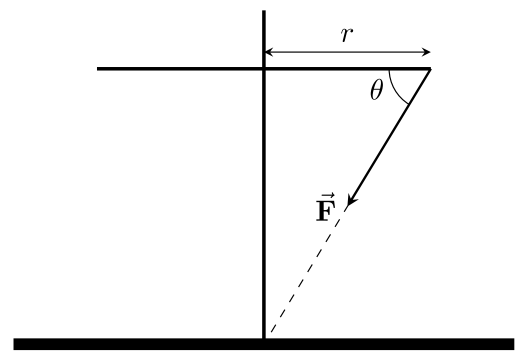
Physics 211 Final Exam, Question xxx

This is not the full exam; this is part xxx of yyy. The full instructions are in part 1; read them before you begin.

1. Imagine a simplified version of a person standing on one foot, rigidly holding their arms outstretched, as seen in the figure.

   The person's arm length is r. You push on their hand towards their foot, making an angle θ as shown. To find out if they fall over, what is the torque applied, using their foot as the axis?

   (a) rF

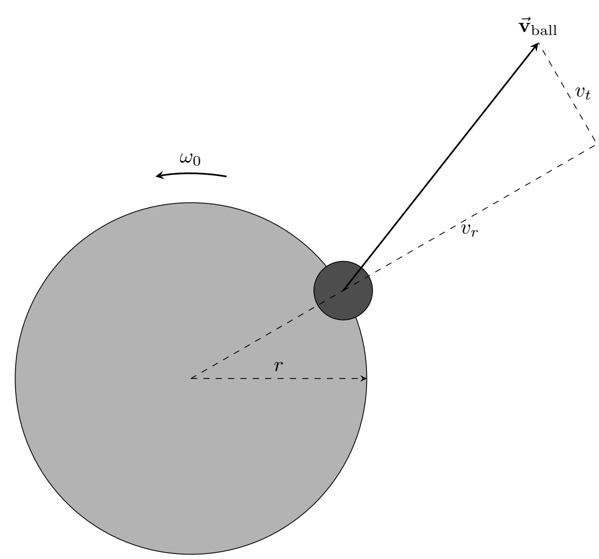
   (b) $rF\sin\theta$

   (c) $rF\cos\theta$

   (d) 0-

2. A 70 kg person (represented as the dark gray circle in the figure) stands at the edge of a merry-go-round with a radius $r = 2$ m that is spinning at an angular velocity of $\omega_0 = 2$ rad/s.

   Assume the merry-go-round is massless. They throw a 5 kg ball in a direction that from their perspective is straight out, giving it a speed of $v_r = 5$ m/s in that direction. But, as we know, the ball will also have velocity tangential to the circle, labeled in the figure as v_t, since before the throw it was undergoing circular motion. After they throw the ball what will be the angular velocity of the merry-go-round and person?

   (a) 1.91 rad/s

   (b) 1.96 rad/s

   (c) 2.00 rad/s

   (d) 2.14 rad/s

The next five problems concern this story:

Two children are throwing a Frisbee back and forth when they get it stuck in a tree.

One of them has a slingshot and she suggests using it to shoot small rocks at the Frisbee to knock it loose. A slingshot is a small device that uses an elastic band (which has the same physics as a spring) to propel projectiles forward. She places a rock in the slingshot, draws it back, points it up at the tree, and then releases the rock; the elastic band propels the rock forward.

The rock flies through the air and strikes the Frisbee on one edge of the bottom. (This collision is close to inelastic.) This knocks it clear of the tree, and also makes it start rotating end over end.

Consider four moments in time:

- Before she releases the rock, when the elastic band in the slingshot is stretched
- Immediately after the rock leaves the slingshot
- Immediately before the rock strikes the Frisbee
- Immediately after the rock strikes the Frisbee and it begins to tumble

3. Which principle could be used to determine how fast the rock is traveling when it leaves the slingshot, if you know the properties of the rock, the slingshot, and how far she stretches it?
   (a) The conservation of momentum
   (b) The conservation of angular momentum
   (c) The work-energy theorem / the conservation of energy
   (d) Kinematics with constant acceleration
   (e) Both (c) and (d)

4. Which principle could be used to determine how fast the rock is traveling when it strikes the Frisbee, if you know the angle and speed it was launched at?
   (a) The conservation of momentum
   (b) The conservation of angular momentum
   (c) The work-energy theorem / the conservation of energy
   (d) Kinematics, assuming constant acceleration
   (e) Both (c) and (d)

5. Which principle could be used to determine the angle that she must launch the rock at so that it strikes the Frisbee, if you know the launch velocity?
   (a) The conservation of momentum
   (b) The conservation of angular momentum
   (c) The work-energy theorem / the conservation of energy
   (d) Kinematics, assuming constant acceleration
   (e) Both (c) and (d)

6. Which principle could be used to determine the velocity of the Frisbee right after it is struck by the rock, if you know the velocity of the rock right before?
   (a) The conservation of momentum
   (b) The conservation of angular momentum
   (c) The work-energy theorem / the conservation of energy
   (d) Kinematics, assuming constant acceleration
   (e) Both (c) and (d)

7. Which principle explains why the Frisbee begins to spin after it is struck by the rock off-center?
   (a) The conservation of momentum
   (b) The conservation of angular momentum
   (c) The work-energy theorem / the conservation of energy
   (d) Kinematics, assuming constant acceleration
   (e) Both (c) and (d)

One vital skill in physics is the ability to look at an algebraic expression and deduce what sort of quantity it might describe.

For each of the following, describe what sort of quantity the expression given might refer to. All symbols have their conventional meanings.

8. $$\frac{m_1 g \sin\theta - m_2 g \sin\phi}{m_2 + m_1}:$$ Is this a ...

   (a) Force
   (b) Acceleration
   (c) Distance
   (d) Energy
   (e) Time

9. $$\frac{v_0 \sin\theta + \sqrt{v_0^2 \sin^2\theta - 2gh}}{g}$$ Is this a ...

   (a) Force
   (b) Acceleration
   (c) Power
   (d) Energy
   (e) Time

10. $$mgv\sin\theta - \mu mgv\cos\theta$$ Is this a ...

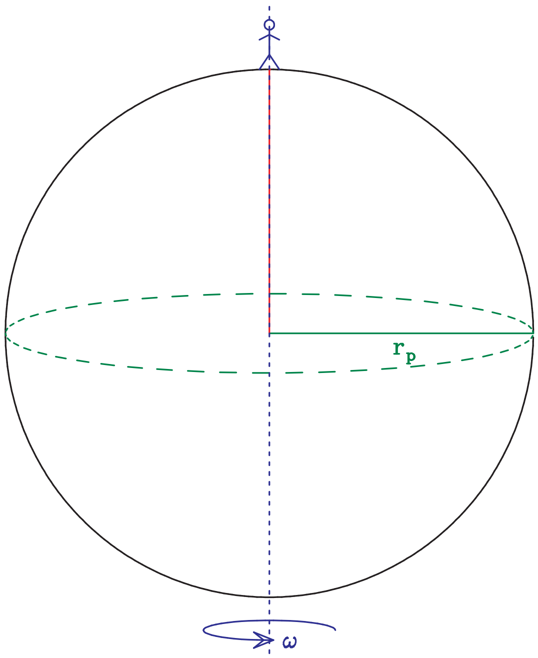
    (a) Torque
    (b) Moment of inertia
    (c) Power
    (d) Energy
    (e) Distance

11. $$k(L - r_0)$$ Is this a ...

    (a) Distance
    (b) Force
    (c) Energy
    (d) Time

Consider a very rapidly rotating spherical planet. It has the same radius r_p and mass M as Earth, and thus the force of gravity on an object with mass m near its surface is mg directed toward its center. However, it is rotating at an angular velocity of $\omega = \sqrt{\frac{g}{2r_p}}$ around its axis. (This value is chosen such that $\omega^2 r_p = \frac{1}{2}g$.)

12. Consider first a person standing on this planet's North Pole as shown. What is their acceleration? *(In the answers, all directions are relative to the person's body.).*



(a) g downwards (directed down toward the center of the planet)

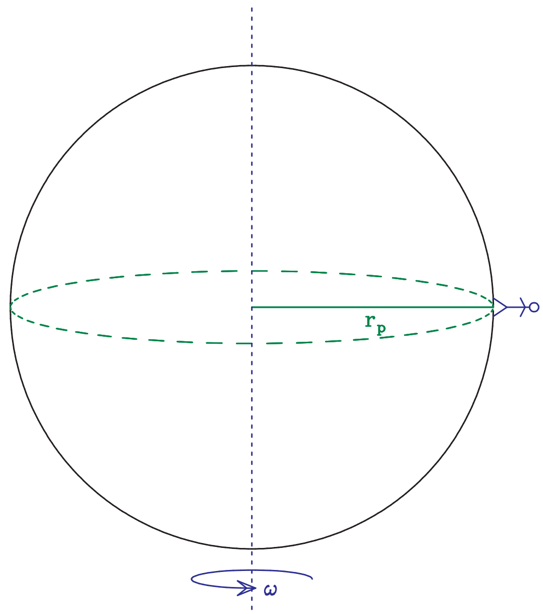
(b) g upwards (directed up in the direction of the person's head)

(c) $\omega^2 r_p$ downwards toward the center of the planet

(d) $g - \omega^2 r_p$ downwards toward the center of the planet

(e) 0

13. Now, we transport this person to the Equator. Now, what is their acceleration? *(Again, all directions are relative to the person.)*



(a) g downwards (directed down toward the center of the planet)

(b) $\omega^2 r_p$ upwards (toward the center of the planet)

(c) $\omega^2 r_p$ downwards toward the center of the planet

(d) $g - m\omega^2 r_p$ downwards toward the center of the planet

(e) 0

14. What will this person's *apparent weight* be while standing on the equator?

(a) mg

(b) $\frac{3}{2}mg$

(c) $\frac{1}{2}mg$

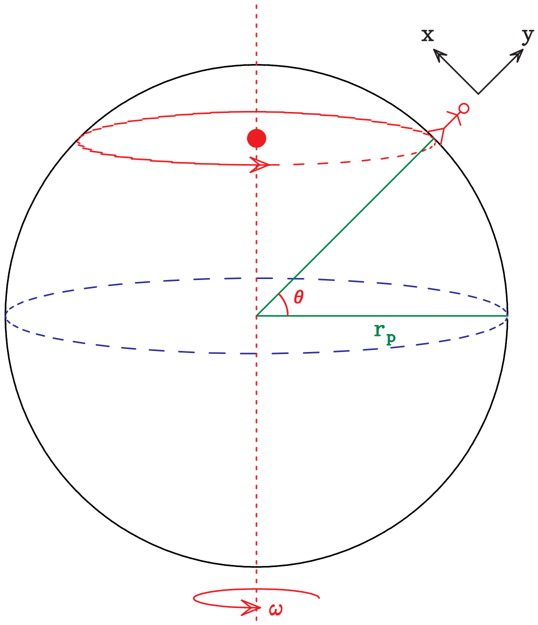
(d) $2mg$

(e) Zero (they will drift off into space)

15. Now, our person walks to the location shown at a latitude θ. As the planet spins, they will trace out the path shown by the red dotted line, following a circular path centered around the red dot.

    In this case, it will be easiest to choose a coordinate system as drawn on the diagram.

    What will the acceleration vector of the person be?



(a) $a_x = \frac{1}{2} g \cos\theta$; $a_y = 0$

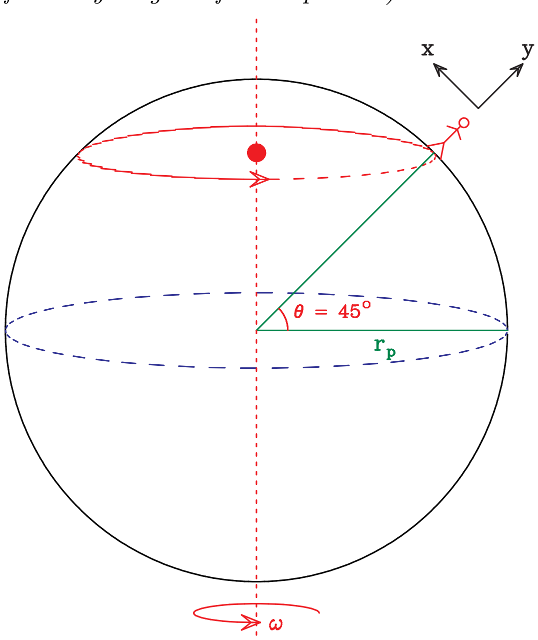
(b) $a_x = \frac{1}{2} g \sin\theta$; $a_y = 0$

(c) $a_x = 0$; $a_y = -mg$

(d) $a_x = \frac{1}{2} g \cos^2\theta$; $a_y = -\frac{1}{2} g \sin\theta \cos\theta$

(e) $a_x = \frac{1}{2} g \sin\theta \cos\theta$; $a_y = -\frac{1}{2} g \cos^2\theta$

16. In this case, take $\theta = 45°$. What will their apparent weight be now? *(Hint: It will help you to draw a careful free-body diagram for the person.)*



(a) mg

(b) $\frac{1}{2} mg$

(c) $\frac{3}{4} mg$

(d) $(1 - \frac{1}{2\sqrt{2}})g$

(e) Zero (they will drift off into space)

17. This person will have a hard time keeping their balance at this position, and may require the assistance of static friction to stay in place. What will the required coefficient of static friction be?

    (a) No static friction will be required for them to keep their balance.
    (b) $\mu_s \geq \frac{1}{3}$
    (c) $\mu_s \geq \frac{1}{2} \sin 45°$
    (d) $\mu_s \geq \frac{1}{2}$
    (e) No amount of static friction will allow them to keep their balance; they will fly into space.