
## Ride Information Provided by Luna Park

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| Radius, that is, the distance from the axle to seat level: | 12m |
| Length of rubber strip on the bottom of the dragon boat: | 10 m |
| Angle between the left and right boat supports: | 32º |
| Mass of the dragon boat: | 2200 kg |
| Max swing: | 60º each way |

## Measurements Needed

- The time for a single oscillation (that is, the boat's movement from one side, to the other, and back to where it started from) when the ride is operating at its maximum.
- The length of time it took for the ride to come to a halt after it began slowing down.

1. Draw a sketch-diagram of the Twin Dragon ride and label the above information appropriately on the ride.

2. As the ride starts from stationary, using point-form, briefly describe how the ride reaches its maximum speed. Use concepts such as "gravitational potential energy," "kinetic energy," "mechanical energy," and "friction".

2. How many people are on-board the ride? ....................................................................................

3. The weight of an average adult person is estimated by engineers as between 65 kg and 70 kg. Using the 70kg estimate, what is the estimated total mass of the boat including the occupants?

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4. While it is swinging from side-to-side, the twin dragon can be said to be undergoing wave-like motion. What name is given to the time it takes for the boat to complete one oscillation?

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5. When it is operating at its maximum, time how long it takes the ride to complete a cycle. (Note: A more accurate reading would be obtained by measuring the time for 4 or 5 complete cycles and then dividing that time by the number of cycles.)

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6. What is the frequency of the ride's oscillation? ........................................................................

*During the course of the boats pendulum movement – that is swinging from side to side – the oscillations can be thought of as consisting of Vertical Movement and Horizontal Movement.*

## Horizontal Movement

7. At what point(s) during the boats motion is the horizontal velocity 0 $ms^{-1}$ ?

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8. At what point(s) during the pendulum motion is the horizontal velocity a maximum?

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## Vertical Movement

9. At what point(s) during the boat's motion is the vertical velocity 0 $ms^{-1}$ ?

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10. At what point(s) during the boat's motion is the vertical velocity a maximum?

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## Momentum

11. At what point in the boat's swinging movement is horizontal momentum a maximum?

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12. At what point in the boat's swinging movement is horizontal momentum 0 $kgms^{-1}$ ?

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13. When is vertical momentum 0 $kgms^{-1}$ ?

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14. When is vertical momentum at a maximum?

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15. Impulse is defined as a change in momentum. At what point during the boat's oscillation is the vertical impulse at its maximum? Explain.

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# Energy Transformation

*Energy is conserved during the ride of the Twin Dragon. Basically, machines are used to start the boat oscillating. This oscillating has both vertical and horizontal components of velocity. To answer the below questions, assume that the ride is operating friction-free.*

16. Briefly explain the transformation of energy that occurs when the ride is operating at its maximum. At this point, assume that only gravitational potential and kinetic energies need to be considered.

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17. At what point(s) in the boat's movement is kinetic energy zero?

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18. At what point is the boat's kinetic energy maximum?

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19. Now using an appropriate reference frame, at what point(s) in the boat's movement is the effective gravitational potential energy zero?

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20. Using the same frame of reference, when is the boat's gravitational potential energy a maximum?

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21. What reference frame did you use in (20) and (21) above?

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22. How does gravitational potential energy relate to kinetic energy at that point where kinetic energy is maximum?

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23. Assume that the boat rises a maximum vertical distance of $h$ during the course of its oscillations. Using the concept of conservation of energy, derive an algebraic expression for the maximum horizontal velocity the boat reaches. To do this, assume that the only energies involved are gravitational potential ($E_p$) and kinetic ($E_k$).

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24. When the boat begins to slow down, time how long the process of stopping took.

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25. To stop the ride, briefly explain the energy transformations that must occur.

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26. The total energy contained within the system of the ride when it is operating at its maximum is simply the gravitational potential energy at that point in the oscillation at which the maximum height (*h*) is reached. That is,

$$E_p = mgh$$

Using this expression and your result from (24), how much energy must be dissipated each second for the ride to stop?

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27. What is the unit for "energy per second"? ..................................................................................

28. The boat has a 10 metre rubber strip at the bottom. What would be the distribution of energy transformation each second for each metre of this strip? (Units would be $Js^{-1}m^{-1}$).

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