# Solutions to Mock Exam #1

Dr. Timothy Leung

1. **(D)** For any projectile, there are two angles that have the same range, and the sum of the angle is 90°. If one of the angle is 60°, then the other angle is 30°.

2. **(B)** The maximum range occurs at 45°, so the horizontal distance will **increase**.

3. **(C)** The driver of the car is rounding a circular path, so the centripetal force on the driver is provided by the difference between gravity (which contributes to $F_c$), and normal force (which contributes against $F_c$, and is what we are solving here), i.e.:

$$F_c = F_g - F_N$$
$$F_N = F_g - F_c = mg - \frac{mv^2}{r} = m\left(g - \frac{v^2}{r}\right) = 50\left(10 - \frac{20^2}{50}\right) = 50(10-8) = \boxed{100\,\text{N}}$$

4. **(A)** The forces that $X$ and $Y$ exert on each other must be equal by the third law of motion, therefore

$$\boxed{F_{\text{up}} = F_{\text{down}}}$$

When Block $Y$ is stationary, the acceleration is at its maximum, therefore the forces $F_{\text{up}}$ must be higher than the weight of block $Y$, $m_Y g$:

$$\boxed{F_{\text{up}} > m_Y g}$$

5. **(C)** There is no external net force, so when the water is added to the cart, the **total momentum is conserved**. As the mass increases, it means that the **velocity must decrease**.

6. **(D)**

7. **(B)** In a vacuum, both objects will have the same acceleration (due to gravity). If both are *released* (i.e. dropped with zero initial velocity), then both will have the same $\boxed{\text{speed}}$.

8. **(B)** The "block-Earth" system does not include the spring, and so energy is conserved from B to C. If this is a "spring-block-Earth" system, then the answer would be A.

9. **(B)** The reflected wave is in the same medium, and so it must have the same speed and amplitude as before (I and II are incorrect). It is reflected from a fixed end, and therefore the wave would be inverted (III).

10. **(B)** The area under both graphs are the same, and therefore the impulse is the same, which means that the change in momentum is the same.

11. **(A)** The definition of equilibrium is that an object is not subjected to any net external force.

12. **(C)** By the conservation of energy,

$$\begin{aligned} U_g &= K' + U_g' \\ mgH &= \frac{1}{2}mv^2 + mgh' \\ H &= \frac{v^2}{2g} + h' = \frac{3.0^2}{2 \cdot 9.8} + 0.4 = \boxed{0.86\,\mathrm{m}} \end{aligned}$$

The calculation would have been 0.85 m if you used $g = 10\,\mathrm{m/s^2}$.

13. **(A)** The path that the block travels is curved, so at the bottom, there will be a centripetal force. In order to generate this centripetal force, $\boxed{\text{normal force } F_n \text{ must be greater than gravity } F_g}$.

14. **(C)** After the block leaves the track, it will travel as a projectile. The horizontal velocity is constant in a projectile, which we can calculate from when the block leaves the ramp. At the highest point of this projectile motion, it has the only horizontal component:

$$v_x = v\cos 30° = 3.0 \cdot \cos 30° = \boxed{2.6\,\mathrm{m/s}}$$

15. **(A)** Satellite 1 is closer to Earth than Satellite 2, therefore $F_1 > F_2$, since gravitational force is inversely proportional to the square of the distance. We can obtain the orbital velocity by equating the centripetal force to gravitational force:

$$F_c = F_g \quad \rightarrow \quad \frac{mv^2}{r} = \frac{GMm}{r^2} \quad \rightarrow \quad v = \sqrt{\frac{GM}{r}}$$

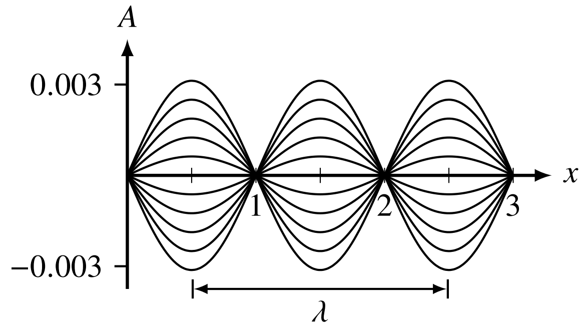
Satellite 1 is closer to Earth than Satellite 2, therefore it also has a higher speed.

16. **(D)** Work is positive if force is in the same direction as motion, and negative when it's opposite. It does not matter if the speed is constant or not.

17. **(D)** This is a completely inelastic collision because the carts stick together. Using conservation of momentum:

$$mv_i = (M+m)v_f \quad \rightarrow \quad v_f = \underbrace{\left(\frac{m}{M+m}\right)}_{\text{slope}} v_i$$

18. **(C)** A standing wave would like this. The nodes are located at $x = 1, 2, 3$. The distance between nodes are half of the wavelength.




19. **(D)** At equilibrium, the gravitational and spring forces on the 3 kg mass must balance, i.e.:

$$mg = kx \quad \rightarrow \quad x = \left(\frac{g}{k}\right) m$$

The stretching of the spring at equilibrium is proportional to the mass $m$. Replacing the 3 kg mass with a 4 kg mass will increase the equilibrium stetch to $12 \times \frac{4}{3} = 16$ cm which is also the magnitude of the "oscillation", if it happens. However, position when direction of motion is reversed is twice the amplitude, i.e. $\boxed{32\,\text{cm}}$.

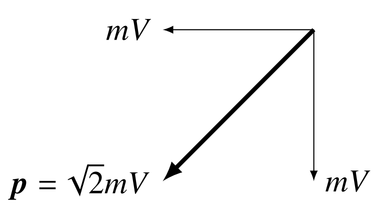
20. **(D)** As the wave moves, energy is dissipated by friction, therefore the amplitude decreases.

21. **(A)** The torque generated by the force is

$$\tau = FL\sin\theta$$

If the force is applied perpendicularly, that would mean a moment arm of $\boxed{L\sin\theta}$.

22. **(D)** The total momentum of the third piece must cancel the momentum of the other two masses, i.e.:

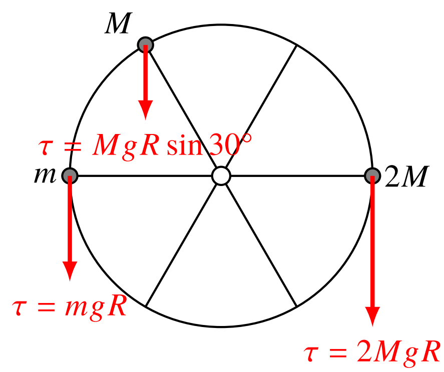



The mass of the third piece is $3m$, therefore the velocity must be

$$\boldsymbol{v} = \frac{\boldsymbol{p}}{m} = \frac{\sqrt{2}mV}{3m} = \boxed{\frac{\sqrt{2}}{3}V\ [\swarrow]}$$

23. **(C)** Binrging the disk up to a higher angular velocity in the same time interval means a higher angular acceleration, which requires a higher torque $\tau = I\alpha$.

24. **(C)** The axle is horizontal, which means that the wheel rotates vertically. The torques genrated by the masses are drawn on the diagram:




If the wheel is in equilibrium, then the torques acting on it must sum to zero, i.e.

$$2MgR = mgR + \frac{1}{2}MgR \quad \longrightarrow \quad \boxed{M = \frac{2}{3}m}$$

25. **(E)** The angular momentum of an object is defined as:

$$L = rmv = 4 \cdot 2 \cdot 4.5 = \boxed{24\,\text{kg} \cdot \text{m/s}}$$

26. **(D)** The weight of the beam acts at the center of mass, and generates a torque of

$$\tau_g = mg\frac{L}{2} = 10 \cdot 9.8 \cdot \frac{2}{2} = 98\,\text{N} \cdot \text{m [clockwise]}$$

while the applied force generates a torque of

$$\tau_F = FL\sin\theta = 200 \cdot 2\sin 30° = 200\,\text{N} \cdot \text{m [counterclockwise]}$$

The net torque is $\boxed{\tau_{\text{net}} = 102\,\text{N} \cdot \text{m}}$ counterclockwise.

27. **(C)** The maximum velocity of a spring-mass system is given by $v_{\max} = A\omega$. The angular frequency is based on mass and spring constant. However, we still need the amplitude, which can be found from the maximum acceleration, $a_{\max} = A\omega^2$, or $A = a_{\max}/\omega^2$.

28. **(B)** The functions for velocity and acceleration is out of phase by 90°.

29. **(A)** When Disk B is dropped onto Disk A, there is no external torque applied, therefore angular momentum remains the same. This means that the angular frequency $\omega$ is decreased by $\frac{1}{2}$. The new kinetic energy is therefore

$$K' = \frac{1}{2}I'\omega'^2 = \frac{1}{2} \cdot 2I \cdot \left(\frac{\omega}{2}\right)^2 = \frac{1}{2}K$$

And the kinetic energy is decreased to $\frac{1}{2}$ of its original value.