of the Moon around the Earth, as well as the period of orbit of the Moon.

19. Actual A.P. Physics B Free-Response Question (2000):



Blocks 1 and 2 of masses  $m_1$  and  $m_2$ , respectively, are connected by a light string. These blocks are further connected to a block of mass  $M$  by another light string that passes over a pulley of negligible mass and friction. Blocks 1 and 2 move with a constant velocity  $v$  down the inclined plane, which makes an angle  $\theta$  with the horizontal. The kinetic frictional force on block 1 is  $f$  and that on block 2 is  $2f$ .

a. On the given figure, draw and label all the forces on block  $m_1$ .



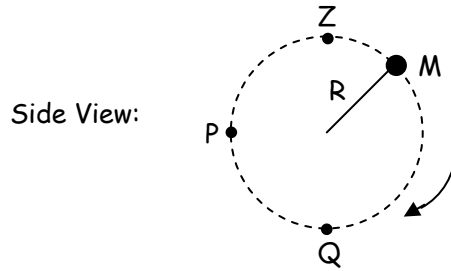
Express your answers to each of the following in terms of  $m_1$ ,  $m_2$ ,  $g$ ,  $\theta$ ,  $f$ .

b. Determine the coefficient of kinetic friction between the inclined plane and block 1.

c. Determine the value of the suspended mass  $M$  that allows blocks 1 and 2 to move with constant velocity down the plane.

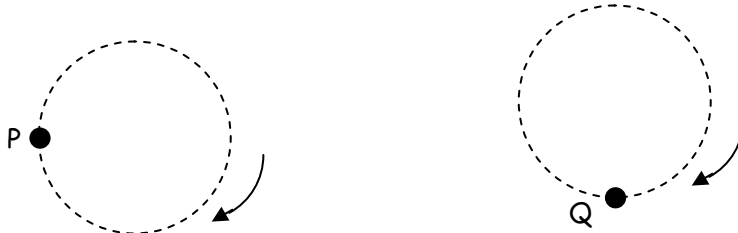
d. The string between blocks 1 and 2 is now cut. Determine the acceleration of block 1 while it is on the inclined plane.

20. Actual A.P. Physics B Free-Response Question (2001):



A ball of mass  $M$  is attached to a string of length  $R$  and negligible mass. The ball moves clockwise in a vertical circle, as shown above. When the ball is at point  $P$ , the string is horizontal. Point  $Q$  is at the bottom of the circle and point  $Z$  is at the top of the circle. Air resistance is negligible. Express all algebraic answers in terms of the given quantities and fundamental constants.

- a. On the figures below, draw and label all the forces exerted on the ball when it is at point  $P$  and  $Q$ , respectively.



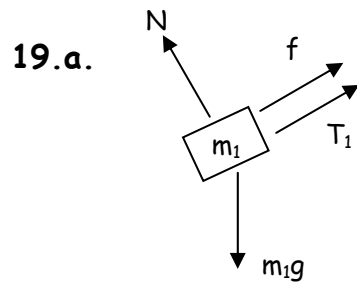
- b. Derive an expression for  $v_{\min}$ , the minimum speed the ball can have at point  $Z$  without leaving the circular path.

- c. The maximum tension the string can have without breaking is  $T_{\max}$ . Derive an expression for  $v_{\max}$ , the maximum speed the ball can have at point  $Q$  without breaking the string.

- d. Suppose that the string breaks at the instant the ball is at point  $P$ . Describe the motion of the ball immediately after the string breaks.

## ***FREE-RESPONSE ANSWERS:***

11.  $T_1 \cos 32 = T_2 \cos 45$  so  $T_1 = 0.834T_2$  Also,  $T_1 \sin 32 + T_2 \sin 45 = 100$ , so substitution gives  $(0.834T_2) \sin 32 + T_2 \sin 45 = 100$   
Therefore,  $T_2 = 87\text{N}$  and  $T_1 = 72.6\text{N}$
12.  $F_N = \frac{F_s}{\mu_s} = \frac{3(9.8)\sin 35}{.2} = 84.3\text{N}$ , so  $F_{\text{app}} = F_N - F_{gy} = 60.2\text{N}$
13. The acceleration of the plane (and ring) is found by  $a = \frac{65-0}{30} = 2.17\text{m/s}^2$ .  
To calculate the angle of the string, think about the two components of the tension force in the string. The x-component is causing the acceleration,  $T_x = ma$ . The y-component is balancing out the weight of the ring, so  $T_y = mg$ . So  $\theta = \tan^{-1}(ma/mg) = 12.5^\circ$
14. On the table,  $T=9a$ . For the block hanging over the side,  $29.4-T=3a$ .  
Substitution gives  $a = 2.45\text{m/s}^2$  so  $T = 22.05\text{N}$ . Then the block's final speed is found with  $v^2 = v_0^2 + 2ax$  to be  $v = 2.43\text{m/s}$ .
15. First convert 78rpm to 1.225m/s. Then find the centripetal acceleration by  $a_c = \frac{v^2}{r} = 10.0\text{m/s}^2$ . The direction of the acceleration is toward the center of the circular path.
16. For the car not to skid, friction must cause the centripetal acceleration, so  $F_{\text{fric}} = m(a_c)$ .  $F_{\text{fric}} = \mu F_N = 13,132\text{N}$ . So the equation  $F_{\text{fric}} = m \frac{v^2}{r}$  yields  $v = 14.03\text{m/s}$ .
17. For the car to stay on the track, gravity must provide the force causing the centripetal acceleration (with  $F_N=0$  to imply that the car is almost ready to leave the track). So,  $F_g = m \frac{v^2}{r}$  yields a speed of 14 m/s.
18. Gravity must be the cause of the centripetal acceleration,  $F_g = ma_c$ , but  $F_g$  is found with Newton's Universal Law of Gravitation. This yields the expression  $v = \sqrt{\frac{Gm_{\text{Earth}}}{3.84 \times 10^8}}$  which gives an orbital speed of 1019m/s. The period is found with the equation  $v = \frac{d}{t} = \frac{2\pi r}{T}$  which gives  $T = 2.37 \times 10^6 \text{ s}$ , or approx. 27.4 days.



b.  $\mu = \frac{F_{\text{fric}}}{N}$  and  $N = F_{gy} = mg \cos \theta$ , so  $\mu = \frac{f}{m_1 g \cos \theta}$

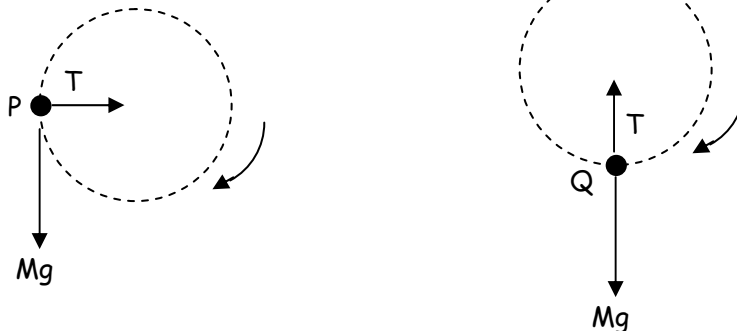
- c. Considering the entire system all at once, the forward forces (x-components of weight of blocks on the incline) are balanced with the backwards forces (friction and the weight of the hanging block).  
 $m_1 g \sin \theta + m_2 g \sin \theta = Mg + f + 2f$

Solve for  $M = \sin \theta (m_1 + m_2) - \frac{3f}{g}$

- d. If the string is cut, block 1 will move down the incline under the influence of gravity and friction. Using Newton's 2<sup>nd</sup> Law:  $m_1 g \sin \theta - f = m_1 a$

and  $a = \frac{m_1 g \sin \theta - f}{m_1} = g \sin \theta - \frac{f}{m_1}$

20.a.



b. At point Z, using Newton's 2<sup>nd</sup> law:  $Mg + T = M \frac{v^2}{R}$

But  $T=0$  because you're finding the minimum speed to stay in a circle, which would be the moment when the string becomes 'un-tense'.

Solve for  $v = \sqrt{gR}$

c. At point Q using Newton's 2<sup>nd</sup> law:  $T - Mg = M \frac{v^2}{R}$

Solve for  $v = \sqrt{\frac{TR}{M} - gR}$

- d. It will continue straight upward, behaving as a vertically-launched free-fall object.