Physics 90 Exam for Unit 3 — Newton and Einstein

APRIL 17, 2020

Do-at-home exam directions. You may use the OpenStax textbook and your class notes, including all materials that I used in lecture.

If you don't have them all handy, you can view all of the Unit 3 materials here:

https://observatree.github.io/physics90/detailed_schedule_unit _ 3.html

You will need a calculator quite a lot on this exam. You can't use Google or your friends.

During the official exam time, 8:00-9:05am, I will be waiting on Zoom (usual meeting code, https://stmarys-ca.zoom.us/j/866254786). If you think you found a typo, or if a question is badly worded, join the Zoom session and ask me about it.

***When done**, submit a one-page (or more if necessary) Word, PDF, or plain text document **with just your answers** using Moodle TurnItIn, like you would a Seminar essay.*

If you have SDS permission for extended time or any other unusual consideration, like your calculator batteries were dead (I'm just making an example up), or you have to take care of something unusual due to shelter-in-place, you may use more than the standard 8:00-9:05am time period, but please complete the exam expeditiously.

Newton's Laws of Motion

1. Free Fall and Newton's Second Law of Motion

According to $F = m\,a$, if an 80 kg person accelerates downwards with acceleration of $9.8\ \mathrm{m}/\mathrm{s}^2$, then there must be a downwards force causing this. (NOTE/HINT: as is often the case, we have to re-use letters — in the $F = m\,a$ formula, m is for mass — in the $9.8\ \mathrm{m}/\mathrm{s}^2$ expression, m is for meters.) The amount of the downwards force must be:

(A) 0.1225 Newtons
(B) 8.16 Newtons
(C) 392 Newtons
(D) 784 Newtons

2. Circular Acceleration

According to the $a = v^2/r$ formula, if a car is going around a circular corner of radius 20 m at a constant speed of 5 m/s, the acceleration of the car is:

(A) 0 m/s^2 (B) 0.25 m/s^2 (C) 1.25 m/s^2 (D) 4 m/s^2

3. Newton's Third Law of Motion

A 180-pound skater pushes on a 90-pound skater with 20 Newtons of force. Thanks to the Third Law, we know that the 90-pound skater is pushing back on the 180-pound skater with:

(A) 10 Newtons of force
(B) 20 Newtons of force
(C) 40 Newtons of force

Newton's Universal Law of Gravitation

4. Newton's Universal Law of Gravitation, Elevator

If you are in an elevator and the cable snaps and you have a tray of coffees in your hands, then when the cable snaps,

(A) You will hit the roof of the elevator because you have less mass than the elevator.
(B) The coffees will hit the roof of the elevator because they are very light compared to you and the elevator
(C) A and B
(D) You, the coffees and the elevator car will all fall together as if weightless, even though gravity is still pulling on everything.

5. Newton's Universal Law of Gravitation, Space Station

Chris Hadfield — the astronaut who played the guitar in the "Major Tom" video — has said "there is no gravity in space." Actually, on the International Space Station (ISS) the astronauts feel weightless because:

(A) the ISS is so far from the Earth, gravity is negligible
(B) the ISS is falling in a circle around the Earth and the ISS, Chris Hadfield, and his guitar are all in free fall together
(C) the ISS's gravity balances the Earth's, so that the net gravity is zero
(D) the rules Newton developed for gravity only hold on Earth, not once you get into space

6. Newton's Universal Law of Gravitation, Proportional Reasoning

The formula for Newton's Universal Law of Gravitation is

$$F = \frac{G m_1 m_2}{r^2}$$

Suppose the Earth's gravity pulls on an astronomy textbook with 4 pounds of force at the surface of the Earth. The distance from the surface of the Earth to its center is r_E. Imagine a platform that is r_E above the surface of the Earth. At this height, the Earth's gravity pulls on the textbook with:

(A) 4 pounds of force
(B) 3 pounds of force
(C) 1 pound of force
(D) 1/3 pound of force

HINT: The distance from the platform to the center of the Earth is $2\,r_E$. In other words, r has been doubled. Everything else in the formula is the same!

Mass, Volume, Density, and the Planets

The definition of density is mass over volume: $\rho \equiv \frac{M}{V}$.

7. Mass of Water in a Swimming Pool

Water's density is $\rho = 1$ kg / liter. This is the same as $\rho = 1000$ kg / m^3. If a swimming pool is 50 m long, 25 m wide, and an average of 2.5 m deep, the mass of water in the pool is:

(A) 3125 kg
(B) 77500 kg
(C) 3125000 kg
(D) 77500000 kg

(Just use the volume = length x width x height formula and make sure your units work out.)

8. Mass and Density of the Planets

The least dense planet is _______ and its density is ______ than water (1000 kg/m^3).

(A) Mercury / greater (B) Mars / less (C) Jupiter / greater (D) Saturn / less

9. An Imaginary New Planet

The four innermost planets are mostly rock, which has a density of about 5000 kg / m^3. The four outer-most planets are compressed gas, and have a density of about 1000 kg / m^3.

Imagine that a new planet is a little bigger than Earth, with radius

$R = 10\,000$ km

and mass about twice Earth's,

$M = 12.6 \times 10^{24}$ kg

Compute this planet's density. From this, you guess that this planet is:

(A) Mostly rock, like the four inner planets.
(B) About half rock, like the four inner planets, and half compressed gas, like the four outer planets.
(C) Mostly compressed gas, like the four outer planets.
(D) An unknown very light substance.
(E) An unknown very heavy substance.

HINT: you are going to need the volume of a sphere $V = \frac{4}{3} \pi R^3$.

Energy, Power, Intensity, Fission, and Fusion

The definition of power is energy over time. $P \equiv \frac{E}{t}$.

Einstein's most famous equation is $E = mc^2$. In this equation, c is the speed of light which is 3×10^8 m/s.

10. Energy and Power

The town of Outback Junction has 3600 houses. Each of these houses uses 2900 W. Using those two numbers and the fact that there are 86,400 seconds in a day, compute the energy used by Outback Junction in a day.

(A) 9 x10^{11} Joules
(B) 9 x10^{11} Watts
(C) 9 x10^{11} seconds
(D) 9 x10^{11} Newtons

11. Intensity

SunPower is in Richmond, CA. They make solar panels that are over 20% efficient! The peak intensity of sunlight (when it is directly overhead) is 1050 W/m^2. A SunPower solar panel that is 0.5m by 1.0m could produce:

(A) 105 Watts
(B) 210 Watts
(C) 315 Watts
(D) 1050 Watts

12. Fission and Fusion

The element that has the least energy (and if all you had was that, you could neither do fission nor fusion) is:

(A) Hydrogen
(B) Helium
(C) Iron
(D) Uranium
(E) Plutonium

13. Ivy Mike Fusion Bomb and $E = mc^2$

The power of the Sun was released on the Earth when the Ivy Mike H-Bomb was exploded in 1952. It produced about 4.5×10^{16} Joules.

How many kg of mass disappeared in this explosion?

(A) 0.5 kg (B) 0.5 g (C) 1.5×10^8 kg (D) 1.5×10^8 g

HINT/RECALL: If you use MKS units (Newtons, Watts, Joules, meters, and seconds) then your answers come out in kg.

14. Elements and the Periodic Table

Group→ ↓Period	1	2		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H																		2 He
2	3 Li	4 Be												5 B	6 C	7 N	8 O	9 F	10 Ne
3	11 Na	12 Mg												13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
4	19 K	20 Ca		21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
5	37 Rb	38 Sr		39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
6	55 Cs	56 Ba	*	71 Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
7	87 Fr	88 Ra	**	103 Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Fl	115 Uup	116 Lv	117 Uus	118 Uuo
			*	57 La	58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb		
			**	89 Ac	90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No		

Uranium *U*, has 92 protons according to the table above. When it fissions it can make Barium (^{139}Ba) and Krypton (^{85}Kr). From the table above, you can tell that ^{85}Kr has:

(A) 85 protons and 36 neutrons

(B) 36 protons and 85 neutrons

(C) 49 protons and 36 neutrons

(D) 36 protons and 49 neutrons

The Properties of the Sun

15. The Size of the Sun

The Sun is 150,000,000 km away and that the Sun and it has an angular diameter of 0.54° in the sky. From these facts and the formula for pie crust length *s* in terms of pie radius *r*:

$$s = \frac{r\,\theta}{57.3^\circ}$$

You learn that:

(A) The diameter of the Sun is: $\frac{150{,}000{,}000\text{ km} * 57.3^\circ}{0.54^\circ} = 1\,590\,000\,000$ km

(B) The diameter of the Sun is: $\frac{150{,}000{,}000\text{ km} * 0.54^\circ}{57.3^\circ} = 1\,400\,000$ km

16. The Amount of Hydrogen in the Sun

The Sun's mass is 1.99×10^{30} kg. The mass of a hydrogen atom is 1.67×10^{-27} kg. Let's just be sloppy and round those two numbers to 2×10^{30} kg and 2×10^{-27} kg. Assuming the whole Sun is hydrogen, how many hydrogen atoms are there in the Sun?

(A) 4×10^{57} (B) 10^{57} (C) 10^{-57} (D) 4×10^{-57}

17. Nuclear Energy in the Sun

The basic reaction (which I am deliberately oversimplifying) in the Sun is four Hydrogens becomes one Helium. In this reaction, 0.02862 u of mass becomes energy. A u is 1.67×10^{-27}kg. From the $E = m c^2$ formula this reaction must release:

(A) 0.43×10^{-11} Joules
(B) 0.43×10^{-11} Watts
(C) 0.048×10^{-27} Joules
(D) 0.048×10^{-27} Watts

18. Nuclear Energy in the Sun Again

The core of the Sun is where the energy is produced. The process happening there is called:

(A) **Fusion**, and **heavy** elements like Uranium are turned lighter elements like Krypton.
(B) **Fusion**, and **light** elements like Hydrogen are turned into heavier elements like Helium.
(C) **Fission**, and **heavy** elements like Uranium are turned into lighter elements like Krypton.
(D) **Fission**, and **light** elements like Hydrogen are turned into heavier elements like Helium.

19. The Structure of the Sun

The Sun's convective layer has convection cells. A common example of a convection cell is:

(A) The heat coming up through a poker rod if the tip of the poker is in the fireplace.
(B) The rays of light coming out of a computer monitor.
(C) The rising currents of water in a pot of water that is about to boil.

20. Structure of the Sun Again

You are outside and you glance extremely briefly at the Sun. The part you are seeing is called the:

(A) **core** (B) **radiative** layer (C) **convective** layer (D) **photosphere**
(E) **chromosphere** (F) the stinking **corona**virus