Rockets

Question:

If there were no launch pad beneath the space shuttle at lift-off, the upward thrust of its engines would be

1. approximately unchanged.
2. approximately half as much.
3. approximately zero.

Momentum Conservation

- A rocket's momentum is initially zero
- The momentum redistributes during thrust
  - Ship pushes on fuel; fuel pushes on ship
  - Fuel acquires backward momentum
  - Ship acquires forward momentum
- Rocket's total momentum remains zero

Question:

If there were no launch pad beneath the space shuttle at lift-off, the upward thrust of its engines would be

1. approximately unchanged.
2. approximately half as much.
3. approximately zero.

Stability and Orientation

- On the ground, rocket needs static stability
- In the air, rocket needs aerodynamic stability
  - Center of aerodynamic pressure behind c.o.m.
- In space, rocket is a freely rotating object
  - Orientation governed by angular momentum
  - Rocket can travel in any orientation

Ship's Ultimate Speed

- Increases as
  - ratio of fuel mass to ship mass increases
  - fuel exhaust speed increases
- If fuel were released with rocket at rest,

$$\text{ultimate speed} = \frac{\text{fuel mass}}{\text{ship mass}} \cdot \text{exhaust speed}$$

- Because rocket accelerates during thrust,
  - ultimate speed is less than given above

Gravity

- The acceleration due to gravity is only constant for small changes in height
- When the distance between objects changes substantially, the full relationship is:

Orbits

- An object that has a sideways velocity doesn't fall directly toward the earth
- The object follows a trajectory called an orbit around the earth
- Orbits can be closed or open, and are ellipses, parabolas, and hyperbolas