4. (I) A 1200-N crate rests on the floor. How much work is required to move it at constant speed (a) 4.0 m along the floor against a friction force of 230 N, and (b) 4.0 m vertically?

6. (I) How high will a 1.85-kg rock go if thrown straight up by someone who does 80.0 J of work on it? Neglect air resistance.
45. (II) Take into account the Earth's rotational speed (1 rev/day) and determine the necessary speed, with respect to Earth, for a rocket to escape if fired from the Earth at the equator in a direction (a) eastward; (b) westward; (c) upward.

Sun rises East → West

So Earth turns West → East

What is the speed of the Earth at the equator?

\[ V_{Earth} = \frac{2\pi R}{T} = \]

What is the escape speed, ignoring Earth's motion?

Last week we derived this: \[ \frac{1}{2} mV_e^2 = GmM \]

Escape: \[ V_e = \frac{\sqrt{2GM}}{R} \]

Consider a rocket fired Eastward with a speed \( V_o \) relative to Earth. It's like throwing a ball out a car window: the ball goes faster if the car is moving.

\[ \begin{align*}
  V_{o + V_e} &\quad \text{EAST} \\
  V_e &\quad \text{effective speed}
\end{align*} \]

\[ V_{escape} = V_e = V_o + V_e \quad \text{Solve for } V_o = \text{rocket speed.} \]
H5(b) Consider a rocket launched WESTWARD.

The rocket must overcome Earth's motion $V_E$.

$V_{escape} = V_o - V_E \rightarrow Solve\ for\ V_o$

H5(c) Consider a rocket launched UP.

$V_{escape} = V_E^2 + V_o^2\ \rightarrow\ Solve\ for\ V_o$
47. (II) (a) Determine the rate at which the escape velocity from the Earth changes with height above the Earth’s surface, \( \frac{dv}{dr} \). (b) Use the approximation \( \Delta v \approx \left( \frac{dv}{dr} \right) \Delta r \) to determine the escape velocity for a spacecraft orbiting the Earth at a height of 300 km.

Re-derive escape speed:

\[
K = \frac{GM}{R_e}
\]

\[
\frac{1}{2} m v_e^2 = \frac{GmM}{R_e}
\]

\[
v_e = \sqrt{\frac{2GmM}{R_e}}
\]

In general, at some distance \( r \) from Earth's center:

\[
v_e(r) = \sqrt{\frac{2GM}{r}}
\]

(a) \( \frac{dv_e}{dr} = \)

(b) We know from #45 that \( v_e = \) at Earth’s surface \( (r = R_e) \). Above the surface:

\[
v(r) \approx v_e + \Delta v \quad \text{where} \quad \Delta v = \frac{\Delta v_e}{\Delta r}
\]

At a height of \( \Delta r = 300 \text{ km} \), \( \Delta v = \)

Then \( v(300 \text{ km}) = \)