Physics 101H

General Physics 1 – Honors

Lecture 51 – 12/09/22

Review II

Final

Exam takes place in **Small 111** from **9 am to 12 noon** on **Tuesday December 13**

You will have 3 hours to complete the exam

- 5 multiple choice questions
- 5 handwritten solution problems

Arrive early, bring paper and something(s) to write with! (Spare paper will be available)

Topics cover Chapters 1 to 17

You may prepare your own formula sheet – **two sides** of **letter paper**

You may bring a calculator, but phones, tablets and laptops are not allowed

Remember you are here to learn and understand the physics!

Example: A locomotive pulls on a series of wagons. Which is correct:

(a) The train moves forward because the locomotive pulls forward slightly harder on the wagons than the wagons pull backwards on the locomotive.

(b) Because action always equals reaction, the locomotive cannot pull the wagons–the wagons pull backwards just as hard as the locomotive pulls forward, so there is no motion.

(c) The locomotive gets the wagons to move by giving them a tug during which the force on the wagons is momentarily greater than the force exerted by the wagons on the locomotive.

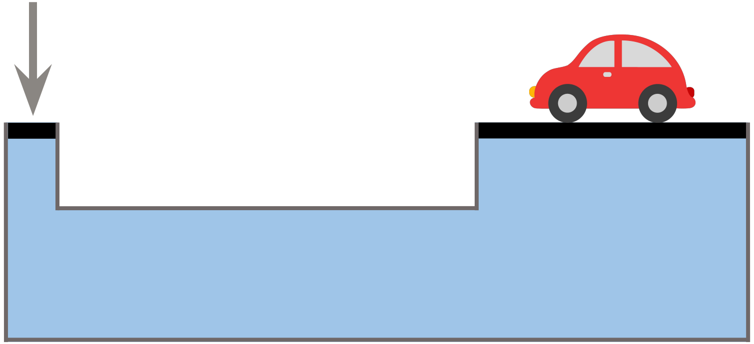
(d) The locomotive's force on the wagons is as strong as the force of the wagons on the locomotive, but the frictional force on the locomotive is forward and large, while the backwards frictional force on the wagons is smaller.

(e) The locomotive can pull the wagons forward only if it weighs more than the wagons.

Example: A 1.5 kg rock is suspended by a massless string from one end of a 1 m measuring stick. What is the weight of the measuring stick if it is balanced by a support force at the 0.25 m mark?

Example: Two wheels with fixed hubs, each having a mass of 1 kg, start from rest, and forces are applied to the top of the wheels. Assuming the hubs and spokes are massless, and a force of 1 N is applied to the smaller wheel, what is the force imparted on the larger wheel that ensures both wheels have the same angular acceleration?

Example: A container full of oil is fitted at both ends with pistons. The area of the left piston is 10 mm^2, while the right piston has area 10,000 mm^2. What force must be exerted on the left piston to keep a 10,000 N car at the same height on the right piston?



Example: If an object floating in a container of water is placed in an elevator accelerating upwards, what happens to the object?

(a) More of the object is below water

(b) More of the object is above water

(c) There is no difference

Example: Two identical pulses of opposite amplitude travel along a stretched string and interfere destructively. Which of the following is/are true?

(a) There is an instant at which the string is completely straight

(b) When the two pulses interfere, the energy of the resulting pulse is momentarily zero

(c) There is a point on the string that does not move up or down

(d) There are several points on the string that do not move up or down

Example: An object hangs motionless from a spring. When the object is pulled down, what happens to the sum of the elastic potential energy of the spring and the gravitational potential energy of the object and the earth?

(a) It increases

(b) It stays the same

(c) It decreases

Example: A particle of mass m is dropped from rest near the Earth's surface at time $t = 0$. The initial position of the particle is $(x,y) = (-d,0)$ (y represents the vertical direction).

(a) What is the angular momentum of the particle about the origin?

(b) What is the torque acting on the particle as it falls?

(c) Show that $\tau = \mathrm{d}L/\mathrm{d}t$.

Example: A rock is released halfway between planet A, of mass $3M$ and radius R, and planet B, of mass $4M$ and radius $2R$, which are separated by a distance $8R$.

(a) What is the magnitude of the acceleration of the rock immediately after it is released?

(b) What is the direction of the acceleration of the rock?

Example: A car with mass 1500 kg is traveling west with speed 15 m/s. A truck, of mass 2500 kg, and speed 11 m/s, travels south and collides with the car at an intersection. The vehicles stick together and slide across the roadway, with a coefficient of friction of μ = 0.5.

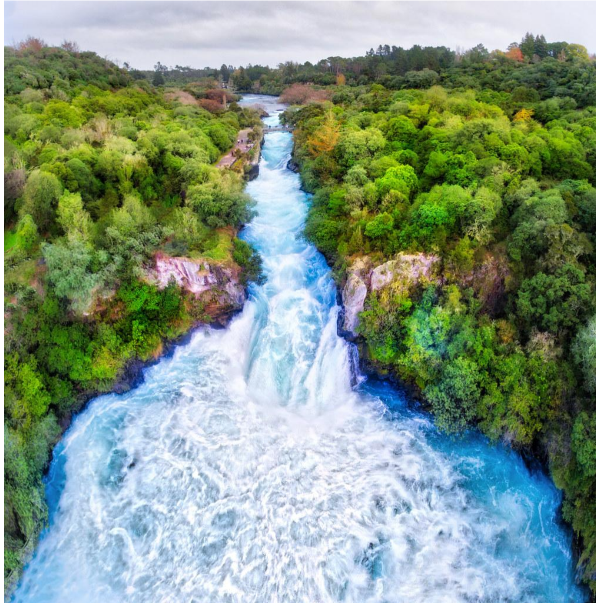
(a) What is the velocity of the car+truck after the collision?

(b) How far will the car+truck slide after the collision?

Example: The Huka Falls on the Waikato river is a famous natural attraction in New Zealand (aka where my brother lives). On average, the flow rate of the river is 300,000 L/s. At the gorge the river is about 20 m wide and 20 m deep.

(a) What is the average speed of the river in the gorge?

(b) What is the average speed of the river when it widens downstream to about 60 m and its depth increases to 40 m?



Example: (a) Assuming that the human eardrum typically has an area of 60 mm^2, what is the smallest power that the ear can detect?

(b) Assuming that this power is emitted by a spherical source at a distance of 1100 m, at what distance from the source is the intensity 10^{-8} W/m^2?

Example: (a) What is the angular momentum of the Earth in its orbit around the Sun?
(b) What is the angular momentum of the Earth spinning about its north-south axis?

Studying for the final

Good luck!

Studying for the final:

- Work through Problem Sets
- Work through examples from class and in the textbook

When working through problems (especially someone else's solution):

- Cover up the solution and try to work out the next step in the solution
- If you can't figure that out, uncover just the first step and then try to figure out the next steps
- Try to *self-explain*, that is – write down your thought process and what principles, concepts or equations are being applied at each step.

Remember that you are here to learn and understand the physics!

[But also remember there are two methods for calculating your final grade]

CONGRATULATIONS!
FINAL IS TUESDAY DECEMBER 13 AT 9AM

PHYSICS 101 - HONORS

Lecture 51   12/9/22

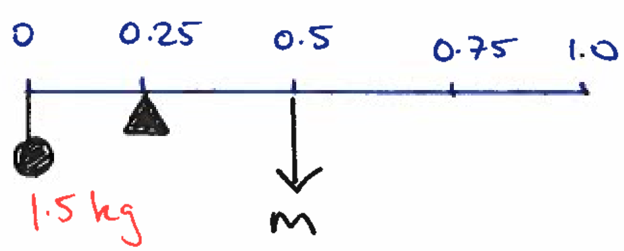
$\boxed{\text{The last one !!}}$

Locomotive example   (slide 3)

Answer is (d) - Newton III => locomotive and wagon exert same force on each other

Newton II => nonzero net force required to accelerate

Rock example   (slide 4)



Equilibrium means

$\vec{F}_{net} = 0 \quad \vec{\tau}_{net} = 0$

Uniform rod => treat mass of rod as acting through the centre of mass, at 0.25 m to the right of the pivot

Newton II for rotation:

$$M \cdot 0.25 - 1.5 \cdot 0.25 = 0 \Rightarrow \boxed{M = 1.5 \text{ kg}}$$

Wheel example (slide 5)

The torque is given by

$$\bar{\tau} = \bar{r} \times \bar{F}$$

and by

$$\bar{\tau} = I \bar{\alpha}$$

We can consider just the magnitudes in this case

$\Rightarrow$ $rF = I\alpha$

For wheel 1

$$\alpha_1 = \frac{r_1 F_1}{I_1} = \frac{0.25 \cdot 1}{1 \cdot 0.25^2} \qquad I_{hoop} = Mr^2$$

$$= 4 \text{ rad/s}^2$$

For wheel 2

$$F_2 = \frac{I_2 \alpha_2}{r_2} = \frac{I_2 \alpha_1}{r_2} = \frac{1 \cdot 0.5^2 \cdot 4}{0.5}$$

$$= \boxed{2 \text{ N}}$$

Piston example (slide 6)

Equal pressure is required to keep the fluid at the same level

$$\Rightarrow \frac{F_1}{A_1} = \frac{F_2}{A_2} \Rightarrow F_1 = 10 \cdot \frac{10000}{10000} = \boxed{10 \text{ N}}$$

Accelerating floating object example (slide 7)

Answer is (c). Acceleration affects water and object equally.

String pulse example (slide 8)

Answers (a) and (c) are correct.

(a) occurs when the pulses exactly overlap

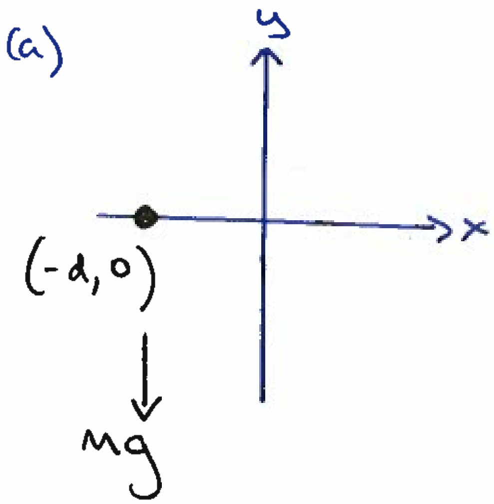
(c) occurs because the point right in the middle cannot move – no matter where it is relative to one pulse, the displacement this causes is exactly cancelled by the other pulse.

Spring example (slide 9)

Answer is (a). When the spring/object passes its equilibrium point it has the same potential (spring and gravitational) energy, but now has non zero kinetic energy. Note that although the gravitational potential energy, it decreases proportional to Δx, but the elastic potential energy increases proportional to $(\Delta x)^2$.

Angular momentum example (slide 10)

(a)



$$\bar{L} = \bar{r} \times \bar{p}$$

$$\Rightarrow L = rp \sin\theta$$

$$= |-d| \cdot mv \cdot \sin 90^\circ$$

To find the speed at time t, we use

$$v = v_0 + at = 0 - gt = -gt \Rightarrow |v| = gt$$

$$\Rightarrow \boxed{L = dmgt}$$

(b) $\bar{\tau} = \bar{r} \times \bar{F} \Rightarrow \tau = rF \sin\theta$

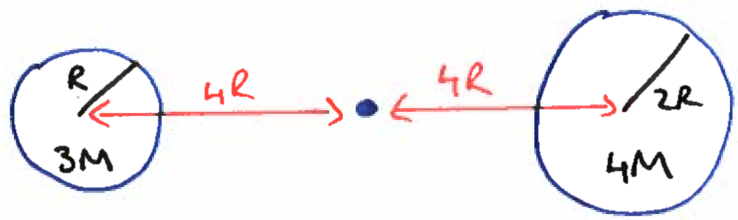
$$= |-d|\,|mg| \sin 90^\circ$$

$$= dmg$$

$$\Rightarrow \boxed{\tau = dmg}$$

(c) $\dfrac{dL}{dt} = \dfrac{d}{dt}(dmgt) = dmg = \tau$ ✓

Rock - planet example (slide 11)



(a) The acceleration due to the small planet is

$$a_s = -\frac{G \cdot (3M)}{(4R)^2} \quad - \Rightarrow \text{ to the left}$$

Acceleration due to the large planet is

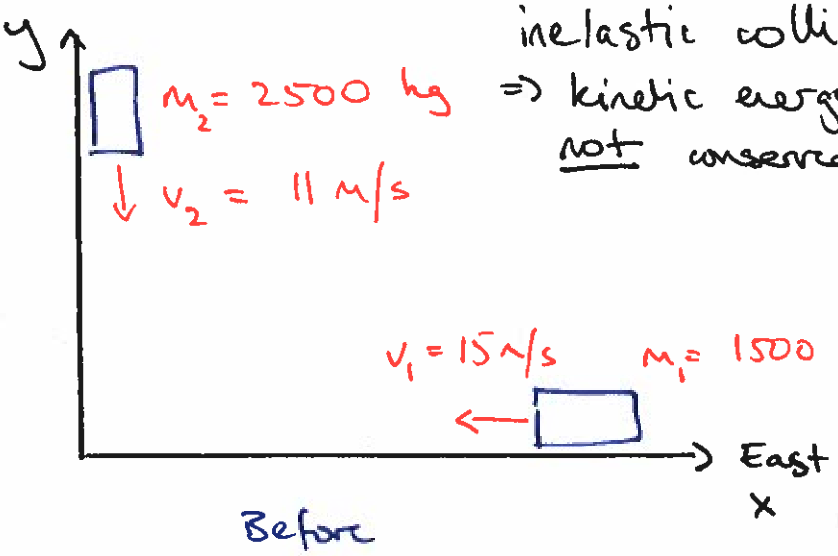
$$a_L = +\frac{G \cdot (4M)}{(4R)^2}$$

$$\Rightarrow a_{TOT} = a_s + a_L$$

$$= -\frac{3MG}{16R^2} + \frac{4MG}{16R^2} = \boxed{\frac{MG}{16R^2}}$$

(b) Direction is towards the right (the centre of the large planet)

Car-truck example (slide 1)



inelastic collision
$\Rightarrow$ kinetic energy **not** conserved

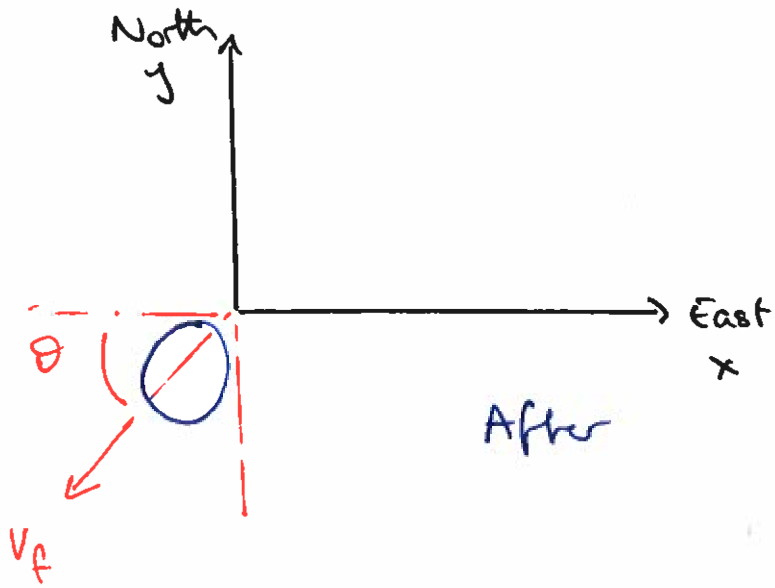
conservation of momentum

$$m_1\bar{v}_1 + m_2\bar{v}_2 = (m_1+m_2)\bar{v}_f$$

$$\Rightarrow \bar{v}_f = \frac{m_1\bar{v}_1}{m_1+m_2} + \frac{m_2\bar{v}_2}{m_1+m_2}$$

or

$$\bar{v}_f = \frac{m_1}{m_1+m_2} v_1(-\hat{x}) + \frac{m_2}{m_1+m_2} v_2(-\hat{y})$$



$$\bar{v}_f = -\frac{m_1}{m_1+m_2} v_1\hat{x} - \frac{m_2}{m_1+m_2} v_2\hat{y}$$

Plugging in numbers, we have

$$\bar{v}_f = -\frac{1500}{1500+2500}\cdot 15\,\hat{x} - \frac{2500}{1500+2500}\cdot 11\,\hat{y}$$

$$\boxed{\bar{v}_f = -5.63\,\hat{x} - 6.88\,\hat{y}}$$

(b) Two ways to do this:

- Work-energy theorem

$$W = -Fd = \Delta E_K$$

$$\Rightarrow \quad d = -\frac{\Delta E_K}{F}$$ so what is the friction?

$$F_K = \mu_K N$$
$$= \mu_K M_{tot} g$$

$$\Rightarrow d = -\frac{\Delta E_K}{\mu_K M_{tot} g} = -\frac{\left[0 - \frac{1}{2}(M_1 + M_2)v_f^2\right]}{\mu_K (M_1 + M_2) g}$$

$$= \frac{v_f^2}{2\mu g} = \frac{v_f^2}{g}$$ because $\mu = 0.5$

$$= \frac{\left((-5.63)^2 + (-6.88)^2\right)}{9.81}$$

$$\boxed{d = 8.04 \text{ m}}$$

- Kinematics (and Newton II)

$$F_{net} = M_{tot}\, a \quad \Rightarrow \quad a = \frac{F_{net}}{M_{tot}}$$

In this case $a = -\frac{\mu_K N}{M_1 + M_2} = -\frac{\mu_K (M_1 + M_2) g}{(M_1 + M_2)} = -\mu_K g$

$$v_0 = \sqrt{(-5.63)^2 + (-6.88)^2}$$

$$= \sqrt{78.91} = 8.88 \text{ m/s} \quad (= v_f \text{ from (a)})$$

$$v = 0$$

$$a = -\mu_k g$$

Use $v^2 = v_0^2 + 2a\Delta x$

$$\Rightarrow \Delta x = \frac{v^2 - v_0^2}{2a} = \frac{0 - v_0^2}{2(-\mu_k g)} = \frac{v_f^2}{2\mu_k g}$$

Same equation as before!

$$\Rightarrow \boxed{\Delta x = 8.04 \text{ m}}$$

Waterfall example (slide 13)

(a) Flow rate is given by $Q = Av$ ← speed

↑ cross-sectional area

$$\Rightarrow v = \frac{Q}{A}$$

$$= \frac{300,000 \times 10^{-3}}{20 \times 20}$$

$$\boxed{v = 0.75 \text{ m/s}}$$

(b) $Q_1 = Q_2$ continuity equation!

$\Rightarrow v = \frac{Q}{A}$

$= \frac{300,000 \times 10^{-3}}{60 \times 40}$

$\boxed{v = 0.125 \text{ m/s}}$

Ear power example (slide 14)

(a) Sound intensity level is

$\beta = 10 \log_{10} \left(\frac{I}{I_0}\right)$

where $I_0 = 10^{-12}$ W/m^2

The smallest sound intensity level is defined as the lower limit of human hearing, $I = I_0$ or $\beta = 0$

Intensity and power are related by

$I = P/A \Rightarrow P = IA$

$= 10^{-12} \cdot 60 \times (10^{-3})^2$

$\boxed{P = 6 \times 10^{-17} \text{ W}}$

(b) $\frac{I_2}{I_1} = \frac{r_1^2}{r_2^2} \Rightarrow r_2 = \sqrt{\frac{I_1}{I_2}} \cdot r_1 = \sqrt{\frac{10^{-12}}{10^{-8}}} \cdot 1100$

$\boxed{r_2 = 11 \text{ m}}$

Earth example (slide 15)

[could also use $L = rp$]

(a) Angular momentum is

$$L = I\omega$$

The Earth can be approximated as a point particle

$$\Rightarrow I = M_E r^2$$

Earth-sun distance

The angular frequency is $\omega = \frac{2\pi}{T}$

1 year

$$\Rightarrow L = M_E r^2 \cdot \frac{2\pi}{(365\ 24\ 3600)}$$

$$= 5.97 \times 10^{24} \cdot (1.495 \times 10^{11})^2 \cdot \frac{2\pi}{365 \cdot 24 \cdot 3600}$$

$$\boxed{L = 2.6 \times 10^{40} \text{ kg m}^2/\text{s}}$$

(b) For a sphere rotating about its axis $I = \frac{2mr^2}{5}$

$$\Rightarrow L = I\omega = \frac{2M_E r_E^2}{5} \cdot \frac{2\pi}{24 \cdot 3600}$$

$$= \frac{2}{5} \cdot 5.97 \times 10^{24} \cdot (6.37 \times 10^6)^2 \cdot \frac{2\pi}{24 \cdot 3600}$$

$$\boxed{L = 6.98 \times 10^{33} \text{ kg m}^2/\text{s}}$$